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First Workshop on Video Analytics in Public Safety June 6, 2016 San Diego, California

First Responders Group

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First Workshop on Video Analytics in Public Safety

June 6, 2016
San Diego, California

April 2017

Prepared for: **The First Responders Group**
Office for Interoperability and Compatibility

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Executive Summary

The first Video Analytics in Public Safety (VAPS) Workshop was held on June 6, 2016, in San Diego, California as a satellite workshop of the Public Safety Communications Research (PSCR) Broadband Stakeholder Meeting, which was held June 7-9, 2016.

The workshop brought together diverse stakeholders interested in increasing the development, reliability and adoption of video analytics to support the growing use of video in public safety while addressing critically important social considerations related to education and public trust. VAPS 2016 was organized by the National Institute of Standards and Technology (NIST) and attended by members of the federal government, state and local governments, public safety video experts, industry researchers, academics, social and legal considerations experts, and international stakeholders.

Specific communities of interest included:

- Public safety and transportation safety video use;
- Computer vision, multimedia analytics, machine learning, data analytics and data science, video compression, video processing architecture, and video privacy research;
- Video analytics, video security technology, video compression, and computing, networking, and telecommunications industries;
- Human-Computer Interaction (HCI), human factors, and visualization research;
- Public safety legal and policy community, social science research community, and social considerations;
- Federal, state, local, tribal, and international video research and development (R&D); and
- Video processing standards.

Prior to the workshop, focus group panels consisting of between 10 to 20 members of each of the first five of these communities held multiple meetings by telephone and web-conference, and prepared joint presentations regarding the current state of the practice/art, challenges, issues, needs, and ideas from their community's perspective. Because the VAPS workshop represented the first time that many of these communities would meet in a technical exchange, the goal of this effort was to prepare high-level perspectives to cross-educate the communities. Panel forum chairs presented each of these communities' perspectives at the workshop, followed by breakout sessions during which a cross-section of the workshop attendees discussed the strategic needs that emerged from the panel presentations.

Highlighted below are the priorities that emerged from the workshop presentations and discussions.

- Analytics solutions to hard content-centric problems supporting increasing demands for video use in situation awareness, triage and forensics and in public safety workflows. Access to state-of-the-art technology, customization and greater engagement with R&D.
- Future frameworks that support coordinated use of video, analytics, tools and systems in the context of a scalable, maintainable, secure and interoperable public safety video ecosystem, and that support the agile and scalable use of huge amounts of video from many sources.
- Development models and frameworks that support R&D; customization of analytics by the public safety community and cost-sharing across large and small public safety jurisdictions; sustainable economics that support commerce both in large companies and emerging innovators; and that support the efficient development of effective workflows in the larger context of public safety operations.
- Development of rigorous understanding of the tradeoffs between humans and automation and hybrid systems including both human, system and data bias. Develop representative data resources that support robust application development and objective measurement of bias and uncertainty.
- A robust R&D-to-deployment community and strategy including increased collaboration within the public safety community and with the full breadth public safety technology R&D stakeholders addressing key technology development needs in the context of evolving legal, policy and social considerations drivers.
- Best practices and standards to support interoperability, efficiency, practical and economic deployment across the diversity in size and scope of public safety organizations across the nation, and industry growth and innovation.
- Strategic development of data and R&D infrastructure resources as well as education, challenge problems, and funding to support creation of critical mass in all of the above.

1 Introduction

The first Video Analytics in Public Safety (VAPS) Workshop, organized by the National Institute of Standards and Technology (NIST), was held June 6, 2016, in San Diego, California. The workshop was a satellite workshop of the Public Safety Communications Research (PSCR) Broadband Stakeholder Meeting, which was held June 7-9. The goal of the VAPS workshop was to create an environment where technical stakeholders of all types could exchange knowledge, practices, needs, challenges, issues and ideas to jointly identify the critical research and development (R&D), resources, standards, and collaboration vehicles and infrastructure to support the creation of a robust public safety video analytics R&D ecosystem. The VAPS workshop sought to inform a national strategy for video analytics R&D and to lay the foundation for the formation of a multidisciplinary VAPS community of interest to foster collaborative engagement on the emerging priorities.

The workshop strategically brought together diverse stakeholders and focused on identifying gaps and challenges related to technological capabilities, standards, education and collaboration related to the development, reliability and adoption of video analytics to support the growing use of video in public safety while addressing critically important social considerations related to policy and public trust. Specific communities of interest included:

- Public safety and transportation safety video use communities
- Computer vision, multimedia analytics, machine learning, data analytics and data science, video compression, video processing architecture and video privacy research communities;
- Video analytics, video security technology and video compression industries;
- Computing, networking and telecommunications industries;
- HCI, human factors and visualization research communities;
- Public safety legal and policy community;
- Public safety social science research community;
- Federal, state, local, tribal and international video R&D communities; and
- Video processing standards community.

1.1 Background

The public safety and transportation safety communities are creating enormous and often-federated video systems to monitor the safety of citizens and urban and transportation infrastructure. However, these communities lack robust, scalable and interoperable technologies to effectively manage and work with the video data in these systems – both in live streams and in archives. Most cities now have thousands of public safety and transportation infrastructure cameras. Some larger jurisdictions have tens of thousands of these cameras. The sources of public safety video are quickly multiplying beyond closed-circuit television (CCTV) including cell

phone video, dash cameras, body cameras, a variety of tactical cameras, robot cameras, unmanned aerial surveillance (UAS) vehicles, as well as video data contributed by the public in emerging multimedia 911 apps and from social media. Hundreds of terabytes of video flow over individual public safety networks, and thousands into federated systems at state and regional levels and into public safety archives each day. The volumes of video are challenging to network communications and to the current, largely manual processes employed by a variety of public safety agencies to comprehend situational awareness and conduct forensic analyses. Current manual-intensive approaches are not scalable as sources of video and analysis needs and public expectations grow.

Computer vision is a growing area of research devoted to creating an automated understanding of the world we see. ***Video analytics (VA)*** are applications of computer vision that leverage information and knowledge from video data content to address a particular applied information processing need. VA is a quickly emerging application area focused on automating the laborious tasks of monitoring live streams of video, streamlining video communications and storage, providing timely alerts, and making the task of searching enormous archives of video tractable.

VA applications typically address information needs that are commonly referred to as the "w" questions:

- **who** (people detection and identification);
- **what** (object, activity, event, behavior, and relationship analysis);
- **where** (frame space, 3D space, and world map space); and
- **when** (date/day, time-of-day, time-of-year).

VA can be applied to **retrospective analysis** of archives (e.g., archive management, search, triage, forensic investigation), **real-time analysis** of live video streams (e.g., situation awareness and alerting, encoding, compression), and **predictive analyses** leveraging both live video streams and archives as well as data from other correlated domains (e.g., prediction based on the past and present, event/activity prediction, anomaly detection). VA is therefore a broad application area. Diverse current technology examples relevant to public safety include:

- Face and iris recognition and other biometrics;
- Soft biometrics (clothing, scars, marks, tattoos, transient features);
- Single camera virtual tripwire and flow analysis and object/person counting;
- Single camera person, vehicle, object detection and tracking, and object left behind detection;
- Text recognition at a distance – License Plate Recognition, logos, scene text;
- Archival video and multimedia repository search and retrieval;
- Duplicate detection and similarity clustering;
- Scene, object and person reconstruction;

- Activity and event detection;
- Geolocation and mapping;
- Summarization and skimming;
- Objective video quality analysis; and
- Video compression.

Current R&D growth areas include:

- Spatial analysis of large areas and geo-spatial analytics;
- Temporal analysis of large volumes of video and "time machines:"
- Spatio-temporal analysis supporting 4-D situation awareness, reconstruction, forensics, redaction and crowd monitoring;
- Multi-camera/multi-sensor processing to support sensor data fusion;
- At-scale video and sensor analytics incorporating embedded/edge analytics, smart sensor networks - sensor-network-driven analytics and video streaming;
- Multimodality and integration of video content representations within broad analysis frameworks;
- Video interaction with fused interactive representations of multiple video streams and usable video/analytics interfaces; and
- Automated interpretation of cognitive load, degradation and human/machine bias.

