Context Enabled Computing

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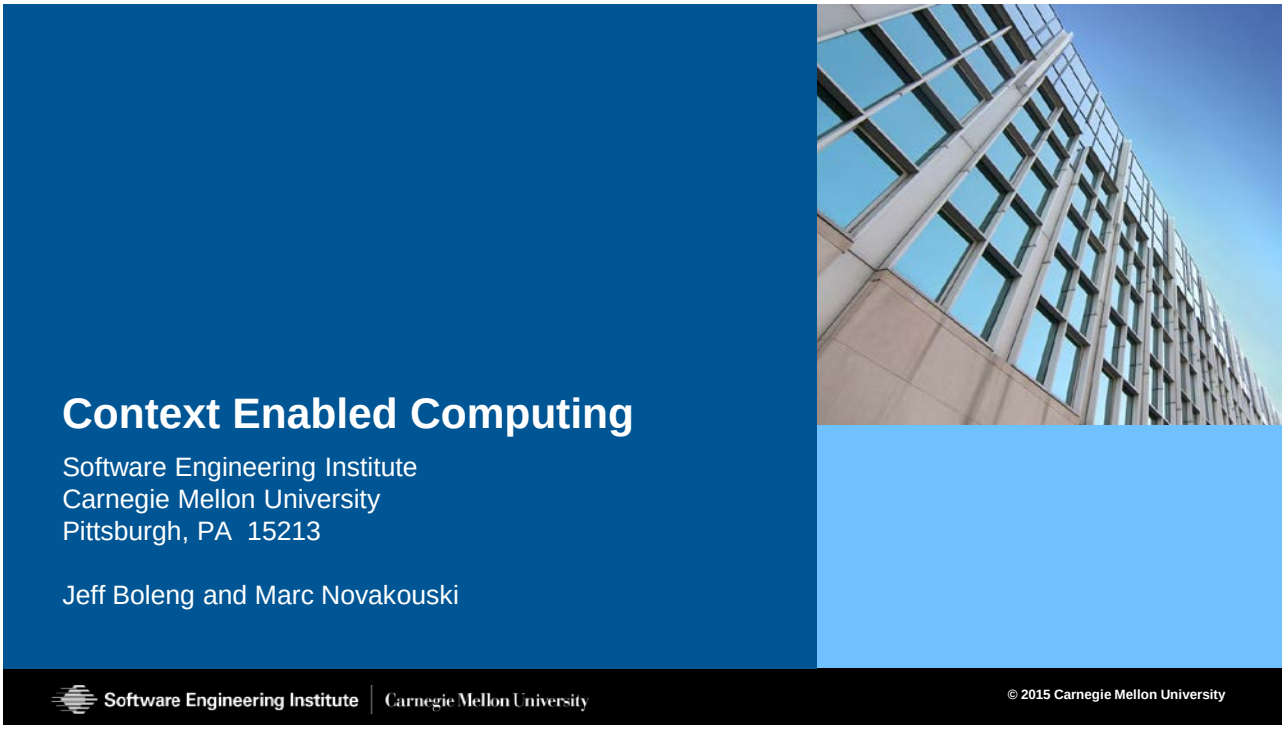


**003 Shane McGraw: And hello from the campus of Carnegie Mellon University in Pittsburgh, Pennsylvania. We welcome you to the Software Engineering Institute's webinar series. Our presentation today is Context Enabled Computing by Jeff Boleng and Marc Novakouski. Depending on your location, we wish you a good morning, a good afternoon, or good evening. My name is Shane McGraw. I'll be your moderator for today's presentation. And I'd like to thank you for attending.

We want to make today as interactive as possible. So, we will address questions throughout the presentation and again at the end of the presentation. You can submit your questions to our event staff at

any time by using the questions tab on your control panel. We will ask a few polling questions throughout the presentation as well. And they will appear as a pop-up window on your screen. The first polling question we'd like to ask is how did you hear about today's event.

Another three tabs I'd like to point out are the files, Twitter, and survey tabs. The files tab has a PDF copy of the presentation slides there now along with other context enabled computing related work and resources from the SEI. For those of you using Twitter, be sure to follow @SEInews and use the hashtag SEIwebinar. Once again, follow @SEInews and the hashtag is SEIwebinar.

And now I'd like to introduce our presenters for today. Jeff Boleng is a principle research scientist at the SEI. He joined the SEI in 2012 after twenty-one years of service as an active duty cyber operations officer in the U.S. Air Force. During his service, he was a member of the computer science faculty at the U.S. Air Force Academy for eight years where he was honored with the Outstanding Academy Educator in Computer Science award for the academic year 2007-2008.

Marc Novakouski is a member of the advanced mobile systems initiative and is a part of the Edge enabled tactical systems team at the SEI. His current work focuses on mobile systems at the edge, networking in

disconnected, intermittent, and low bandwidth environments, context awareness, and advanced soldier situational awareness. Marc has over fifteen years of professional software development experience spanning the defense, commercial, and academic fields.

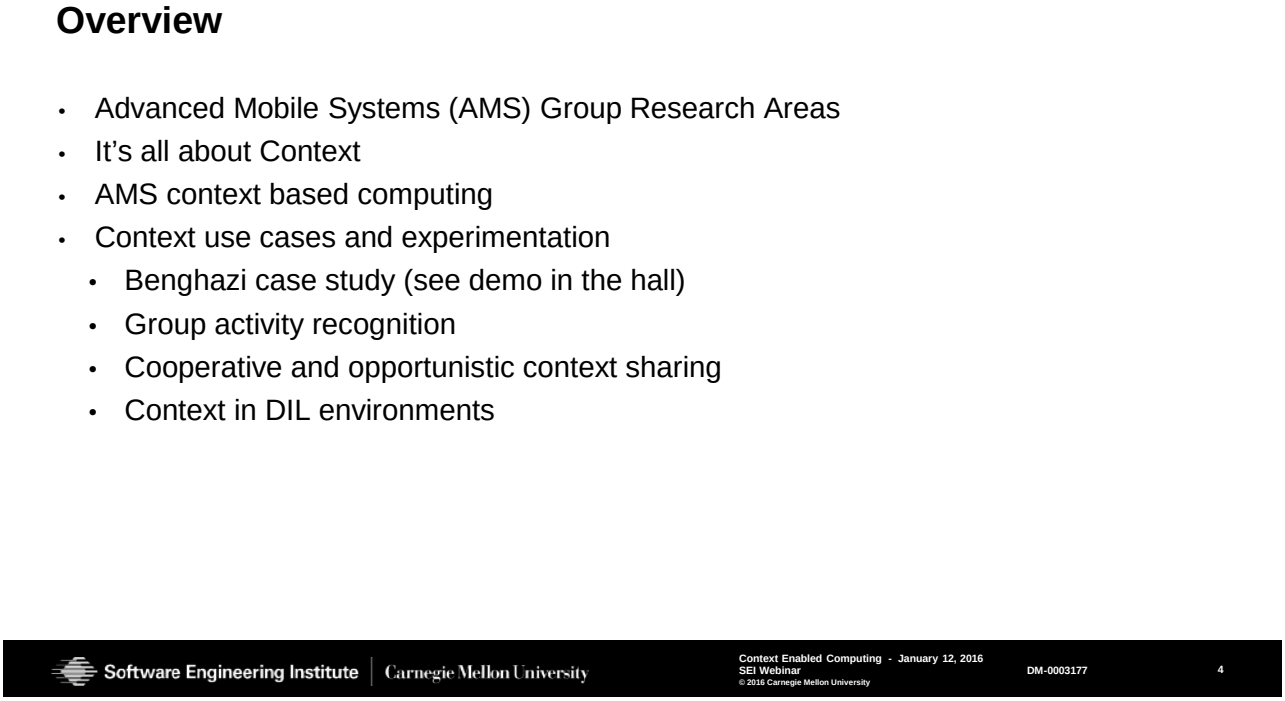
Now, I'd like to turn it over to Jeff Boleng. Jeff, Marc, welcome. All yours.

Jeff Boleng : Thank you very much, Shane.

Marc Novakouski : Thank you.

Jeff Boleng : So, today we're going to talk about a lot of the research and results we've been doing with context enabled computing here at

Overview



**004 A brief overview, I'm going to give a little background about the group we work in in the advanced mobile systems group and then sort of give some background and rationale for why context-- why we think context is certainly important and where context I think is really a burgeoning interest for mobile and the computing industry in general, talk about some of the stuff we've done in the advanced mobile systems group. And then we're going to go through a lot of use cases and experimentation that we've done to date. And hopefully that will highlight a lot of the research and the results we've got. And we welcome your questions throughout. So, Shane will field the questions. And we're going to dive right in.

Advanced Mobile Systems (AMS)

Advanced Mobile Systems (AMS)

Investigates efficient and easily-deployable mobile solutions for teams operating in edge environments. Edge environments are characterized by dynamic context, limited computing resources, high stress, and poor connectivity.

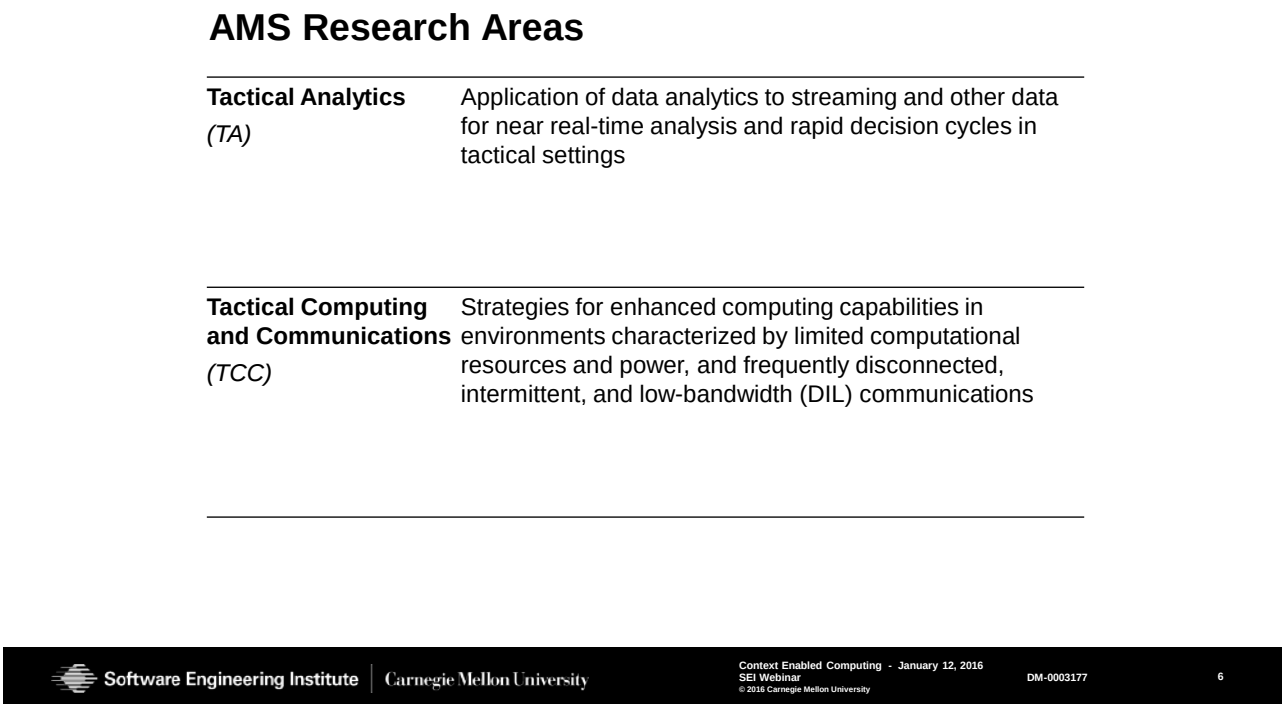
AMS prototypes capabilities for stakeholders operating in mission-critical environments that

- improve situational awareness and data analysis
- reduce cognitive load and complexity by exploiting contextual information
- increase computing power, data access, and survivability while reducing power demands

AMS facilitates interactive mission assistance in edge environments by leveraging available sensors and information from other people and systems.