Breakthroughs in the scientific disciplines of computer vision, machine learning, data science, distributed computing, high-speed networking and others are enabling significant advances in video processing. These breakthroughs will play critical roles in future public safety video applications across all VA areas. Given the explosion of video in public safety, the strategic incorporation of next-generation video analytics into public safety systems and workflows is critically important. VA will play an essential role at the collection devices, in the public safety communication networks, in the data management back ends, and in real-time interactions across a variety of stakeholders and automated systems that span agencies, jurisdictions and sectors. Indeed, VA will play an important role across the entire workflow of future systems (see Figure 1).

Figure 1 Major Public Safety Video Workflow Components

Significant coordinated activities in R&D, measurement, standards, education, outreach and collaboration will be essential to support the robustness, efficiency, usability, physical and cyber security, and interoperability of these systems while balancing the public's need for increased safety, transparency and privacy.

Because of a confluence of challenges in the public safety video landscape, public safety VA R&D and standards activities have somewhat lagged behind other domains (e.g., social media). However, the landscape is quickly evolving that will permit the enrichment of the public safety video ecosystem with automated video analysis capabilities:

- **Computing power, networking and storage** have reached levels that support scalable computer vision technologies and wireless communications have become pervasive permitting the deployment of video systems at virtually any location.
- **A broadband public safety network** that can support robust and standardized data communications within and across jurisdictions is taking form.
- Consumer camera technology, mobile phone technology and gaming processors are leading the way for a surge in public safety technology.
- **Sources of public safety data are exploding** and on the move. Video is being widely adopted in the public safety community and supported by a growing security electronics industry (including CCTV cameras, body worn cameras, dash cams, UAS systems, robot cameras and a variety of tactical cameras). These data can provide both a means to develop and evaluate future systems as well as motivate the creation of a surge of applications and industries.
- **Research in VA** technologies are maturing to usable levels of performance *for some data/environments.* Some of these technologies (e.g., license plate recognition, object and person detection, virtual tripwire, low-level activity detection) now work extremely well under constrained conditions.
- **Brain-inspired technologies for "teaching" software to understand the complexity of the visual world are** emerging in the form of deep-learning systems and other applications of artificial intelligence. Computer vision and VA are at the cutting edge of artificial intelligence and are stimulating a variety of new research communities and applications.
- **Public safety collectively has the largest amount of video data and analytic needs** – likely far exceeding that of the social media industry. Significant potential exists for both the development of new technologies and new markets in public safety VA.

- Increasing needs for the public safety community to leverage its video resources in cost-effective ways and exchange knowledge and data across jurisdictions in real time will drive the development of standards that promote interoperability, efficiency and commerce.

In 2014, the White House Office of Science and Technology Policy (OSTP) National Science and Technology Committee (NSTC) Networking and Information Technology Research Directorate (NITRD) formed a coordination group to foster federal interagency collaborations in the emerging area of Video and Image Analytics (VIA). VIA is made up of organizations from across the entire federal space engaged in R&D in a tremendous diversity of application areas related to federal needs in VA. VIA became a formal working group in 2016, and its charter includes developing an interagency R&D strategy to identify federal priorities regarding fundamental and applied research needs within the federal government related to VA. VIA recognized the emerging need with regard to the development of technologies to support VA in the public safety domain and worked together with the executive office of the White House OSTP, the longstanding DHS-led Video Quality in Public Safety (VQiPS) working group, and the NIST PSCR Program to organize a cross-cutting workshop focused on this area. The workshop was designed to lay the groundwork for future public-safety-focused research and, more importantly, foster the beginning of a diverse community of interest made up of public safety video experts, industry, academia, social science and legal communities, federal R&D organizations, and standards organizations. Together, this community will work together to both identify strategies and create collaborative efforts related to research, measurement, standards, technical education and public awareness to strengthen the technologies related to video analysis in the public safety community.

The Video Analytics in Public Safety (VAPS) Workshop was designed as a satellite workshop of the Public Safety Communications Research Broadband Stakeholder Meeting to maximize interactions with public safety communications stakeholders.

1.2 Workshop Format and Pre-Workshop Activities

Prior to the workshop, five focus group panels were established consisting of between 10 and 20 experts – each panel representing a sample of a key VAPS stakeholder community:

- Public safety and transportation safety video use and analysis;
- Industry VA R&D and related technologies and standards;
- Academic research in areas relevant to public safety video technologies;
- Human factors, HCI and visualization research; and
- Legal, policy and social considerations.

The focus groups sought to develop an understanding of the overarching needs and issues from each of these five communities' perspectives. They also sought to educate the other communities about their community, how they perform their work, what they struggle with, and what they think is needed regarding public safety VA capabilities and standards. Representatives of the panel's community led each focus group panel. The panels met virtually during the month of May 2016 and prepared joint briefings regarding the current state of the art/practice, challenges, needs and ideas with regard to research, measurement, standards, education and collaboration. The briefings developed by these panels sampled the knowledge and perspectives of stakeholders to promote cross-education of the workshop participants and to seed workshop discussions. The panel chairs presented the briefings in flash summaries at the beginning of the workshop.

Following the focus group panel presentations, attendees were divided into technical breakout sessions cutting across the stakeholder communities where participants jointly identified issues, needs, R&D priorities and ways forward for research, measurement, standards, education, outreach and collaboration. These breakouts drew from the breadth and diversity of the workshop participants and the materials presented earlier in the day.

The workshop included a collaboration highlight session that featured existing collaborative public safety/academic research projects. The workshop also featured an interactive technical poster/demo session that included lively presentations spanning topics related to knowledge emerging from fundamental research to video analysis applications and public safety programs. Meeting attendees were also invited to post comments to a live social media feed and to share materials on a workshop sharing site.

1.3 Workshop Summary

John Garofolo from NIST chaired the workshop. He gave an introductory briefing on the purpose and structure of the workshop followed by a briefing by Cuong Luu from DHS Science and Technology Directorate on the VQiPS program and practitioner-focused community of practice. It then moved into the flash reports from the five stakeholder communities, cross-stakeholder collaboration example briefings, an interactive demo/poster session and two strategic breakout sessions.

1.4 Focus Panel Flash Reports

1.4.1 Public Safety and Transportation Safety Video Practitioners Panel Report

Panel Chairs: John Contestabile, NPSTC VTAG/Johns Hopkins Applied Physics Laboratory (APL) and John Powell, Los Angeles County Sheriff's Department (retired)

Panel Participants: Ahsan Baig, City of Oakland; Chad Carpenter, South Dakota Division of Criminal Investigation; Kim Coleman-Madsen, Colorado Office of IT; Ron Derderian, Beverly Hills Police Department; Ralph Ennis, Metropolitan Police Department DC; Ed Freebom, Unmanned Experts; Michael Garris, NIST; Charles Guddemi, U.S. Park Police; Jack Hanagriff, Houston Police Department; Samuel Hood, Baltimore Police Department; Drew Jurkofsky, Unmanned Experts; Ashish Kakkad, San Diego County Sheriff; Roland Kearney, Drug Enforcement Administration; Tracie Keesee, New York City Police Department; Hoyt Layson, TPD Corp.; Jonathan Lewin, Chicago Police Department; Ed Mills, Colorado Office of IT; Martin O'Farrell, Capability Adviser Protective Security, UK Home Office Science; Eddie Reyes, Amtrak Police Department; Jared Vanden Heuvel, Texas Department of Public Safety; and Fred Scalera, former New Jersey Statewide Interoperability Coordinator.

The VAPS Public Safety/Transportation Panel opened the panel reports and provided an overview of the DHS VQiPS Program, of which VAPS is a part. The VQiPS group provides unbiased guidance and resources to assist public safety in defining and articulating its video quality and video-over-broadband needs. VQiPS educates public safety professionals and end users about video system components; provides users with a network optimization model for use in testing and making more efficient network resource decisions; and provides recommendations for dynamic spectrum allocation based on user applications and network capacity. Many of the VQiPS tools and resources are available from the PSCR: http://www.pscr.gov/outreach/video/vqips/. This site includes links to the *VQiPS Guide to Defining Video Quality Requirements*, the *Digital Video Quality Handbook*, the *VQiPS Recommendations Tool for Video Requirements*, the *Video Quality Glossary*, and review reports from past VQiPS workshops and conferences. VQiPS has also published technical reports on specific topics such as visual quality, object of recognition and visual acuity, which are available from https://www.dhs.gov/science-and-technology/voice-video-and-data-public-safety. For researchers and developers in the fields of video processing and visual quality (both objective and subjective assessments), the Consumer Digital Video Library (CDVL) is available at: http://www.cdvl.org/.

In two conference calls prior to the VAPS Workshop, the Public Safety/Transportation Panel members discussed the following questions and articulated the associated answers:

1. What is the public safety/transportation community and who are its stakeholders?

   The core public safety community consists of traditional first responders such as fire, law enforcement, and emergency medical services (EMS), while the larger community may also include allied agencies such as transportation/highways/public works, public health/hospitals, utilities

(electric, water, wastewater), and others. The panel decided to adopt this more inclusive definition because video is used and shared extensively across each of these communities.

2. What is the growth in needs (for video analytics)?

   The following video analytics capabilities identified as needed by this community:

   - Recording;
   - Playback;
   - Video synopsis (so one does not have to view hours of video);
   - Video search for target type, event type, color, size, time range, similar targets, etc.;
   - Use of metadata and forensic indexing;
   - License plate recognition (LPR);
   - Encryption;
   - Storage (self-contained, local and remote);
   - Redaction (automatic);
   - Facial recognition systems;
   - Object left behind;
   - Object identification (e.g., object color signature);
   - Ingress/egress into zone;
   - Thermal imaging, smoke/flame detection;
   - Object stopped or non-motion detection;
   - Object removed;
   - Object detection;
   - Object tracking and path analysis, movement with or against flow;
   - Cross-line detection;
   - Activity mapping;
   - Queue monitoring; and
   - How to reduce false positives in the above.

3. What video needs are most urgent?

   The following needs were identified as most urgent:

   - Storage - access, integrity, size of cloud, local capability;
   - Redaction;
   - Security;
   - Applications that run on the edge (i.e., camera) to mitigate bandwidth and storage limitations;
   - VA Interoperability and Management with audit trail/evidence chain of custody/security. This need includes:
     - Standardization of video metadata;

- Enhanced interoperability and video sharing by allowing one vendor's analytics to run on another vendor's data/metadata (e.g., sharing with forensics, other jurisdictions);
- VA requirements for real-time video sharing;
- VA requirements for post-incident video sharing;
- Forensics; and
- Capability for reviewing pre-incident archival footage (e.g., to investigate what precipitated the incident).

4. What is the public safety vision for video/video analytics?

   The vision for video is to provide near real-time situational awareness of an unfolding situation as well as contribute to the post-event evaluation. To do so, video must be discoverable, accessible, transportable, of sufficient quality and secure. For maximum usefulness, video needs to be seen in context with other information such as viewshed, location data, other GIS layers, metadata, etc.

5. Are there any gaps/needs?

   The following five items were identified as needs:

   - Interoperability - standards are needed to allow the video itself to be shared as well as for the video metadata and video analysis applications to be more interoperable;
   - Ability to discover and access cameras, including those not owned by public safety;
   - Ability to move video efficiently to avoid bandwidth and storage issues;
   - Tools and techniques for efficiently redacting video; and
   - Minimum acceptable video quality to perform certain public safety tasks, including an understanding of how video transmitted across both wired and wireless networks affects quality (e.g., bandwidth limits).

1.4.2 Social Considerations Panel Report

Panel Chair: Don Zoufal, CrowZnest Consulting, Inc./University of Chicago

Panel Participants: Kevin Branzetti, New York County District Attorney's Office; Josh Dennis, Chicago Fire Department; George Hough, Fire Department of New York; Jennifer King, University of California Berkley; Jake Laperruque, Constitution Project; Ruben Madrigal, Chicago Office of Emergency Management and Communications; Lynda Peters, Chicago Law Department/Center for Homeland Defense and Security; Jill Ramaker, Northern Illinois Public Safety Training Academy; and Seth Stoughton, University of South Carolina Law School

The Social Considerations Panel (SCP) discussed the legal, ethical and social concerns surrounding the developing VA field identifying opportunities, challenges

and gaps posed by the application of these technologies. One issue, around which there was largely uniform acceptance, was that the rapid pace of technology development posed significant challenges for legal and social governance structures. Those structures typically take more time to accommodate change. There was also general acceptance that analytics could be utilized to improve awareness and support governance. The major gap discussed revolved around the ability to structurally comprehend and mitigate the potential risks of the use of automated analytics in the public safety workflow.

In response to the questions regarding challenges, opportunities and gaps, the committee's discussion focused on the following areas:

- Substantive issues concerning individual and community rights;
- Substantive issues concerning standards and impacts;
- Roles of government and the private sector;
- Existing frameworks for review and governance; and
- Paths forward for social research and action.

Each of the discussion points is outlined more completely below.

Substantive Issues Concerning Individual and Community Rights — The following topics were identified and discussed:

- **Privacy** – This is concern regarding increasing technological abilities to identify individuals and comprehensively understand their activities over time. The emergence of analytics such as facial recognition, link analysis and computational developments allowing for the collection and analysis of growing amounts of unstructured video data has substantial potential implications for personal and community privacy rights and expectations. Particularly affected are the following privacy aspects:
    - **Anonymity** — This is the concept of being able to move through public areas without being identified. There is question over how much of this is a "right" and how much is an expectation. Although there may be a right not to be identified arbitrarily in public, there is not necessarily a protection from being identified.
    - **Reserve**- This is the concept that persons should be able to keep to themselves pertinent details about their lives. Large-scale and intrusive surveillance potentially threatens that right.
- **Balancing surveillance for the common good with personal privacy** – The use of camera networks and other sensor arrays and technologies that allow for the activities and movements of individuals and objects to be analyzed across time and space is a game-changer in terms of public safety, but also a potential slippery slope in terms of privacy. Technological capabilities enabled by the use of large-scale sensor networks with advanced

communications and analytic systems are accelerating with the creation of advanced surveillance technologies. The application of automated analytics to the data generated from these devices introduces increased privacy challenges, but can also be used as a privacy firewall to limit human inspection. Societal norms regarding surveillance have been somewhat fluid as technologies have accelerated which bring increased convenience and knowledge to the public, while the laws and policies to govern these technologies lag greatly behind the technical capabilities. This gap has created privacy risks that are difficult to measure. Without clear policies and effective means to measure conformance, these risks cannot be mitigated or even properly assessed. The effect of this gap has been to create unacceptably long policy development cycles that are ultimately dependent on legal proceedings. The lack of agility in technology policy development has been challenging to both the public safety community and the public.