**005 So, the advanced mobile systems group at AMS is about twelve people that do research specifically in technologies to aid dismounted soldiers and first responders that operate in edge environments. So, we characterize edge environments by things that have limited computing resources, limited power, poor connectivity, and also high stress. So, that focuses our research on things like being power aware, and working well in low bandwidth environments, and also doing things to help reduce the stress that a soldier or first responder might feel while working in an Edge environment. So, things like cognitive load become very important for a lot of the research that we're doing as well.

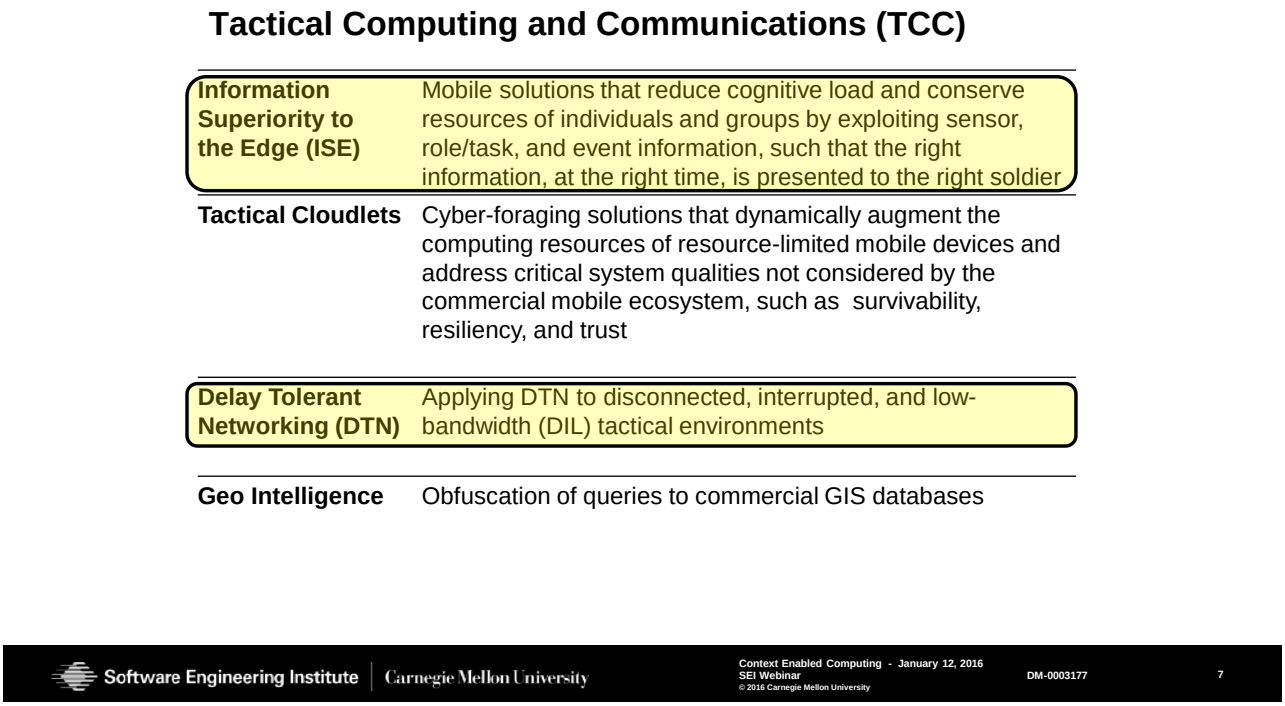
AMS Research Areas



**006 Within the AMS research areas, we've got two big components. One is tactical analytics. And we can think of this as really the services and the application software that an edge user would use, either a soldier or a first responder would use. And then the other big area of research is tactical computing and communications. And we can think of that as the infrastructure piece to host the tactical analytic applications that run. So, in the tactical computing and communications piece, it's much more about-- we have a line of research called Cloudlets where they're mobile clouds that can host a lot of the tactical analytics that we've got. And a lot of the routing work that we'll talk about today, context enabled routing, falls under the

tactical computing and communications.

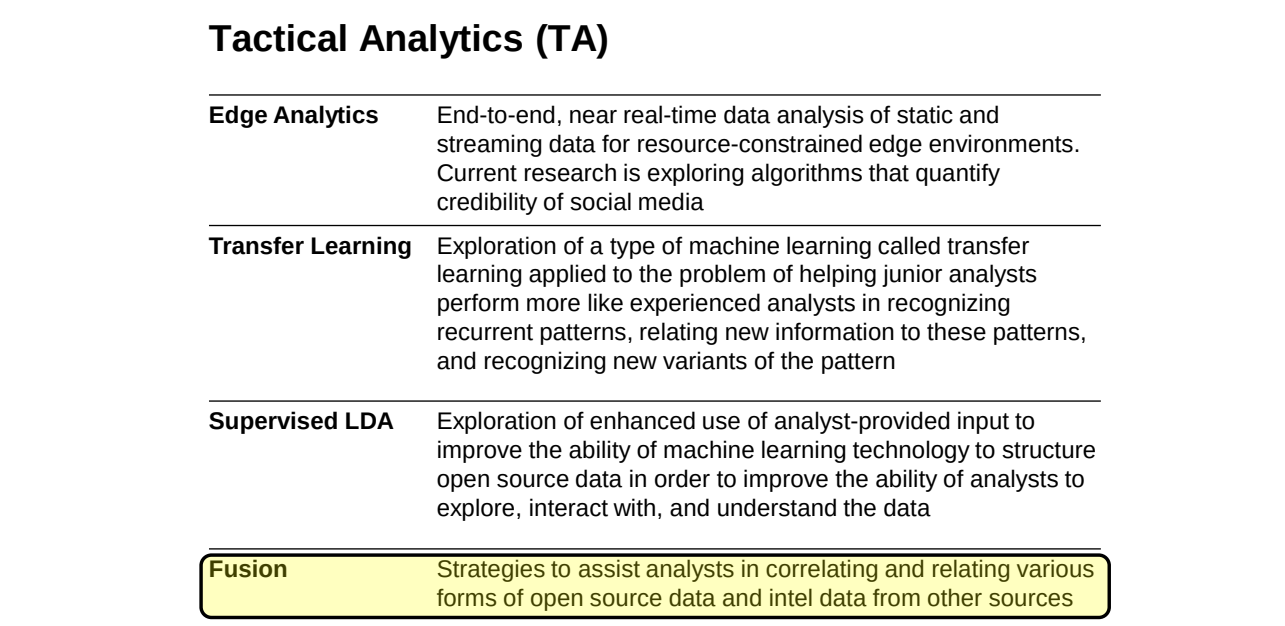
Tactical Computing and Communications (TCC)



**007 So, in that piece, technical computing and communications, we've got four big areas. The ones we're going to talk are information superiority to the edge. That's a context aware mobile application, mobile situational awareness application, that Marc's going to cover in depth. And then also delay tolerant networking, we've done a lot of work, once we get into these intermittently connected edge environments, usually everything's wireless connectivity, especially tactical military radios. Sometimes, work in challenged environments that are very intermittent and low bandwidth, so we've done a lot of

work with delay tolerant networking. We're going to talk about today about how we use context to increase the delivery and better utilize the bandwidth in those edge networks.

Tactical Analytics (TA)



**008 And under tactical analytics, I'm going to briefly talk about edge analytics because we used that in some experimentation to use environmental context, things like what's going on in social media, in order to help inform the behavior and actions of the people in an edge environment. And then also about some fusion strategies, how we used context to do some data fusion strategies.

It’s all about Context

It’s all about Context

- “Understanding and using context”
  - Anind K. Dey, Personal and Ubiquitous Computing, 2001

“Context is any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves.”

- Traditional usage is person, location, and time
  - Example: Cursor on Target (CoT) -- What, Where, When
- Again from Dr. Dey

*“A system is context-aware if it uses context to provide relevant information and/or services to the user, **where relevancy depends on the user’s task**.”*

- Personal and environmental context
- Context is the next battle in mobile
  - Google Now vs. Siri vs. Cortana vs. Amazon Echo vs. ???

**009 So, for Marc and I, a lot of the work we do, we believe that context is incredibly important. We are lucky enough to collaborate with a CMU professor, Dr. Anind Dey. We call him the father of context computing. I don't think he-- he's not always flattered by being the father of context computing, but-- I think he's younger than I am. But he authored one of the seminal papers back in 2001 about using context in computing. And so traditionally, when we talk about what context is, a lot of times it's a person at a location and a time doing something. And so, that's one of the examples. The military example of that is Cursor on Target. It's a well-known XML schema that really is a very simple thing that's got a what, where, when

for events that can happen in an edge environment.

Our goal is to expand that. Marc's going to talk a lot more about how we expand that to make the context that we leverage a lot richer. And then there's a couple of definitions you'll see on your slides about how Dr. Dey defined context. And we try to stick really true to that. So, it's any information that's relevant to the task a user's doing at that time.

And then also want to make a distinction early on because it will come down later in the presentation about personal versus environmental context. So, from personal context, it's really a lot about what am I doing now, what data's on my phone that's about me that it can mine. And then environmental contexts are those things that definitely impact and influence me but I don't have any control over. And in a lot of cases we want to fuse those two bits of context to help our systems deliver information more effectively, or save resources, or help reduce my cognitive load and make my decisions easier by presenting me the right information.

Marc Novakouski : And to be clear, when we talk about environmental, we are talking about more-- that word is a little bit overloaded. What we're talking about here is anything that is external that influences me. So, that could be environmental as in the weather because my plans will change depending on the weather.

They almost did today. It was hard to get in to work, lovely Pittsburgh, but also the environment in terms of the political mood. That's certainly going to influence what's being talked about on social media. Also, you know the sort of tasking that the government might have funding for, so the government just put out an extra 1.3 billion dollars I think in NASA's funding. So, their context is completely changed. And they're trying to figure out how to deal with how they're going to do their tasking. So, there's all sorts of environmental, external context that influence me that may be worldview. It may have to do with people that I know of. It may have to do with just the weather and the Earth itself. And we're trying to find a way to bring all those together to better understand what you're doing and what kind of information you need.

Jeff Boleng : Yeah, so it's been-- the popular press recently has started to come up with articles about context being the next great battle in mobile. And so, if you look at some of the things that happen with Google Now and over the last couple of years as the Android operating system upgraded, I started realizing my Google Now cards are starting to shock me with the things that they know are upcoming for me. So, it tells me my flight's in a couple of days. Here's a restaurant you might want to try based on other things that I've done. That's all about how these agents are using my context to help me. Of course, SIRI does a lot

of that. Cortana now with especially Windows 10, Cortana and then the Amazon Echo is another good example. And then whatever the next device, the question marks on the slide, is, whatever that next device is. So, there's definitely a big battle going on of how can we effectively leverage context in order to gain market share, better assist users, and present information more effectively.

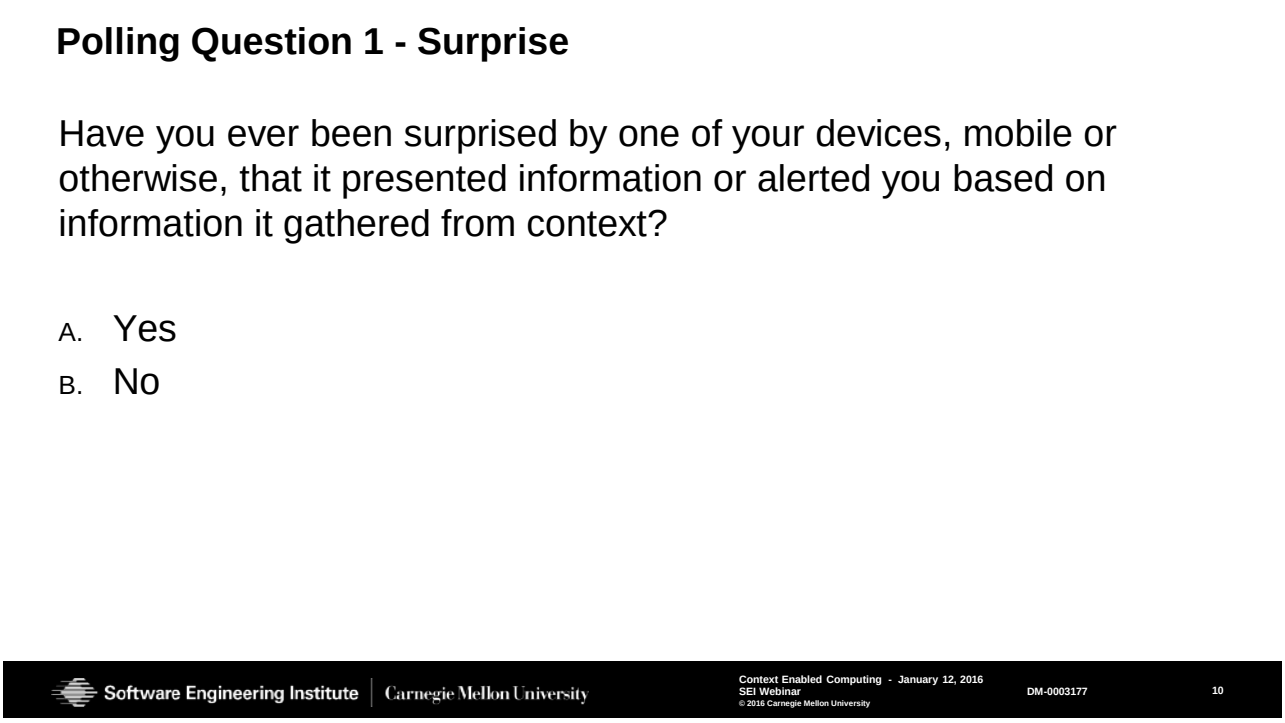
Marc Novakouski : And one of the best situations is in kind of considering the idea of the push versus the pull notification. So, I need to know what my calendar has. I need to know what my set of tasks. I don't remember what it were from yesterday. So, I pull up my calendar. It lets me know I have a meeting at one. I have a meeting at three. Whatever it is, Google Now will now push to you, "Hey, look it's pretty bad traffic. You should head home. I know that you usually try to go home at 4:45. You have dinner at 6:00," or whatever. "You need a certain amount of time. Traffic's pretty bad today." And we have a couple of early adopters in our group because Advanced Mobile System's got a bunch of young guys in there trying to take advantage of the best technology. And they're just playing with this stuff and finding out yeah. So, it's starting to tell me stuff that I didn't know I needed to know. So, getting understanding more than just what I know I need to know, but also ambient information around me that could affect me that I didn't even

think of. So, that's kind of the real barrier that we're trying to break into.

Jeff Boleng : And bring those technologies to bear for first responders and dismounted soldiers specifically.

Marc Novakouski : Exactly.

Polling Question 1 - Surprise



**010 Shane McGraw: So, polling question number two you'll see on your screen here now. We'd like to know have you ever been surprised by one of your devices, mobile or otherwise, that had presented information or alerted you based on information it gathered from context. We'll take about ten or fifteen second to vote there. So, I'm assuming you guys have had--

Jeff Boleng : I've always been surprised, especially like I said, a couple of years ago when Android started-- with Google Now started really mining my emails more effectively and presenting stuff to me. And we had another member of our team, we were in California at an exercise, and another member of our team-- how did that go with-- maybe we won't tell that story.

Marc Novakouski : I'm not entirely sure.

Jeff Boleng : It basically assumed he was someplace that he really didn't want to be.

Marc Novakouski : Right. It was sort of--

Jeff Boleng : Presenting a bunch of information that was interesting.

Marc Novakouski : We take a trip out to California, or at least we used to, to go to a government testing event. And while we were out there, it told him to go to this particular area just in the area. And it ended up being something to do with Valentine's Day. It anticipated that he needed to meet this person. And we were like, "That's really creepy." But hey, you know there's actually some thought behind that. But you know the sort of things where it actually, without him even making travel arrangements for one of those trips like some of us go some times, some of us go another time, it told him,

"You need to leave now because traffic to the test location is really bad."

Shane McGraw: So, no surprise, seventy-seven percent with yes that they have been surprised.

Jeff Boleng : Good.

Shane McGraw: Back to you Jeff.

Jeff Boleng : I'm starting to think this is more of a generational thing because I think people of my generation, I feel like I'm a little older than I want to be right now, but I'm surprised by the things technology are doing for me. But I'm-- certainly my fourteen-year-old daughter with her iPhone, she's just-- yeah, never surprised at all.

AMS Context Based Computing

AMS Context Based Computing

- Expand context to include
  - *User*, *location*, *time* ***and***
  - *Mission*, *role*, *task*
- Leverage context across the group
  - First responders and teams of soldiers operate in groups with common mission
- Enable adaptive behavior via rules engine
  - User context cues sensor tasking and information delivery
  - Sensor data cues context changes

**011 In fact, I think she's surprised when it doesn't tell her what she should be doing.

Marc Novakouski : Exactly.

Jeff Boleng : So, I'm going to turn it over to Marc to talk about this information superiority to the edge, like I said, is a handheld digital situation awareness application that we developed as a research prototype to implement a lot of the ideas we've got about leveraging context. And so, Marc's going to do a little bit of a deep dive there.

Marc Novakouski : Right. So, just the kind of the elevator pitch for this line of work. What we kind of said in late 2010 is-- when we formed the Advance Mobile Systems group, is that we were really concerned with getting the right information at the right time to people in these real high leverage situations. So, somebody who's out in the field, whether it's a soldier in Afghanistan or wherever he happens to be or she happens to be, or if it's a first responder, the earthquake in Haiti a couple years ago, the situation in Japan, something like that. So, those people are in really challenged environments. And a lot of times, they have a high information need but a limited ability to gather that information, to be aware of that information, to be aware of the information they need, and very limited ability to actually go ahead and get it because of connectivity

issues, because of power issues, because of cognitive load issues.

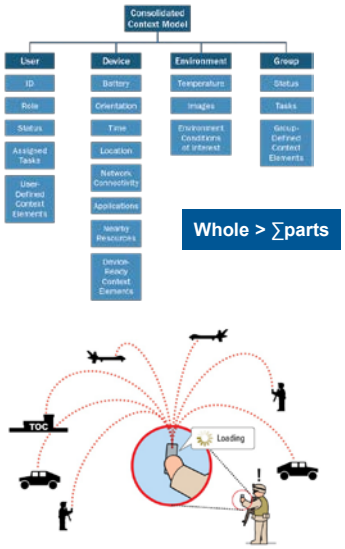
So, we kind of tried to say is across the entire bandwidth of what Advanced Mobile System does is how do we address each one of those problems. And out of each one of those problems grew a different field of work. The information superiority to the edge piece of work, that task, was really about saying okay given that I am, for example, a soldier or a first responder out in the field, what are my information needs and how do I make sure that I, A, can get that information, and B not be overwhelmed by it.

And really the key insight that we had with that particular piece of work was that the people in these high leverage situations are generally not working alone. They work as part of a team, part of a group. And that identity within the group, both as the group as a whole, but also their part-- their role within that group is a big driver to what their information needs are. And so, if I'm a particular soldier, I'm a medic on a squad, or I'm the infrastructure guy who knows how to set up 4G Wi-Fi hot spots, I'm a first responder, then I have a specific role. And I have specific tasks. And I have an overall mission that my entire group is all participating in. So, our work, with respect to the information superiority to the edge task, was to try to leverage the context of the group and be able to use that to push the information that they need to them

when they need it as well as filter out the information they don't.

And that filtering piece, because they're very busy you know-- If you're dealing with a disaster situation, you're too busy to filter all the alerts on your mobile device. If you're being shot at in the field, you're clearly too busy to use your mobile device to figure out what's going on. That really kind of only the information you need is really focused upon what is your role within that particular task within that particular group. And what we did is we started to build a system to not only understand the group context, but then to be able to process that and enable adaptive behavior via a custom rules engine that built so that we could take context cues from sensors, from external devices, and then use those to determine what the context information that an individual needs, and pull that or push that to the necessary person. Next.