Although much of the public discussion has focused on concern regarding the governmental use of analytics for surveillance, there is a growing realization that private surveillance and the control of data derived from such surveillance present a very new kind of challenge to privacy. Such concerns extend to the phenomena of the growth of large corporations whose business models are focused on deriving and leveraging information from the data created at the intersection of consumer electronics and social media. The technologies created by these industries have enabled incredible capabilities in crowdsourcing information to address both individual and market needs and an array of services that provide benefit to society ranging from product sales to citizen science. Such technologies can be used to address large-scale information needs that provide incredible utility to the public, but can also potentially be used for surveillance of citizens and communities. The investigation that happened after the Boston Marathon Bombing in 2013, where thousands of images and video clips of the bombing were provided by the public to the police, demonstrates the potential power and utility of data-driven analytics in solving and preventing crimes and acts of terrorism. There is a compelling need to enable the use of these technologies for public safety. Concurrently, there is a need to protect the privacy of the public while doing so. These drivers need not be in conflict if the proper technological controls, policies and laws are in place to protect the public in both dimensions.

Substantive Issues Concerning Standards and Impacts — The following issues were identified:

- **Defining appropriate standards on data quantity and quality** — A focus on articulating quantity and quality requirements and limitations is needed. Concepts such as data minimization to protect privacy and quality

requirements of use of images and analytic techniques as evidence in legal proceedings are two examples of these issues.

- **Changing social/cultural standards** — The U.S. Supreme Court, in addressing many of the cases involving technology, has noted the changing attitudes of the public particularly with respect to expectations of privacy. Understanding those attitudes and changes over time is important to addressing governance issues.
- **Impact on the public actors utilizing technology (police and EMS)** — Not only does technology create privacy concerns for the public, it also impacts first responder personnel and how they perform their jobs. Understanding their privacy concerns, as well as civil liability issues, labor and employment issues, and even criminal rights protections (such as self-incrimination) are important challenges as technology becomes an increasing part of first responder work.
- **Automation and its limits —** The seemingly exponential increase in technology capability sometimes creates unrealistic expectations in the public regarding what technology is actually available and what it can deliver. This perceptual gap created by news articles on emerging technologies and technologies used in fictional television programs and movies is often referred to as the "CSI effect." It is important for the public, public safety personnel, and the legal and policy communities to better understand current technological capabilities and practices.
- **Disparate impact (communities) positive and negative - bias in data - bias in configuration** — Understanding that issues such as sample or selection bias can affect the way algorithms work and infuse bias into analytic processes. The process that humans utilize to prepare and analyze data inevitably introduces human bias. Such bias can be complex and challenging to measure, but must be better understood and mitigated.
- **Translating technology to human experience** — The pace of technology change requires better education and training efforts so individuals better understand how technology can and does affect them in both positive and negative ways. Oftentimes the convenience, efficiency or effectiveness of technology driven by analytics can impact data security and privacy.

Roles of Government, the Private Sector and the Public — The panel recognized that it requires engagement from a range of communities – each with important perspectives and differing roles in developing a robust understanding of the effect of analytics on the public, as well as in the governance of those effects. The government community spans federal, state and local organizations, and judicial, legislative and executive roles. Additionally, the issue of governance and use of analytics in a global environment where data gathering and use can easily spill over national borders, the role of other nations, and international treaties and

organizations needs to be considered. Given the significant role the private sector has played in analytic development and application, their role is also critical to understand. Finally, given the democratizing effect of technology and analytics, the evolving role of the public must also be considered.

Existing Frameworks for Review and Governance — A preliminary literature search revealed significant research and activity in several countries outside of the United States engaged in developing policies, laws and frameworks related to the use of technology and data regarding the public. As an example, Canada and the United Kingdom (both countries with legal traditions similar to the United States) have strong codes for regulation of data use. Framework development is beginning within the United States at NIST and organizations such as the International Association of Chiefs of Police and The Constitution Project are offering frameworks for consideration about analytic technology development and its use within technology programs.

Path Forward — The SCP offered the following areas of analysis as a path forward for addressing social, ethical and legal issues:

- Matching substance with roles and process;
- Gap analysis;
- Missing considerations;
- Cycle of technology and its relation to legal, ethical and policy considerations;
- Redaction structure/guidelines;
- Privacy impact assessment;
- Measuring achievement; and
- Process for outlining operational issues
  - Scope
  - Use
  - Retention
  - Access.

A focus on these issues will not address or resolve all of the concerns regarding the growing application of analytics, but they may serve to address some of the more immediate concerns and provide a foundation for further analysis.

1.4.3 Academic Research Panel Report

Panel Chairs: Dr. Jason Corso, University of Michigan and Dr. Gerald Friedland, International Computer Science Institute

Panel Participants: Terry Boult, University of Colorado – Colorado Springs; Edward Delp, Purdue University; Jim Hieronymus, University of California – Berkeley; Sanjeev Koppal, University of Florida; Shmuel Peleg, The Hebrew University of Jerusalem; Jacob Sniff, Harvard University; Jacob Chakareski, University of Alabama; Alex Hauptmann, Carnegie Mellon University; Anthony

Hoogs, Kitware Inc.; Ram Nevatia, University of Southern California; Weisong Shi, Wayne University; and Paul Wehner, MITRE

The academic research panel discussed research challenges around VA for public safety in the context of the task presented in the other panels. There was consensus that some capabilities in the form of early research results exist, and concrete challenges in the area could probably be initially tackled with generic datasets. In general, however, there is a pressing need for data sets and funding in the area.

The major challenges in capturing data for public safety have been addressed with traditional surveillance cameras, sets of cameras and recently wearable cameras, and car-mounted cameras. VA, however, is still in its infancy. Research results in the area of privacy-preserving optics, thermal privacy and cryptographic obscuration can help to detect an object or person and then encrypt it in place so that a critical area can only be observed with a cryptographic key. This allows for (semi-)automatic redaction of sensitive data. The GARI system allows for the automatic detection and classification of gang graffiti and gang tattoos. A third example of early capabilities was the detection of gun shots using acoustic sensors and deep learning.

Among the many hard problems discussed was the detection of anomalous events, context-driven privacy and real-time analysis, especially under the constraints of low-quality data, crowded scenes and energy efficiency. Research tasks should be well defined and accompanied with data and clear evaluation metrics. Initial data may be found in consumer-produced videos, e.g., in the YFCC100M dataset or NIST TRECVID datasets.

Agreement was reached that the topic is so new that research funding is needed in all areas, i.e., in the form of research programs, technology transition efforts, data collection, annotations and measurement tools, and benchmarks. The panel discussed that a start could be that relevant federal research funding requires or incentivizes certain mechanisms that facilitate VAPS success. Moreover, it is important that funding mechanisms promote the creation of open protocols rather than proprietary ones, and include provisions or incentives for data availability in research to municipalities and organizations receiving funding.

Many current federal R&D programs in this area focus on addressing needs in sensitive, sometimes classified, operations. These programs do not tend to foster open research. Developing consortia-based collaborations with industry in addition to federally funded R&D might help foster more open research and synergy as there is potentially a large amount of infrastructure and data to be leveraged from a variety of surveillance business domains (e.g., retail and facilities security). Automotive cameras are another source of rich content, if legal barriers to sharing this data can be overcome. Furthermore, annotations of consumer-produced data uploaded into social media could provide additional useful research data.

1.4.4 Human Factors, HCI and Visualization Research Panel Report

Panel Chairs: Lauren Brush, Johns Hopkins University Applied Physics Laboratory and Dr. Eric Frost, San Diego State University

Panel Participants: Grant Fredericks, Forensic Video Solutions; David Gray, XPLANE; Lina Karam, Arizona State University; Jim Keener, SSI Guardian, LLC; Tracie Keesee, New York City Police Department; Christian Kijora, United States Coast Guard; Robin R. Murphy, Texas A&M University; and Beth Plott, Alion Science and Technology

The Human Factors (HF) discussion group included representatives from public safety, VA research and human factors who met to discuss the human elements that limit the end users' performance and efficiency when working with video data to maximize performance.

VA is often used to address cognitive factors such as attention span, reaction time and cognitive loading. However, the physiological effects of activity, environment and structural characteristics; differences in vision, hearing, and touch; and psychological factors such as motivation, stress, training, and emotions can all affect user performance and should be considered during the VAPS strategy effort.