Information Superiority to the Edge



Group context aware reference architecture, middleware, data model, and prototype implementation to reduce cognitive load and conserve resources by using sensor, role/task, and event information to deliver the right information, at the right time, to the right soldier

Context Model: Expand the context model beyond time and location, resulting in broader and more complete understanding

Context Reasoning: Broader context model allows reasoning and reaction to the context of the individual, other individuals, the group, and the organization.

**012 So, I'm going to go in a little bit on a deep dive. We have a lot of slides, so we're not going to get to all of them today. But just to give you kind of an overview of where we came from, the first thing that we had to do in order to make this work real was to try to build a context model that really kind of expands beyond just time and location, that who, what, where, when kind of thing. So, if I pull up my Android phone or my iPhone, and I pull up the calendar app, it's what do I have on my schedule, where is it, and when is it. That's true in the defense world. It's true in social media. It's true on my mobile device.

But we need to be able to reason beyond that. And so, we built, using the context toolkit that Dr. Dey, that

we talked about previously, we worked with him and vetted our model with him to try to expand that model out to start to add in things like roles, tasks, group identities, different types of location, all those different elements, and then the interactions actually, the relationships between my skills, the group that I'm part of, and then the tasks that I'm actually performing.

Jeff Boleng : I think one of the real keys to being able to do this is to have a rich enough data model to capture the semantics of the context that you've got. And it's not a matter of having the perfect data model.

Marc Novakouski : Right.

Jeff Boleng : I mean the best data model that covers everything. It's a matter of having a data model that has got sufficient richness in it that the semantics are easy are easy to capture.

Marc Novakouski : Right.

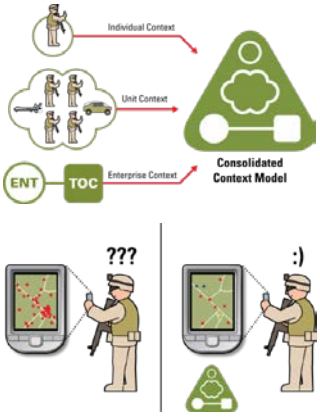
Jeff Boleng : So, I think as a first step was the data model.

Marc Novakouski : Absolutely. And having worked in this field, we both knew that there's no data model that's ever perfect. We know that. There's no ontology that covers everything. There's no data model that will ever allow us to process every different type data. That changes. But if we can generalize to the very basic elements, then any

kind of data the comes in externally, whether it's from this defense program, whether it's from the Red Cross, whether it's from DHS, we can bring that in, and we can understand it as how it relates to the individual user. And then that can inform our model. And by generalizing and building this general model, and then building a general-purpose rules engine that basically just uses various elements of Boolean logic, that allows us to react in arbitrary ways that change over the course of a mission. So, that is the second part, which is to say once we had that model up, building this general-purpose context reasoning engine allowed us to start to react to do different things, to push information, to pull information, to deal with different situations, to deal with different roles in different ways.

Information Superiority to the Edge

Information Superiority to the Edge



Resource Usage: Use of broader context allows smarter and more efficient resource allocation.

Cognitive Load: Richer context models can decrease the soldier's cognitive load required to capture, visualize and react to situational information.

Research Focus: Leveraging individual and group context to reliably deliver the right information, to the right soldier, at the right time

**013 Jeff Boleng : It ends up being-- I think the next slide might have it. No, it doesn't. So, it ends up being the fact that that rules engine is nice because sensor inputs, context of different levels, either very raw sensors or even high-level context can come in and trigger the rules engine to deliver information. But also user actions and previously delivered information can trigger the rules engine to then re-task sensors.

Marc Novakouski : Right.

Jeff Boleng : So, we get a really nice feedback loop throughout the whole thing.

Marc Novakouski : Right. And the kind of the value of what we're trying to achieve, the two main things we're

trying to talk about that we've discussed-- but just to be very clear about this, resource usage. So, I'm on the field. I have so much battery. I only have so much bandwidth. It's going to be going in and out.

Jeff Boleng : Limited compute power.

Marc Novakouski : And limited compute power. So, I need to be able to use all that information as smartly as I can. And if I don't have to burn cycles uploading, or downloading, or processing something that isn't important for me, that means I can operate at maximum effectiveness for much longer. So, that means that overall the group is doing better. Better overall efficiency, that's what we're trying to engage there.

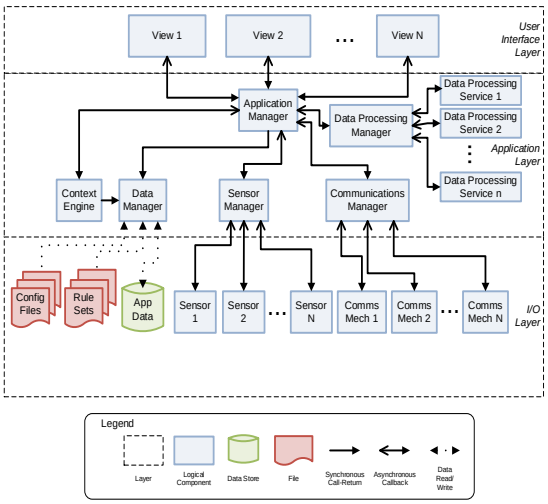
And then the other thing, again, is if we're really busy with high-leverage safety critical, life critical situations, I can't have my cognitive state be shifted from this alert to that alert to all sorts of different things, what's happening on my Twitter feed, whatever it is. I need to be able to focus in on my task and only have the things that are relevant to my task or super critical things that I have to react to immediately because they override my current task be part of what I am being presented by my mobile device. That allows me to stay much more focused on my task. And we'll talk about a couple experiments that we had where we were able to

show that a little bit, initial steps kind of a thing.

Jeff Boleng : Yeah, a simple example of resource optimization is something like the system understands that a group of individuals all have a shared mission, and they're all going to the same destination at the same time. They're in a vehicle, perhaps. One of the most power hungry things we have on our mobile devices sometimes is our GPS. If we're all in the car together, why do we need everybody's GPS turned on when we can just share location from one GPS to the others. Or, better yet we could scavenge the GPS from the car and then just share it to our devices and report things like blue force tracking and location for situational awareness, then not burn all the resources of every phone.

Marc Novakouski : Right.

Reference Architecture for Mobile Applications at the Edge (ISE & DTN)



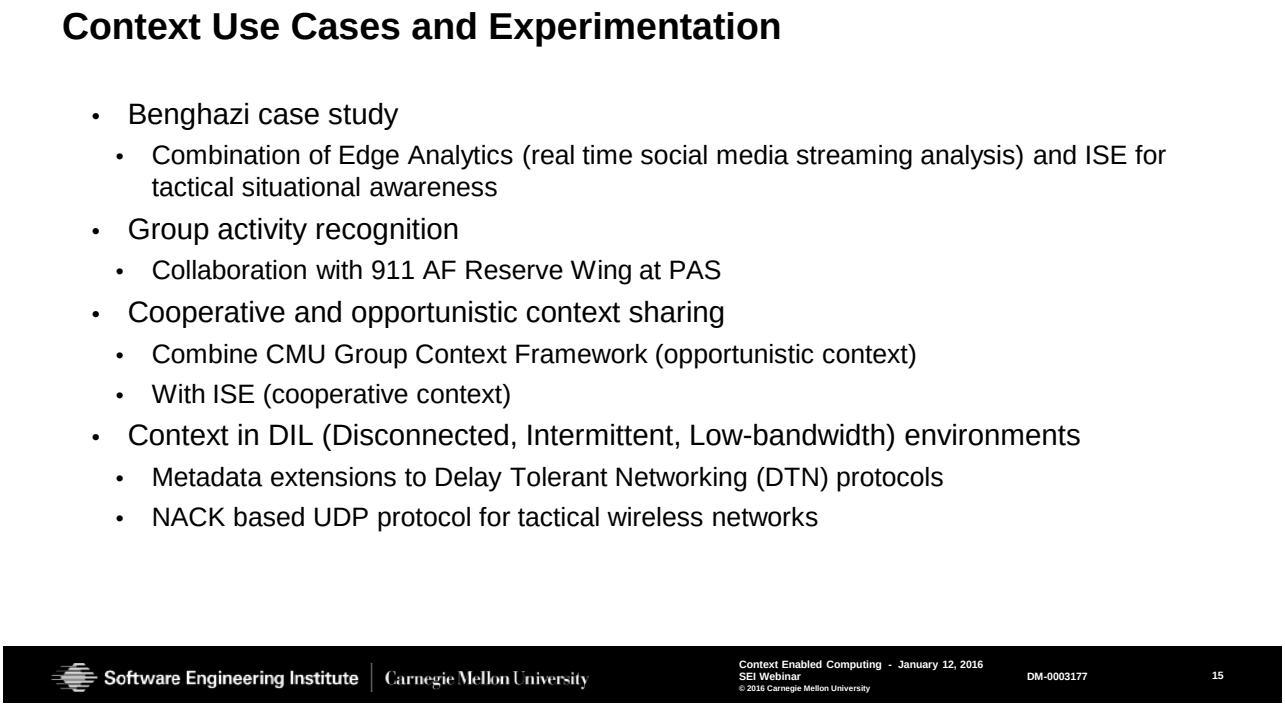
Key Qualities

- Modifiability
  - the ability to change between the views, rules, configurations, sensors, and radios without significant effort
- Extensibility
  - the ability to integrate new views, sensors, radios, profiles, and rules without impacting the rest of the architecture

**014 So, the last thing we want to talk about with respect to ISE is that all of the different research areas that the AMS program, the team, has kind of worked on has focused on generalization. We want to be able to say, "Here's a general-purpose solution for computing at the edge, for research scavenging at the edge, for analytics at the edge sort of thing. And in every case, what we've been able to do is we've been able to do is we've been able to generalize, and produce, and publish a reference architecture for applications that would be able to handle these sorts of tasks. If you email the group, I'm sure we can provide you some links to some of those papers if you have interest. But what we have on the slides right now is the general purpose reference architecture that is

used and actually implemented in our ISE prototype. And then there are corollaries and companion reference architectures for the other fields that we can provide as well.

Context Use Cases and Experimentation



**015 Jeff Boleng : Well, I thought we had a polling question here. All right. So, now we're going to dive into-- I'm going to talk a little bit of a case study that we did around the consulate attack in Benghazi and talk about some group activity recognition that we did. Marc's going to talk about that. That was a fun thing to do. Then another event we experimented with cooperative versus opportunistic context sharing, which I'll describe more. And then at the end, we'll get into what we've

done to use context for tactical networks.

Marc Novakouski : Right.