The panelists identified four categories of end users of VA within the public safety audience (defined here as civil defense, law enforcement, firefighting, EMS and public transportation). Creators operate the equipment used to capture event data. Subjects of public safety video have distinct needs for privacy. Data consumers must be able to store, locate, analyze, extract and redact critical information. Federators/distributors are tasked with securely storing data as well as locating and providing appropriate data to others.

When considering public-safety-related tasks involving video, the panelists felt that each fell into one of three very high-level groups with different critical needs and problems: real-time situational awareness and target recognition, post-event data analysis or prediction, and prevention of future events.

Real-time analysis faces three primary hurdles. The volume of data requires automation to process data in real time and enable humans to focus on targeted data. Inconsistencies in analyst bias, training and technical understanding can affect analysis of the data. Improvements are needed to visualize camera position and perspective, geospatial context, narrative time sequence, overlays onto 3-D surfaces, and social media input integrated with the content.

Post-event analysis faces the issues above as well as significant issues in storing, retrieving, redacting and distributing data while maintaining chain of custody and authenticity. Predictive analysis efforts are hindered by the difficulty of translating the human decision-making process to a computer-based system capable of

predicting or preventing an event. Issues to be overcome include assessing available systems, identifying limitations, and addressing those limitations with innovative methods and technologies. Alternative methods of visualizing integrated data, such as 3-D displays and augmented reality, may offer ways to address current limitations.

The human factors panel identified several areas in need of continued effort as the VAPS strategy is developed. Generate user requirements by leveraging user requirements already collected by VAPS members, developers and vendors of existing VA systems with insight into the problems they are attempting to resolve, and continuing to gather input from end-users. Research to continue to analyze human factors issues and needs and user input throughout the VAPS development life cycle ideally would involve developing personas and scenarios; task analysis to study user workflows; find bottlenecks and identify solutions; find gaps between what the user needs and what the system provides; develop case studies related to temporal and geospatial organization, perspectives of massive video data sets, and the use of display on 3-D surfaces such as a model of a city; and generate metrics to measure performance and identify gaps. Further, there is an expected need to effectively filter and analyze the relevance of social media video.

1.4.5 Industry Perspectives Panel Report

Panel Chairs: Dr. Peter Tu, GE Global Research and Dr. Sharath Pankanti, IBM T.J. Watson Research

Panel Participants: Isaac Cohen, United Technologies Corporation (UTC); Tim Faltemier, Progeny; Alan Finn, UTC; Dashan Gao, Qualcomm; Gleb Geguine, GE-Current; Uriel Halioua, Taser; Brian Lande, Polis-Solutions; Hoyt Layson, TPD; Stuart McKee, Microsoft; Eduardo Monari, Fraunhofer; Jacob Sniff, Imaging-Tech; Karsten Steinhaeuser, Progeny; Steve Surfaro, Axis; and Jonathan Wender, Polis-Solutions

Summary of the current state of the art: VA applications can be categorized as: 1) forensic – what has happened; 2) predictive – what will happen; and 3) prescriptive – what actions should be taken. Common algorithms include person tracking, vehicle tracking, tripwires, motion detection, face recognition, license plate reading, left object detection, slip and fall detection, crowd formation, and loitering. Methods for algorithmic development include: in-house development of generic capabilities; building on open source repositories; building on licensed third-party capabilities; and custom development for specific entities. Computing platforms range from processing at the edge to analysis in the cloud, using generic as well as specialized hardware implementations. From a business model perspective, one can expect offerings ranging from component-level modules to end-to-end solutions. Increasingly, imaging devices are taking advantage of depth perception and spectra that go beyond the visible range. In terms of

communications infrastructure, the community is taking advantage of analog, digital and wireless capabilities.

Thoughts on future development: Increasingly, software developers will need to take advantage of new hardware innovations. With the increasing reliance on machine learning methods such as deep learning, developers will require access to ever-increasing quantities of data for both training and evaluation purposes. Going beyond static datasets (which can be overlearned), future algorithms will require constant novelty allowing for a state of never-ending unsupervised learning. This will require a migration from data-sets to data-sites and, perhaps, data-cities.

In terms of scale, installations of the future will migrate from hundreds of cameras to tens of thousands. In addition, these solutions will be based on loosely coupled federations of hundreds of contributors. Further, the infrastructure of the future will allow tracking each feature of the system along with its (e.g., machine learnt) provenance to facilitate fair and objective credit assignment to each contributor.

Industry must take up the challenge of integrating social science and ethics into technology development. Expectations of privacy are evolving, however. Now that everyone is a stranger, does video analytics become a proxy for trust? Does video equal a new kind of truth? These are challenging dynamic issues that must be addressed as privacy and functionality are balanced and harmonized in research, products and operations.

The value proposition of VA must also evolve. The prevention of loss vs. revenue generation has always been a hard sell. Yesterday we recorded the past, today we understand the present, tomorrow we will predict the future. This technology quickly goes from commodity to intractable. Fully automated visual surveillance is a Turing test problem. The traditional goal of VA is to be able to extract the gist of things that is relevant to a particular information need or decision-making process. As these needs expand to all potential information and decision needs, this becomes a fundamentally hard problem, which will require new forms of Artificial Visual Intelligence (AVI) approaches.

Recommendations: Industry should be open to new technologies and keep algorithms sufficiently generic and/or extensible to accommodate new types of data enabled by future innovations in hardware. As a community, we will need to develop new large-scale sources of data (along with sustainable techniques for automatic performance evaluation on these sources of data) that continually challenge our algorithms for ushering in a new age of continual improvement through learning and adaptation. Further, we need to better understand how to balance privacy and surveillance requirements in the solutions we develop.

The emerging scientific area of AVI has the power to transform many work and need areas in public safety beyond surveillance – including training, logistics and

supply optimization, EMS analysis, fire analysis, verification, inspection, prediction and others. As a result, it is logical to start thinking of the development of the next generation of (visual) intelligence applications together rather than narrowly focusing on the requirements of surveillance applications alone. One way to facilitate the development of such a roadmap is by explicitly and effectively standardizing an extensible, open, scalable architecture for visual intelligence infrastructure that is designed in such a way to accommodate the breadth of public safety needs and that can readily exchange useful information with other systems.

1.4.6 Public Safety/Research Collaborations Panel

Panel Chair: Barry Luke, Deputy Executive Direction, National Public Safety Telecommunications Council

Panel Participants: Ahsan Baig, City of Oakland; Chad Carpenter, South Dakota Division of Criminal Investigation; Kim Coleman-Madsen, Colorado Office of IT; John Contestabile, Johns Hopkins University/APL; Ron Derderian, Beverly Hills Police Department; Ralph Ennis, Metropolitan Police Department DC; Ed Freebom, Unmanned Experts; Michael Garris, NIST; Charles Guddemi, U.S. Park Police; Jack Hanagriff, Houston Police Department; Samuel Hood, Baltimore Police Department; Drew Jurkofsky, Unmanned Experts; Ashish Kakkad, San Diego Co. Sheriff; Roland Kearney, Drug Enforcement Administration; Tracie Keesee, New York City Police Department; Hoyt Layson, TPD Corp.; Jonathan Lewin, Chicago Police Department; Ed Mills, Colorado Office of IT; Martin O'Farrell, Capability Adviser Protective Security, UK Home Office Science; John Powell, LA County Sheriff's Department [ret]; Eddie Reyes, Amtrak Police Department, Jared Vanden Heuvel, Texas DPS; Fred Scalera, New Jersey Office of Homeland Security; Brian Shepherd, Colorado Office of IT; Shing Lin, Harris County Texas; William Schrier, Seattle Police Department; and Dr. Jason Thornton, MIT Lincoln Laboratory

A public safety collaboration panel was organized to highlight current cross-stakeholder VA R&D - both within the United States and internationally. Presentations were provided by the Chicago Police Department, the United Kingdom Home Office, MIT Lincoln Laboratory and the Seattle Police Department covering various issues associated with video systems and the use of analytics.

Chicago Police Department/University of Illinois Collaboration

Presented by: Jonathan Lewin, Deputy Chief, Chicago Police Department

The Chicago Police Department (PD) is a progressive law enforcement agency that understands the important of technology and which has implemented a number of significant programs which include video and analytical platforms. The agency uses a variety of video input sources including body cameras, license plate reading cameras, and fixed camera systems to include public visible and covert operations. Chicago PD also works to leverage the use of video captured by private sector

businesses, schools and other government facilities. Video ingested into the Chicago PD system is used for a variety of crime prevention, emergency response and investigative purposes. It has been testing facial recognition technology which will allow it to link images to known persons. Facial recognition systems are programmed to identify the presence of subjects who are most at risk to commit violence (based on prior criminal history). Chicago PD also monitors "open source" social media channels to identify crimes that are about to be committed, as well as locate information to assist with criminal investigations. In some cases, Twitter traffic following an incident can help identify witnesses. The agency also has access to portable camera systems that can be deployed quickly for spontaneous or preplanned events. To test the effectiveness of camera systems, the agency embarked on a project to examine the statistical effect of camera placement on crime rate. It then worked to devise optimal placement strategies based on machine learning. Citywide, 2,143 cameras were examined to compare the crime rate pre- and post installation of the video system. The study demonstrated crime reduction between 17 percent and 22 percent over a 24-month period. Finally, the agency is studying the ability for camera systems to accurately detect information that deviates from the baseline image. This includes analysis to detect crime (e.g., identification of a person who has been shot, the display of a weapon, narcotics transactions and other suspicious behavior); to detect public safety issues (e.g., a crowd gathering, a person who has collapsed, swimmer in distress in the water, activity in a closed park); and detect traffic incidents (e.g., traffic crash, speeding, highway congestion, boat accident).

United Kingdom Home Office/Research Community Collaboration

Presented by: Martin O'Farrell, Centre for Applied Science and Technology, United Kingdom Home Office

The United Kingdom's Home Office provided a presentation on the Video Analytics in Law Enforcement (VALE) project. VALE began in 2015 with the development of use cases that leveraged video resources to support police agencies. Of the 89 use cases identified by first responders, six were selected as the most viable and were advanced for testing. The selected use cases included: (1) detection of crowd movement; (2) child abduction; (3) multi-camera tracking of persons as they move through an area; (4) suicide risk on a train or subway platform; (5) incursion into confined spaces; and (6) street robbery. The European Union agreed to fund collaboration between law enforcement, academia and industry on these issues. Work is ongoing to address the various use cases. It was noted that there is an extreme cost to government agencies when someone commits suicide by jumping in front of a train as well as the associated business disruption cost. Funding for these programs was based on the goal of being able to prevent or disrupt activities before they occurred. Sixteen organizations have submitted bids to the European Union to work on this program.

Seattle Police Department/Hackathon-style Video Redaction Incubator Collaboration

Presented by: Bill Schrier, Chief Information Technology Officer, Seattle Police Department

The Seattle Police Department (SPD) currently uses a large number of in-vehicle camera systems as well as automated license plate reading technology. The city does not allow public mounted camera systems without specific city council approval. SPD recently completed a body camera pilot project in advance of an agency-wide rollout. SPD has identified a number of challenges associated with video use. Its review concluded that there was a substantial increase in agency workload to support video systems. This includes the need to tag, upload, review, analyze and provide video to authorized entities. SPD believes that some of these issues can be overcome with technology, including the use of video reporting with officer narration and the use of voice activated applications. Management of multiple video platforms also creates issues for an agency. Most agencies support a multitude of video systems, including body camera, in-car dash-cam, pole mounted, surveillance units, interrogation cell and others. Each of these systems may be managed differently with unique video tagging and storage requirements. Analytics become critical to fully leverage the available video capabilities so agencies do not accumulate an enormous amount of stored video that cannot be used. SPD also noted that the video equipment itself must be designed to work in a public safety environment including ease of use for the officer and ruggedization. The need for the camera to reliably record video, or alert the officer when it is not recording, has malfunctioned or has failed to upload must all be addressed. Body camera systems should also be integrated with other video and communications systems. An officer's body camera should start recording automatically if they press their radio emergency alarm. The dispatcher should be able to remotely turn on an officer's body camera if conditions raise suspicion on the officer's safety. Video should be easily shared with individuals in roles who need rapid access for situational awareness and safety. A dispatcher should be able to view a real-time video feed during an officer involved emergency event. An incident commander should be able to access different camera feeds to support resolution of a critical incident.

Redaction and public access to stored video continue to be a concern for law enforcement agencies. Technology should provide for reliable facial redaction on an enterprise-level scale. Other metadata elements should also be redacted automatically (where that data is protected). This includes GPS data embedded in the video that would identify an officer's home address or the location of a safe house or domestic abuse shelter.

MIT Lincoln Laboratory/ DHS/Washington Metropolitan Area Transit Authority (WMATA/Amtrak Collaboration

Presented by: Jason Thornton, Homeland Protection Division, MIT Lincoln Laboratory

MIT Lincoln Laboratory has been working with the DHS S&T to examine video analytic pilot projects and to create a list of lessons learned. One pilot project involved the assessment of prototype VA capabilities to help analysts at mass transit facilities make better use of high volumes of video data. The goal was to obtain actionable information more quickly to speed the arrival of an intervention. The project examined both real-time monitoring (for event detection and cues reported by personnel) as well as forensic review of past events. A number of capabilities were examined, including the ability for a video operator to be alerted to the placement (and abandonment) of an object. The video system would "jump back" in time to show the arrival of the person who left the object. Video summarization was also examined, where long sequences of video can be transformed into shorter video clips for easier consumption. Path reconstruction was also reviewed in which a single individual could be tracked as they moved through an area covered by different cameras. Testing of these capabilities has been started with the WMATA Rail System in Washington, D.C. and with Amtrak Corporate Security in several states.

A number of important lessons were identified in conducting this project:

User Engagement:

- System must work with existing infrastructure
  - Seamless integration (e.g., via direct connection to Video Management Systems (VMS)) promotes frequent use
  - Cannot make excessive demands on bandwidth or server licenses
- Discuss and demonstrate capabilities early and often
  - Guides functionality in the right direction
  - Most valuable feedback comes from direct use of prototypes
  - Using the tools will often spur ideas for new features, modes of use, etc.
- Software must be reasonably robust
  - System must be stable enough for persistent use in wide range of scenarios
  - Requires good vetting and quality control before releasing to users

Integration issues:

- Analytics must be flexible when handling video inputs
  - Resolutions, frame rates and lighting conditions vary quite a bit
  - Must handle intermittent dropped frames without failing

- Cooperation with VMS vendors is essential
  - Most vendors offer a Software Development Kit (SDK) interface
  - It can benefit both parties (VMS and analytics researchers) to integrate successfully
  - Standards for data retrieval interfaces would enable much faster integration

2 Breakout Discussions and Findings

Breakout Chairs: John Audia, Navarro; Simson Garfinkel, NIST; Reva Schwartz, NIST; Andrew Weinert, MIT Lincoln Laboratory

Breakout Rapporteurs: Nancy Forbes, NITRD; James Horan, NIST; Fouad Ramia, NITRD

The VAPS 2016 workshop included two strategic breakout sessions with four simultaneous groups of about 20 participants organized to draw from across the stakeholder communities represented in the workshop. The breakouts encouraged vigorous discussion across traditionally disparate entities. It had the following overarching objectives:

- Improve the level and quality of community engagement;
- Develop a strategic analysis of gaps/issues/needs related to technologies, best practices, and collaboration incorporating diverse perspectives; and
- Kick off a VAPS Community of Interest.