Benghazi Scenario - Background

Benghazi Scenario - Background

Request by DoD stakeholders

- Develop prototype from existing technology to demonstrate mobile handheld situational awareness (SA) to aid US personnel in foreign countries

Combine two ongoing research prototypes

- Information Superiority to the Edge (ISE)
  - Group context aware middleware and handheld SA
- Edge Analytics
  - Streaming data analysis to support rapid Intelligence Preparation of the Battlespace (IPB)

Link Open Source Intelligence (OSINT) to mobile Situational Awareness (SA)

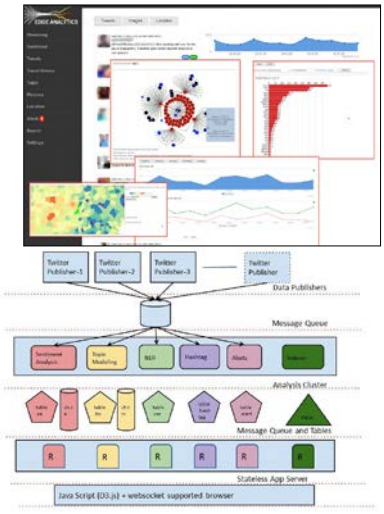
**016 Jeff Boleng : Moving data through technical networks. So, I think everybody in the audience is probably pretty aware of the event that happened. I think it was 2012 at the consulate in Benghazi when the ambassador was killed. We had a request from some of our DoD stakeholders to do a what-if analysis and combine two of our tools. One of the tools that we used was the ISE prototype that we talked about where if there were a bunch of people on the ground in Benghazi that day that had had a mobile situational awareness tool that could leverage

context and key and cue properly combined with another system that we've got that basically takes streaming, open-source intelligence, so social media type data, and gives you a view of what is the sentiment or what is the-- what are the breaking trends and stories in social media or in politics while I'm operating with my handheld situational awareness tool. If we combine those two systems, what effect might that have had in a scenario like the Benghazi scenario? So, essentially so we wanted to link open-source intelligence gathering to mobile situational awareness cued by context.

Edge Analytics

Edge Analytics

- Scalable architecture for real time streaming data
- Initially focused on Twitter
  - Extended for arbitrary text input
- Used in numerous field experiments
  - CreationFest 2013 and 2014
  - Little League World Series
  - Wireless Emergency Alert Service
  - MIT LL Next-Generation Incident Command System
- Pluggable analysis engines
- Accessible via web browser



**017 This is just a little quick overview, this slide, of the edge analytics system. It's an architecture

that scales very well for real time streaming analysis of data. It's got a pluggable analysis engine. You can put a variety of analysis algorithms, plug it into the framework really easily, do things like we do geo-inferencing, which tries to locate a tweet if it's not geographically tagged by the content of the tweet. It was originally focused on tweets on Twitter. It's been expanded to do arbitrary text. And we're looking at other modalities like images, video, and voice. It will do things like sentiment analysis, named entity recognition. It's got a whole bunch of those pluggable analysis engines. And so, we wanted a couple that capability with the ISE capability that Marc talked about.

Benghazi Scenario - Background

Benghazi Scenario - Background

Between September 11 and 17, 2012, diplomatic missions in the Middle East, Asia, and Europe were subject to protests and violent attacks in response to an inflammatory video, *Innocence of Muslims*.

**018 So, I'm going to give a quick just couple slides of background of the events that really happened then. This is all taken out of the Benghazi Senate report. We did a very close reading of that and a lot of the popular press of the day. So, you know that between September 11th and 17th of 2012, as a result of the release of the web video "Innocence of Muslims", there were widespread protests in the Muslim community across the Middle East, Asia, and Europe.

Cairo: Reaction to YouTube Trailer

Cairo: Reaction to YouTube Trailer

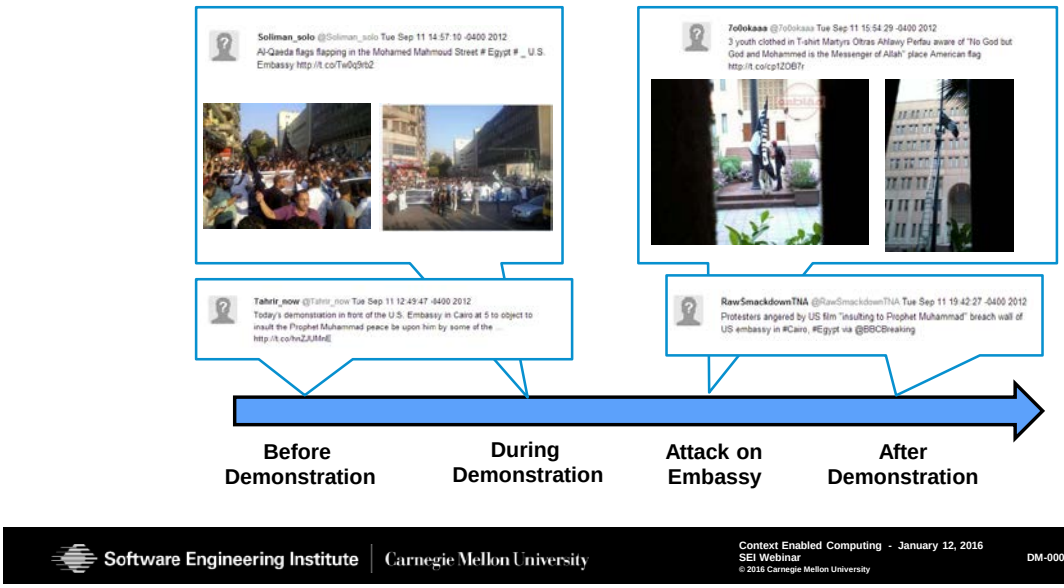
11 Sep 2012 @ 5pm:
About 3,000 demonstrators assemble outside the American Embassy in Cairo.

About a dozen men scaled the walls and tore down the US flag, replacing it with the black Islamist flag bearing the inscription Shahada (“There is no god but God and Muhammad is the messenger of God.”)

**019 These things ended up that in Cairo, there was a demonstration of about three thousand people outside the U.S. Embassy that that then turned into a breach of the embassy wall and the tearing down of the American flag. And there were

people injured there. And that happened about 5:00pm on 11 September.

Cairo Demonstration Timeline



**020 Then later that night is-- oh this is, sorry, a depiction of the Cairo timeline. Well before the demonstration, several hours before the demonstration, we saw a lot of social media traffic asking for support of the demonstration outside the embassy in Cairo. So, it was one of those events that was planned by someone and definitely publicized on social media to get more people there. And then the attack comes down, and there's imagery on the slide there of them taking the American flag down in the embassy, and then after the demonstration, the fallout that happened after the demonstration. So, that all trended

on social media, and we used our social media, our edge analytics tool, to comb social media and find a lot of that information.

Benghazi: Reaction

Benghazi: Reaction

11 Sep 2012 @ 10:40 pm: Large numbers of armed men shouting "Allahu Akbar" descend on the compound from multiple directions lobbing grenades over the wall followed by automatic weapons fire and RPG's. The assailants are backed by truck-mounted artillery and anti-aircraft machine guns.

**021 And then later that evening, around ten o'clock is when the attack on the consulate in Benghazi happened. And so, that all-- this is an actual image of that attack that then trended on social media within about forty minutes of the attack. So, that all was what happened. And then the next thing I go into will be sort of the case study that we did.

Polling Question 2 – Social Media

Polling Question 2 – Social Media

Can information valuable to law enforcement and defense be obtained by twitter and social media?

A. Yes
B. No

**022 So, we have a polling question though, right?

Shane McGraw: You'll see that popping up on your screen now, polling question number three. Can information valuable to law enforcement and defense be obtained by Twitter and social media? I think we know the answer here.

Jeff Boleng : I think so. There are different answers though. A lot of people say there's nothing but garbage out there.

Shane McGraw: Yeah, I was going to say. That was going to be my exact question. What about fake information? How do you guys handle it? Is that something that you're

going to cover later, or is that not something on the radar yet?

Jeff Boleng : No, that actually is on the radar. It's not a part of the context research we're doing, but there's another part of our group is actually-- was funded this year-- actually in 2015, one of their research focuses was coming up with automatic ways to deal with the veracity and the validity of the information in social media because information operations is as old as human speech. We try to deceive our adversaries all the time.

Shane McGraw: The Trojan horse.

Jeff Boleng : Absolutely. Yeah, absolutely. And it's well known that there are a lot of information operations campaigns that occur in social media. And so, we've done some implementation, mostly a bunch of research on, how can we look at the information and cross-correlate across multiple sources to verify the validity of that source. And some of it comes down to-- and I guess it is related to context because some of it comes down to the source of the information. Who's sending it? Is it a wire service, or is it a random individual? Or is somebody that is maybe not a wire service but a well-known but respected blogger or social media person? And cross correlating how many channels are we hearing this on and how many variations of the story are they? And try to use algorithmic means, we're using machine learning heavily for

this to say is that now a valid piece? And it's never a yes/no answer. It's always a we have with seventy percent certainty that this event had occurred or is occurring now.

Marc Novakouski : And then the question is seventy percent good enough?

Jeff Boleng : Right, yeah. And then you need a human back in the loop.

Shane McGraw: So, to close the loop on the polling question, one hundred percent yes.

Marc Novakouski : All right.

Jeff Boleng : We got an A.

Note

Note

The following participants and events are notional and were created to explore what might have been possible by integrating social media information (OSINT) with traditional intelligence combined with improved mobile situational awareness and communications.

**023 All right. So, the next few slides that I'm going to talk about are-- it's a notional exploration of what would have happened if we'd have had these systems available during that Benghazi attack. And we walked through. This was one of those things where we actually rehearsed the whole thing with the handhelds in our hand using the system and saying, "I'm over here doing this," and "I'm over here doing that." We even got to the point where we were using some real packet or mesh radios to move the data around. We wanted to be as realistic as we possibly could.

Preparation

Preparation

- Analyzed over 1.2M tweets from the 2 weeks surrounding the Benghazi and Cairo events
- Geographically centered on Benghazi and Cairo
- Numerous keywords included in search
- Included English (≈60%) and machine translated Arabic tweets (≈40%)
  - Not a perfect translation, but suitable for machine learning algorithmic analysis
- Integrated two existing research prototypes to enable data sharing

**024 So, I'll try to go through this quickly because we have plenty more to talk about. So, in preparation for

this, we-- you can go to Twitter, and you can buy historical tweets it turns out. We bought about a little over a million tweets from the two-week period surrounding Benghazi and Cairo with a whole several dozen keywords in them that matched the tweets-- those keywords occurred in those tweets. Again, geographically centered on Benghazi and Cairo, about sixty percent English, and about forty percent Arabic. So, another offshoot of this research was that we had the Arabic tweets machine language translated-- or machine translated into English. It's not a perfect translation. But it turns out, we use a lot of machine learning algorithms in this analysis. And machine learning algorithms kind of, for some purposes, are agnostic to how good the translation is. So, we were able to effectively use those as training and analysis for our machine learning algorithms even though they were machine language translated. So, there's a lot of machines in the loop here, which is sort of interesting then. And then we integrated those two research prototypes.