These objectives were selected because they support many relevant technical and end-user activities, including R&D, measurement, standards, technical education and outreach, and collaboration. Over two sessions, participants in the VAPS Workshop breakout panels discussed a variety of needs and priorities for public safety video applications and for critically important R&D activities and resources. The following major points and themes came out of the breakout sessions:

2.1 Technology-related Needs and Issues

Economics and interoperability:

There are challenges in developing cross-cutting real-time video analytics applications within public safety because most public safety communities utilize a patchwork of systems and architectures, and as some of these systems rely on in-field communications, connectivity cannot be assumed. Interoperability is a significant challenge within these systems since a variety of proprietary systems are typically involved. This makes the development of analytic solutions quite daunting. Standards are needed to support more effective interoperability at the communications, computing, device and data levels.

Although some proprietary architecture standards are emerging, the current economics of public-safety-focused industries do not seem to support moving towards open and streamlined standards which would maximally foster novel R&D and the development of an open market of analytic tools. This is in stark contrast with the successful approach that has been taken by the social media and consumer device industries, which have focused on leveraging their infrastructure and resources, and supporting open standards to accelerate applications industry growth on their platforms. On the surface, these industries appear to be quite similar. They have markets for collection and interaction devices, communications, data analysis and data storage. However, the divergent approaches these highly-related industries have taken as a result of their differing origins is astounding.

Researchers and small applications businesses have flocked to the social media/consumer device industry in droves and it has grown dramatically in size and diversity. In contrast, the relatively small burgeoning surveillance-focused video analytics research community that was developing in the 2000s has stagnated. It appears that young researchers and application developers have been effectively disenfranchised from engagement in public safety because both the barriers of entry and failure risks are too high.

The current public safety video ecosystem was formed from a physical-security-equipment-centric model rather than an application model such as those being used within the social media industry. Equipment-centric models do not readily lend themselves to growth of IT innovation unless they have most of the market share or have embraced interoperability outside of traditional equipment stovepipes. The constraints imposed by this model are impacting development of commercially viable interoperable video use and analysis solutions. Because of this, we continue to observe analysis and management solutions that exist solely within vendor stovepipes and that have limited quality, utility and flexibility and, often, have high cost of use and maintenance with few economies of scale. These issues are likely due to the fragmentation of this market. What is clear is that the public safety community needs state-of-the-art analytic technologies that are tightly integrated with their video systems, greater engagement with research and small innovators, and more tractable costs for deployment and maintenance of analytic tools.

The great divide between situation awareness and forensics:

There appears to be somewhat of a disconnect between the use of video for real-time situation awareness and its downstream use in forensic investigation. The priorities in each of these communities are dramatically different and sometimes in conflict since public safety's focus is on maintaining and utilizing real-time communication channels (and accepting various forms of degradation when connectivity and bandwidth are limited), whereas the forensics and legal communities are concerned with data consistency and integrity. It would be helpful if there was greater coordination between the public safety community and forensics community

towards the creation of requirements and best practices that could better support both the real-time and the forensic use of video. It is clear that as technology progresses, the lines between real-time analysis and forensic analysis will blur. It is also clear that analytics will significantly replace human eyes in large-scale analyses in both of these domains. A key consideration moving forward is in the definition of video quality for each of these communities with regard to their human and analytic applications and how such quality could be measured and co-optimized in both public safety and forensic workflows. These considerations will significantly impact future communications and storage systems and the effective utilization of analytics across the workflow.

Resources and tools to support public safety needs – perhaps crowdsourcing is the answer:

Funding is a challenge for the public safety community and often necessitates investment in the urgent rather than strategic needs. Funding appears to be available to public safety to support deployment of new devices, but it is difficult to find funding to maintain existing ones or to develop analytic and data management capabilities to work with the immense data produced by the proliferation of devices. Likewise, it is challenging for the research community to identify funding to support both fundamental and applied R&D related to public safety needs. Most small jurisdictions cannot afford traditional analytic solutions bundled into proprietary video collection and management systems and often find that such solutions do not meet their specific needs. Only the largest cities can afford to develop analytic solutions that are customized for their needs. Tools and solutions are needed that permit public safety to develop cost-effective real-time and forensic analytic and data management applications for their needs that they can control and maintain. Since many jurisdictions are being crushed under the weight of the data they are collecting, these solutions are becoming urgent. One answer to this conundrum may be in a crowdsourcing development process managed and undertaken by the public safety community itself. In the future, public-safety-created analytics and data may be shared across jurisdictions to support a cost-sharing model that leverages custom capabilities being generated by the public safety community themselves.

Resources and tools to support research needs – data sharing is critically important:

While the public safety community struggles with ineffective data analysis and management tools, the research community has inadequate research data and tools to develop the technologies that are needed to support future public safety capabilities. The research community requires significant amounts of representative data to engage in effective R&D. Sensitivities related to evidential data management and privacy make the sharing of operational video an enormous hurdle. The challenges are further compounded in that most data is collected within proprietary systems and formats and is difficult to curate for research. Tools to support R&D that address annotation, management and evaluation of research solutions are critically needed as well. Moreover, modular R&D frameworks are

needed to support effective scalability of both research and deployment activities. Such frameworks will also need to support applied research in edge computing and the integrated deployment of edge-enabled devices. All of these challenges will need to be addressed to effectively engage the research community in developing technologies that support quickly-emerging public safety video analysis needs.

Modular tools to support public safety workflow could help:

Tools to support the more effective management of video workflows was also described as a significant need. For example, with the expansion of video capture capabilities, such as body-worn cameras, along with the increasing need for transparency, the need for video redaction was identified as a high-priority topic. Current video management and redaction tools vary greatly depending on Concepts of Operations, jurisdiction and local laws, and there are many general weaknesses. The participants suggested the following areas for further investigation:

- Development of best practices to support consistent and efficient video workflows where technology is utilized, including identification of workflow taxonomies and common processes;
- Identification of best use of human analysis combined with automation, including conditions of use, data conditions and jurisdictional policies; and
- Development of tools to support more efficient and effective workflow processes including (but not limited to) automated/accelerated review, detection of key elements, clustering/segmentation and filtering, redaction, annotation, transcoding, compression, quality control, etc.

It is quite evident that these three areas are not independent. Best practices and, ultimately, policies would need to be developed that comprehended all three areas and research in these areas would need to be coordinated. This area could potentially develop into an accreditation program as it solidifies.

Video analytics as part of the greater public safety communications technology ecosystem:

Finally, video is not an island in the increasingly complex public safety data ecosystem. The utilization and fusion of complementary data sources and modalities is quickly becoming a priority need. Public safety data currently spans video of many forms, inter-responder audio communications, 911 communications, geospatial data and sensor data. These data will expand as new communications and sensor capabilities become available. The utilization and optimization of the diverse and dynamic sources of data for real-time situation analysis within the fabric of complex communications networks presents a Big Data challenge that is unprecedented in other domains. R&D-focused communications and processing frameworks are needed to support the development, simulation and deployment of future public safety analytic capabilities. Likewise, both physical and cyber security

will continue to become more important factors as video and video analytics play an increasingly important role in public safety. Technologies, best practices and standards that are developed to support video use and analytics in public safety must incorporate protection of the security, integrity and availability of the critical data and communications systems that support real-time and forensic public safety applications.

2.2 Best Practices

Optimizing analytics in the human decision loop and humans in the analytics loop:

As mentioned in the previous section, it is critically important that users of VA technologies understand their strengths and weaknesses and leverage them appropriately. VA can be used as a force multiplier where there are not sufficient human eyes on video and in understanding geographic and temporal patterns and anomalies. They can also be used to discover forensic elements that human eyes cannot readily detect. However, these tools will not be perfected in the near future and must be used carefully with an understanding of both their strengths and weaknesses. Therefore, virtually all video analysis workflows that employ automated analysis technologies should include a human in the decision loop. An objective understanding of how to most effectively couple human users with such tools remains somewhat elusive – especially when humans provide feedback to improve these technologies. The failure modalities of both humans and analytics must be well characterized and users must be properly trained in their use, especially in how to recognize bias introduced by the analytic, the human or the human-analytic combination. This is largely an unexplored area, especially in public safety applications. We have no real starting point since the performance of either group on the constellation of public safety video analysis tasks is unknown. The development of best practices for the development and deployment of video analytics and the training of users in their proper use is extremely important. Likewise, it is important that a shared understanding of analytic capabilities, taxonomies and data be developed, and that best practices be developed for the sharing of these tools across agencies and jurisdictions.

Constructing meaningful data for R&D:

It is extremely important that best practices be developed to support the creation of future datasets that will drive the research since the compositions of these datasets – both for system development and assessment – will heavily influence both the strengths and weaknesses of future public safety analytic technologies. Biases in datasets are known to heavily impact the machine learning technologies that are derived from them. This is a largely unexplored area and one in which the public safety community could act as a leader to the greater machine learning community.

Mindful R&D and deployment practices:

Finally, developing best practices for R&D and VA deployment related to legal, policy, privacy and social considerations will help to ensure that both the R&D community and public safety community understands how to plan and perform research and transition activities that effectively addresses these concerns.

2.3 Collaboration and Coordination

Development of collaborative research:

There was a vibrant discussion regarding future collaborative activities and there was concurrence that cross-cutting activities that bring R&D stakeholders together, such as VAPS, should be continued. Much collaborative work lies ahead in joint development of datasets, research infrastructure, measurement methods, and standards and best practices. Data will play a critical role in both fostering a research community and focusing research on public safety priorities. Open research frameworks that promote the sharing of research and development of scalable R&D will also be extremely important. Likewise, development of collaboration research projects that are inclusive of public safety stakeholders will help to ensure proper focus and utility and future deployment.

Development of collaborative R&D frameworks and sustained engagement:

It was suggested that VAPS could potentially evolve to act as a collaboration multiplier, providing a focal point for the sharing of knowledge, R&D frameworks and tools. It could also act as a jumping-off point for further public safety engagement in the form of surveys and roadmapping activities. Workshop participants expressed a unanimous desire for VAPS to continue to hold regular periodic workshops highlighting relevant projects, collaboration activities and opportunities, and knowledge exchange and planning.

Broadening engagement:

It could be useful to align future activities and workshops with events which have activities and participants with which it would be strategically useful to more deeply engage. Furthermore, there was desire for continuing team-focused collaborative efforts to be developed in priority areas. Such efforts might be at a regional effort and have their own meetings, as well between major VAPS events. Collaborative work could include the development of datasets, methodologies, resource catalogs, frameworks, tools and best practices. Future VAPS workshops and activities might also expand participation to more greatly include:

- Strategic mix of large and small public safety organizations;
- Federal, state and local government agencies;
- National laboratories and Federally Funded Research and Development Centers;
- Federal and state fusion centers;

- International associations in law enforcement and public safety;
- Hospitals and emergency services;
- Universities/public education systems;
- Insurance industry; and
- Sports, entertainment and retail venue industry.

3 Conclusions and Next Steps

The workshop concluded with a discussion regarding key takeaways and next steps. The following is a summary of both the conclusions that came out of the workshop and follow-up discussions that have helped to further develop these concepts.

Workshop Takeaways:

- The stakeholder communities cannot be islands. The workshop showed that knowledge sharing and strategic collaboration across traditional lines can play a powerful role in innovation. Robust collaboration between the communities that were brought together in the workshop and beyond is essential to developing the effective public safety video analytics ecosystem of tomorrow. The research community needs to understand public safety needs and nuances and public safety needs to be directly involved in shaping R&D. Furthermore, R&D cannot be performed in a technology vacuum that is ignorant of legal, policy and social considerations.
- Public safety has a substantial list of VA technologies they need. An extensible approach to analytics creation is necessary to support these needs – especially when it is clear that these technologies will need to be customized to the environments and policy frameworks they will be used within. Technology to support data management and archival analysis is critically important now.
- Data drives R&D and representative data is needed to both attract and focus the research community on the important hard problems. In addition to making data available for research, a significant effort needs to be made to understand the relationship between data and analytics, in how to construct datasets that minimize data bias, and appropriately test technological weaknesses in the context of data-driven/deep learning methods.
- Hard technology challenges are going to require new R&D and test and measurement approaches. These include video redaction, multi-camera analytics, distributed analytics, mobile camera analytics, embedded systems and Internet of Things, edge analytics, and multimodal analytics such as gunshot detection. In addition, a number of important enabling technologies that will be critical in controlling future data streams and data storage parameters will require novel R&D and measurement. These include stream/multi-stream and storage management technologies that incorporate

data optimization, smart compression for preserving bandwidth for data on the move, and quality analysis for optimizing data for particular uses by humans and analytics.

- Understanding the human factors related to video use, scaling and bias are important to consider. Analytics may be used to support interfaces and generate visualizations that reduce cognitive load.
- Legal, complex jurisdictional policy and social considerations must be comprehended in public safety VA systems and in the research that is conducted to create these systems. Where possible, analytics should be leveraged to support governance and increase privacy.
- Technologies, best practices, and standards that support both physical and cyber security in the future public safety video ecosystem are essential so that video and video-derived data and systems are protected and reliable, and so that data integrity is maintained across systems and workflows.
- Innovative development approaches, standards, R&D frameworks, and tools and research resources that foster interoperability and lower the bar for research and innovation, as well as deployment and information exchange, are essential for the future public video analytics ecosystem. R&D needs to be economical, sustainable and customizable for the public safety and research communities and profitable for industry. New development models exploring modularization, open standardized development frameworks, shared data and tools, and crowdsourced R&D may help address the challenges.

Next steps as suggested in the workshop:

1. Collaboration and Coordination:
   - Develop a standing group (potentially a hybrid of VQiPS and VAPS) representing the diversity of the stakeholder community that was brought together in VAPS and focused on strategic planning, coordination and broad engagement spanning research to deployment in public safety video analysis methods and technologies.
     - Work with the public safety community and across R&D stakeholders to develop challenge evaluations and R&D projects on key technology needs and infrastructure to support robust collaboration.
     - Begin activities focused on developing best practices, frameworks, and scaling and sharing strategies with regard to future standards related to the role of VA in the future public safety video ecosystem.
     - Perform outreach to major organizations/events in the key stakeholder areas and utilize educational and social media tools to generate awareness and participation. Develop educational materials and experiential prototypes that support the public safety community in

understanding the state-of-the-art and how they might go about developing their own analytics.

- Organize periodic workshop events to highlight successes and foster collaborations.

2. Technology Research, Development, Testing and Evaluation:
   - Develop R&D projects, developmental tools, datasets, data sites, evaluation infrastructure and other developmental resources to support key public safety VA technology development and evaluation needs identified in #1.
     - Address R&D specific priorities in workshop report regarding analytics, frameworks and data.
     - Foster potential corporate and federal R&D funding and prize competitions for innovative ideas, frameworks, methodologies and high-performing novel solutions to address key technology needs.
     - Explore agile methods for fostering R&D and innovative multi-stakeholder communities.

3. Public Safety Incubators/Deployment Centers:
   - Create infrastructure in regional public safety centers of gravity to support cross-cutting development and assessment of applied pilot projects to accelerate R&D refinement and deployment.
     - Harden research grade technology in terms of robustness, efficiency, scalability and usability, and integrate it into existing systems.
     - Create prototype systems to demonstrate emerging capabilities and best practices.
     - Create reusable infrastructure and methods for standing up new analytics and measuring transition performance that can be exchanged across jurisdictions.
     - Provide feedback to the academic and industry research communities and deployment knowledge to the public safety community.