Scenario Overview

Scenario Overview

Several notional people that could have been in Benghazi at the time of the attack

(BT) Business Traveler – a US citizen travelling and operating in Benghazi strictly for business purposes.

(CE) Consulate Employee – a US consulate employee stationed at the diplomatic mission in Benghazi, but not present on the compound at the start of the attack.

(SO) Special Operator – multiple US Special Operations personnel on a variety of missions in Benghazi at the outset of the attack.

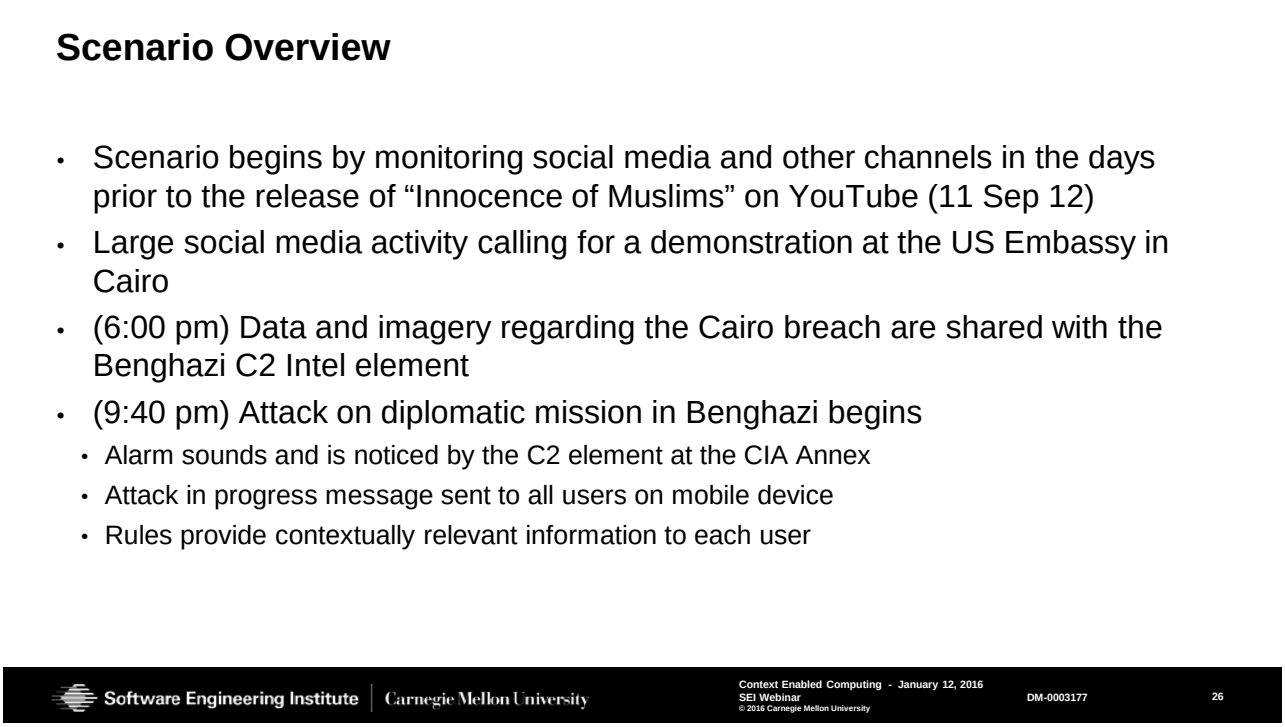
(QRF) Quick Reaction Force – the members of the quick reaction force that deployed from the CIA compound near the diplomatic mission after the attack began.

(C2) Command and Control – a command and control element at the CIA compound that would have been monitoring OSINT and other sources of intelligence before the attack and coordinating response and C2 of the various other actors as events unfolded.

**025 So, sort of an overview, we had five different actors in this script that we had. We had a business traveler. You could think of that as many business travelers. In fact, part of the discussion we had with our DoD stakeholder that wanted us to look at this was what if we could give state department personnel and business travelers, anybody that goes to a potential hot spot country, what if we could give them a mobile app that we could keep in touch with them and know where they are if something goes wrong and then cue them and alert them in case they need to go do something. So, we had a business traveler role. We had a consulate employee role. So, somebody with a hand-held was one of the consulate employees. We had some special operations personnel

that may have been in the country on other missions perhaps. The quick reaction force is the one that was at the CIA annex just southeast of the consulate compound. And then we had a command and control element that we were assuming was-- could have been collocated at the CIA annex with the QRF, or could have been even out of the country.

Scenario Overview



**026 So, the scenario begins in Benghazi with them monitoring the social media that's happening in Cairo. And remember that happened five or six hours before. The demonstration in Cairo happened five or six hours before the attack on the consulate. So, that would have immediately, if they'd been monitoring those channels-- they

probably actually were monitoring CNN and stuff. I don't remember that date if-- how soon the Cairo events actually came out on the news. But that would have, certainly if they would have been monitoring social media because there's no filter on social media, so it's raw, but it's fast. It's timely. They would have seen the demonstrations occurring in Cairo and said maybe we should do something to up our security posture here in Benghazi. So, in our scenario, about six o'clock, the data and imagery regarding the Cairo breach are shared with the Benghazi command and control element.

And then at nine forty the attack on the Benghazi consulate actually begins. And that's when things go into event.

Screen shot examples

Screen shot examples

BT is instructed to leave the city, egress routes to airport and bus station avoiding the attack are presented

SO personnel are notified and allowed to respond in support or continue on current mission, routing to attack is presented

**027 So, what you see here is a couple of screen captures from our actual situational awareness tool. Excuse me. On the left, you'll see the view that the business traveler had. And they get an alert in their alert panel on the upper right there. And what's happening here is each individual is just generating events and information on their handheld device specific to their role. And the system knows, the rules engine is set up to know, which recipients are supposed to get which sets of alerts, and which pieces of information so that it's not a broadcast everybody gets everything. It's very much tailored to the people that need to get it.

So, when an event like this-- there was a rule in the rules engine that

fired that said when aggression happens, we need to tell the business traveler to just leave. And so, what happens when that event hits the business traveler's mobile device is it automatically generates routes to them to the bus station, and the airport, and the nearest public transportation to get out of the country. So, that's what you see in the left panel there, the dark blue and the light blue routes. Those are automatically generated for the business traveler to be able to evacuate the country.

And then that same event that was generated by the command and control element triggered the special operations forces to say, "Hey we have a potential mission re-tasking for you. Do you want to respond to this? Do you want to stay on your current mission?" Because it may be a very high-priority mission, "Do you want to stay on your current mission, or do you want to re-task to support the ongoing attack at the consulate compound?" And if they say, "Yeah, I'm going to respond to the attack," it automatically generated the best route for them.

And then there were some other elements of the scenario where there was actually a predator video that was able to respond to this event in real life that noticed some blockades on some streets and some tire fires and stuff. And those routes can change in real time based upon if I'm in route and a blockade event happens, it will automatically reroute

me around that blockade event, those kinds of things.

Marc Novakouski : Right.

Jeff Boleng : Those are all pieces of context that the system's able to do without anybody having to worry-- having to think through that. What you had to do was plan in advance and make sure the rules were there so that when those information elements happen, the rules engine fired effectively. But during the heat of combat when your cognitive load is really stressed, you don't have to think through that chain of events. And the system that helps take that off you. We were talking about an Eisenhower quote on the way over. I think it was Eisenhower. Plans are worthless but planning is everything. And so, this is the case where prior planning and having the rules in the rules engine is the essence of being able to have the system work properly.

Marc Novakouski : What the general-purpose rules engine, the general-purpose model, allowed us to do is to specialize our response to a particular action in both the sending and the receiving side. So, if the consulate sends out an alert to everybody in Benghazi, the business traveler is able to get one alert. The special operations or consulate employee will get a different alert. They got the exact same message, but depending on what their role is and what their needs are, they're

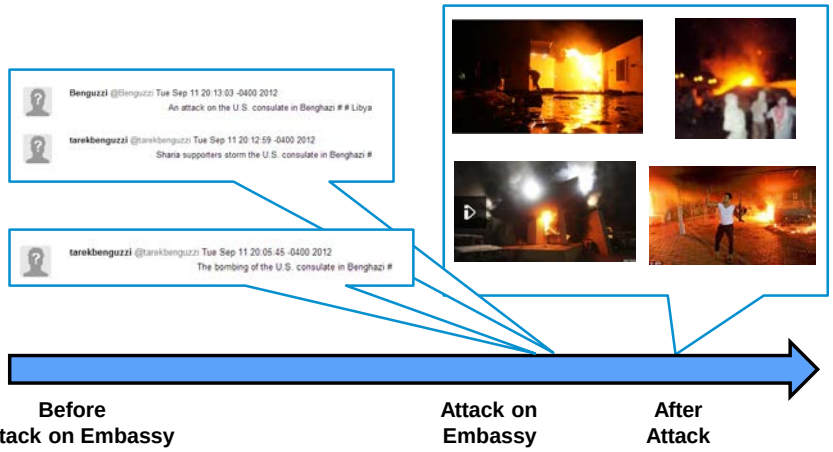
going to get different instructions. So, that's one end of it.

Another end of it is to say okay, here's a particular type of actions. I'm only going to send that out to the people that are going to actually respond, the special operators, the quick reaction force, whatever it is. So, you can tailor in multiple levels and have different types of responses. And in order to support that level of customization, to be able to understand those roles, you really need that context model that allows you to (inaudible) all those elements and how those things work together as well as the rules engine that allows you the flexibility to recombine things as you will.

Benghazi Timeline

Benghazi Timeline

- Tweets and social media artifacts of attack appear 20-25 minutes after the outset
- Annex aware of attack sooner, but not on scene, OSINT shared with them en-route providing valuable intel of emerging situation



**028 Jeff Boleng : So, I hope that's a good illustration of how we're using context in this context. So, I think I'm going to move quickly through these next couple of slides--

Remainder of the scenario

Remainder of the scenario

- Scenario continues with SO personnel responding and assisting QRF
- SO provides over watch and intel to QRF before they arrive at consulate
  - Images, video, approach routes, and map annotations all provided
- Consulate employee is routed successfully around roadblock and is extracted by QRF
- Real time location of all personnel appropriately shared based on need to know
- Scenario concludes with coordinated extraction of all personnel via the airport similar to Senate report
- Full scenario details sensitive

**029 So that we can get to more of this. The remainder of this scenario-- a lot of this plays out where the quick reaction force responds. And they're given better information so that they're more prepared as they respond to the attack at hand, which they didn't have at the time. In real life, they didn't have that. And there were some tragic events. And we lost some individuals in that response.

So, the rest of the scenarios-- the details of the scenario are a little

sensitive so they're not included here. This was published at a MILCOM paper in 2014. So, I think there's a more thorough discussion of this particular scenario and the prototyping that we did in that MILCOM paper.

Edge Analytics: What we learned from twitter

**030 Marc Novakouski : And to be clear, we're not trying to say that our efforts would have necessarily made everything okay. What we're saying is that--

Jeff Boleng : Not at all. Yeah, not at all.

Marc Novakouski : Given a better understanding of context, we potentially could have done a better job of providing those people in those

really high-leverage situations a much better ability to respond appropriately.

Jeff Boleng : And make better decisions. It's all about having better information to make better decisions in a more timely fashion so your decision loop is as tight as possible.

So, some of the things we learned, we learned from Twitter that our assessment is that in Cairo, the demonstration was well-planned. And in Benghazi, it probably wasn't planned. Sorry, the demonstration was well-planned in Cairo. And the breach of the embassy was not planned. That was an outgrowth of just the crowd getting out of hand. And in Benghazi, there was zero evidence of anything trending about a demonstration in Benghazi. It was all-- nothing happened until about twenty-two minutes after the attack on the Benghazi consulate. Nothing occurred on social media until about twenty-two minutes after that attack began.

Marc Novakouski : Right. And so, the general idea here is to say okay if we have a way to kind of mine the social media, this environmental context, can we learn about that? So, we see in Cairo that there was people talking about a demonstration. And everybody got together a demonstration. There were pictures. There were tweets. And then the demonstration got out of control, which we're all familiar. That's a thing that happens. And then the

event slowly died down and control was regained.

In Benghazi, we have a very different lesson, which is to say that out of nothing, in terms of our social media, our environmental context, now we have a situation where everything got really violent really quickly.

Jeff Boleng : Very quickly.

Marc Novakouski : And we-- the evidence, looking back historically and going through the Senate report, shows that this is most likely a coordinated attack with people that had, you know, weapons and were trying to cause damage and take lives. So, if you are someone who is responsible for responding to that sort of event, then recognizing what's going on in this environmental context, recognizing that a demonstration might get out of kind of control, but you might be able-- you're not going to be looking at loss of lives and a certain set of possible actors, or you're going to have a lot of innocent bystanders, you're going to have a very different response.

Jeff Boleng : Yeah, just knowing that-- the simple fact of just knowing, "I'm responding to a demonstration that go out of control," versus, "I'm responding to a well-planned coordinated attack," it's a very different set of responses that I may have to have.

Marc Novakouski : Right.

Value of OSINT (environmental context)

Value of OSINT (environmental context)

Forensic Analysis

- apply data mining techniques to historical data

Reactive Intelligence

- provides situational awareness to reacting teams such that they are informed of emerging events and can react to those events

Predictive Intelligent

- that allows reacting teams to prepare for an event that has a relatively high likelihood of occurring

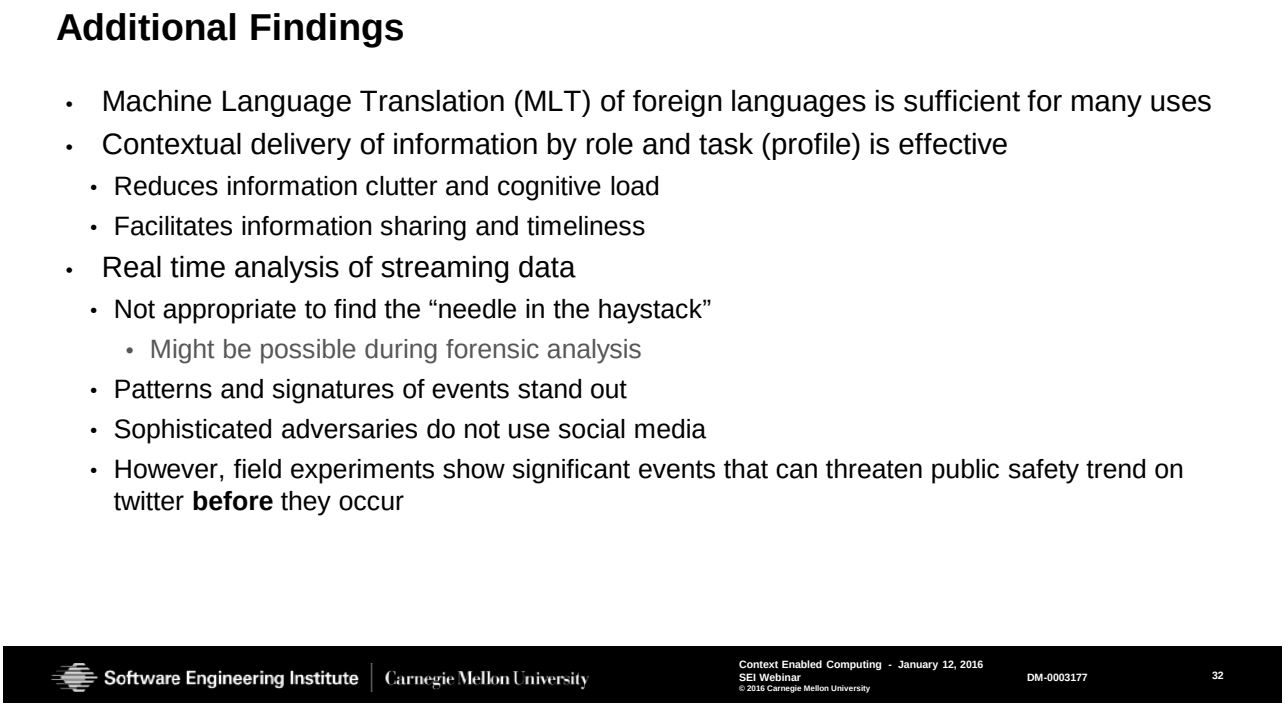
Preventative Intelligence

- that allows reacting teams to head off certain events by providing information that reduces the likelihood of these events

**031 Jeff Boleng : We also found that you can use open source envir-- open source intelligence or environmental context for a variety of things. In this case, we showed an example of using it for forensic analysis. So, we applied a bunch of data mining techniques to historical data to do a bunch of what if analysis. You can also use it for reactive intelligence, which is a situation is emerging. And I'm getting information that helps me react better, or possible predictive or even preventative intelligences where I can notice a trend occurring that's similar to other trends that have occurred. And I can do something to change the way that trend is occurring so that I can either lessen the damage, or even prevent a bad outcome. Marc Novakouski : Right, so people

have the right to demonstrate. And we're not going to be able to stop all demonstrations. But we can kind of look at the arc of demonstrations--

Additional Findings



**032 On social media and say typically when this happens, then things start to get out of control. So, if we can be aware of that when demonstrations happen, try to provide preventative measures to keep things from getting out of control, then it is a better situation overall. Now, we're not saying that is a definite thing that exists. But we have the ability to look at the data and try to figure out if there are things we can do.

Jeff Boleng : Yeah, so a few additional findings. We found out that

machine language translation of foreign languages is sufficient in a lot of cases. You don't get the fine points. But if you want to find the trends, it's good.

Contextual delivery of information by role and task, which is what the ISE system that we talked about does, is very valuable. In fact, it can reduce clutter and cognitive load, facilitate information sharing and timeliness. It's really a nice thing to have to be able to have those rules built in a rules engine to know who gets what data when and to what degree they get it, how it gets prioritized. It even gets prioritized differently for different people.

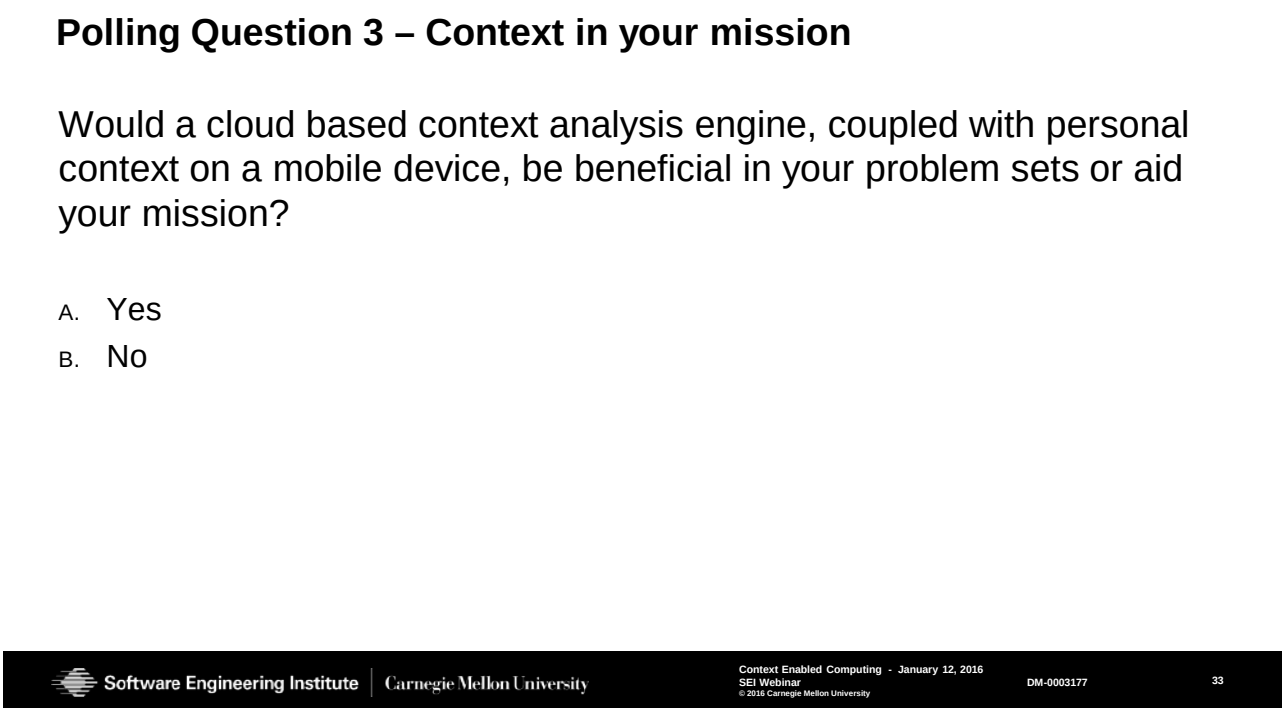
And then real time analysis of streaming data, we did real time analysis of streaming data after the fact. So, we just restreamed it at the same rate. But one of the things is it's not necessarily appropriate to find a needle in the haystack. You can find the needle in the haystack after the fact with forensic analysis, but not probably during the event. But definitely patterns and signatures of events do stand out. So, as soon as something comes-- rises above the noise, even a little above the noise, that's where you can start to see those trends occur.

And then another thing that I think is obvious to most people is that sophisticated adversaries don't use social media to plan these events. But they may use them during the event for coordination. I think that

was the case in Paris actually during the tragedy there that they were using social media during the event.

And then I do think that social media, Twitter is just an example, social media can be very beneficial for public safety and defense.

Polling Question 3 – Context in your mission



**033 Shane McGraw: Okay, next polling question, we'll launch it now. Would a cloud-based context analysis engine coupled with personal contexts on a mobile device be beneficial in our problem sets or aid your mission? And while you're voting on that, we're going to take a question from Rafel asking what are the biggest barriers to leverage contexts in an application or system?

What are the biggest barriers to leveraging context?

Jeff Boleng : Biggest barriers, I have an initial hit. And then I'll let Marc answer too. I think one of the biggest barriers is context comes from everywhere, from sensors of different types, from raw sensors like inertial management units, that is really high rate lots of data sensor that you have to distill to find out this means I'm shaking my hand. The data that's saying that is really hard to interpret. So, the barrier I think is since the data comes from everywhere, it's all kinds of different formats. It's all different levels of semantic meaning. So, normalizing all that data into some kind of a data model I think is crucial. So, a big barrier is just the real heterogeneity of the data involved in really leveraging a lot of different contexts.

Marc Novakouski : And I would definitely agree. I mean the thing that allowed us to do the work that we're doing was to start with that context data model that was focused on the expanding the context toolkit. In addition, it's a matter of understanding that these are really complicated things. The decisions I make come from a lot of different areas that I wouldn't necessarily expect, that there may not even be a sensor for, right?

Jeff Boleng : Think about now with the Internet of Things proliferation of sensors, we're going to have context data everywhere. We just are going

to have to figure out what to do with it. And my lightbulb will tell me what the temperature is all the time. Why do I want to know? I don't know.

Marc Novakouski : And if the lightbulb is-- there was a thing I read about a lightbulb burnt out, like the-- but the thing was badly coded. And so, it started spamming the Wi-Fi. And so, the guy lost Wi-Fi. So, those sorts issues--

Jeff Boleng : Angry lightbulb.

Marc Novakouski : Exactly. Those sorts of issues are the challenge here, bringing in all of the different feeds, normalizing, and then understanding how to recombine.

Jeff Boleng : Yeah, putting the-- the semantics really only come from all that data, all that context data, if you get them into a good data model I think.

Shane McGraw: Okay, to close out our poll, sixty-five percent with yes, they would benefit from a cloud-based context.

Marc Novakouski : Cool.

Shane McGraw: Two thirds.

Jeff Boleng : Yeah.

Group context recognition

Group context recognition

- Required a scenario with realistic feedback → paintball
- 20+ volunteers from 911th Air Reserve Wing
- Small squad tactics as scenarios
- 7 group activities, 10 individual activities, 3 IMU's and phone per person

**034 Shane McGraw: Can we follow up with one more question from Scott.

Marc Novakouski : Sure.

Shane McGraw: A little bit lengthy, but relevant to where we're at. So, can you talk about getting business people out of the area in your scenario? How do you avoid clustering American citizens to create a new potential target of opportunity for those intending to do harm? Do you suggest routes and have them accept them so you know how many are taking each route? Or lately, when you are tracking someone, there's always the potential that those intending to do the harm are intercepting the tracking. Does that limit the applicability of this to those

with certain secure electronics to assure these plans aren't being compromised?

Jeff Boleng : Okay, so there's some layers to that one. Yeah, definitely. So, first off, I want to say the level of prototype experimentation we did was not as detailed as saying we're going to field this and we may have a whole bunch of different travelers. So, we need to make sure we don't cluster them and make them targets. So, we didn't go to that scale. But, I would say that's an excellent observation. And the rules need to be put in the rules engine, which the system's totally capable of, to make sure that if we have to do a mass evacuation of people from an emerging event like that, the rules can be actually situate coded so that it will send them to different places and it will balance their travel. And their locations are always constantly reported as well. So, it can, in fact, try to keep them, make them as small a target as possible or keep them dispersed. So, that's all possible.

Now, the other part is more of the security of the system, I think, the other layer there is. And we have to assume at least security industry best practice security that's as good as we get with our cellphones and stuff now. I think that, I mean, a lot of my services with Google or on iPhone services with Apple, a lot of those are not military grade secure. But I think they're secure so that we can sleep pretty well at night that our privacy is

being preserved as well as the company that we decide to trust is preserving it, if that makes sense. So, I actually think the system can be useful without industrial grade-- or military grade crypto. Actually, our cellphones have military grade crypto. I mean they use all the same algorithms. So, I think that it can be effective as using industry best practice security. And if the adversary is sophisticated enough to be able to want to attack that -- that piece of the security of the system to track the people that are evacuating, that's something we're going to have to just-- we're going to have to develop countermeasures for, I guess.

Marc Novakouski : Right. I would imagine there would-- any hypothetical situation that the State Department put out an app that did this sort of thing-- not our app because we're not trying to market this. This is just the prototype. But if the State Department did that, there would definitely be someone in the loop who would be doing the coordination and all those sorts of things. And the back and forth in terms of de-clustering or whatever is part of what could be possible if you had an understanding of who was doing what, where, and when.

Jeff Boleng : Yeah, but I mean that's one of those things about planning is everything that-- coming up with that idea is a great observation that you need to plan to make sure that doesn't happen.
Marc Novakouski : Yeah, sure.

Jeff Boleng : So, I'm going to turn it over to Marc. We wanted to do-- expand from individual contexts like am I walking, am I sitting, am I sleeping, what am I doing based on IMU, inertial management measurements, to if we have a whole group of people operating together, can we recognize what that group is doing. And so, Marc's going to talk about some experiments that we did with that that we had a lot of fun.

Marc Novakouski : We did, absolutely. So, we tried to say okay, so how can we kind of expand that context, what are the interesting things we can do. And one of the experiments we did with Dr. Dey was he had a couple of students were actually actively involved in doing activity recognition. And we said could that be expanded to group activity recognition. And how would we even test that?

So, after doing a bunch of research and kind of saying okay so, what we could do is we could take a bunch of people together, put a bunch of IMUs on them and say, "All right, I'm going to put you in a situation where you guys need to move as a unit." Now, because we work with a lot of military scenarios, we said okay, we have this connection with the 911th Air Reserve Wing here in Pittsburgh, they're out by the airport. And we would get them all in. And we would say, "Go play some paintball and see what happens."

Jeff Boleng : Well, the interesting

really thing is we actually went out and were collaborating with the folks at the 911th to begin with. And we said let's just do some walking scenarios and say, "What if there were an IED here, an improvised explosive device here, how would you respond?"

And it turns out we put the inertial measurements on them. And they responded certain ways. But they didn't respond with the level of--

Marc Novakouski : Conviction.

Jeff Boleng : Conviction and urgency that they really would have. And so, we decided we needed a better feedback mechanism. And it turns out when you play paintball, when you get hit with a paintball, it really hurts.

Marc Novakouski : Yeah.

Jeff Boleng : So, for small squad tactics, we wanted to see if we could recognize the group activity recognition automatically of small squad tactics. It turns out the feedback level that paintball gives you is enough that they behave realistically.

Marc Novakouski : They really do. I mean this is why we decided not to go with laser tag or anything like that.

Jeff Boleng : Right, there's no feedback loop.

Marc Novakouski : Exactly, so, we

had a whole bunch of fun. And we allowed them to go out there and shoot themselves. And we determined that actually there is some viability here.

Jeff Boleng : There's results here, yeah.

Group activity results

Group activity results

- Multiple Gigabytes of video data – challenging to annotate
- 5 types of classifier: SVM, decision tree, kNN, naïve bayes, neural network (# of hidden=10)
- Best combination of sensors: Phone (acc) + YEI arm sensor + YEI leg sensor
- 81% accuracy of individual activity recognition (SVM)
  - Shooting, covering, running, etc.
- 71% accuracy on group activity recognition (kNN and Neural Net)
  - Advance, covered advance, covering fire, etc.

**035 Marc Novakouski : One of the more interesting lines of research that we came up with, we have multiple gigabytes of video data that we took. It was definitely challenging to annotate it all. We had to go through saying this player is doing X. This player is doing Y. As a team, the group is doing this. And we're using

Reservists, so they're actually using relatively--

Jeff Boleng : Accurate squad tactics.

Marc Novakouski : Accurate squad tactics. And so, we could really get a sense for what each squad was trying to achieve in addition to what the individual was doing at the time. So, now, we're not the machine learning experts. We used the guys at CMU to really kind of get that knowledge. We used a number of different classifiers, a couple of details here about what the best combination of sensors because we had different sensors all over the body. We wanted to try to get a sense for what the best way to detect what your behavior was.

But ultimately, we said for a particular type of classifier, machine learning classifier, given these sets of sensors, we actually came up with an eighty-one percent accuracy of individual activity recognition and then on top of that, seventy-one percent accuracy of group activity recognition. Now, this is obviously initial results. But we did this over a whole bunch of games, took a whole bunch of data.

Jeff Boleng : We had fifteen or twenty scenarios on the paintball field changing people's roles. And to be more clear, I guess, the individual activities we were looking for were things like shooting, taking cover, running, those kinds of things.

Marc Novakouski : Yeah.

Jeff Boleng : And then as a group, was the group advancing together, were they doing a covered advance where same of the people gave covering firewall, the others advanced, was I doing covering fire? So, we were able to actually accurately automatically recognize individual and group activity with pretty good confidence.

Marc Novakouski : Yeah, I mean obviously this is very initial data. We're in the process of getting the data together hopefully to do some publications on this.

Jeff Boleng : It was a good excuse to get my boss to pay for paintball.

Marc Novakouski : Exactly. That was a lot of fun. But yeah, so--

Jeff Boleng : I think he's watching.

Marc Novakouski : So, the future-- the future of this, of course, is that if this is a real thing that we can leverage, then any kind of team based activity where you have coordination, we can start to do training. We can start to do real time returns in terms of what is the squad doing. And that's activity recognition. So, if in the fog of combat, or you're in a very precarious situation in a catastrophe, earthquake or what have you, and everybody else decided to get out of Dodge, and they just started running, and you just aren't aware of that, well it'd be really good to get an alert to know

that everybody's running. You'd better start doing that, too.

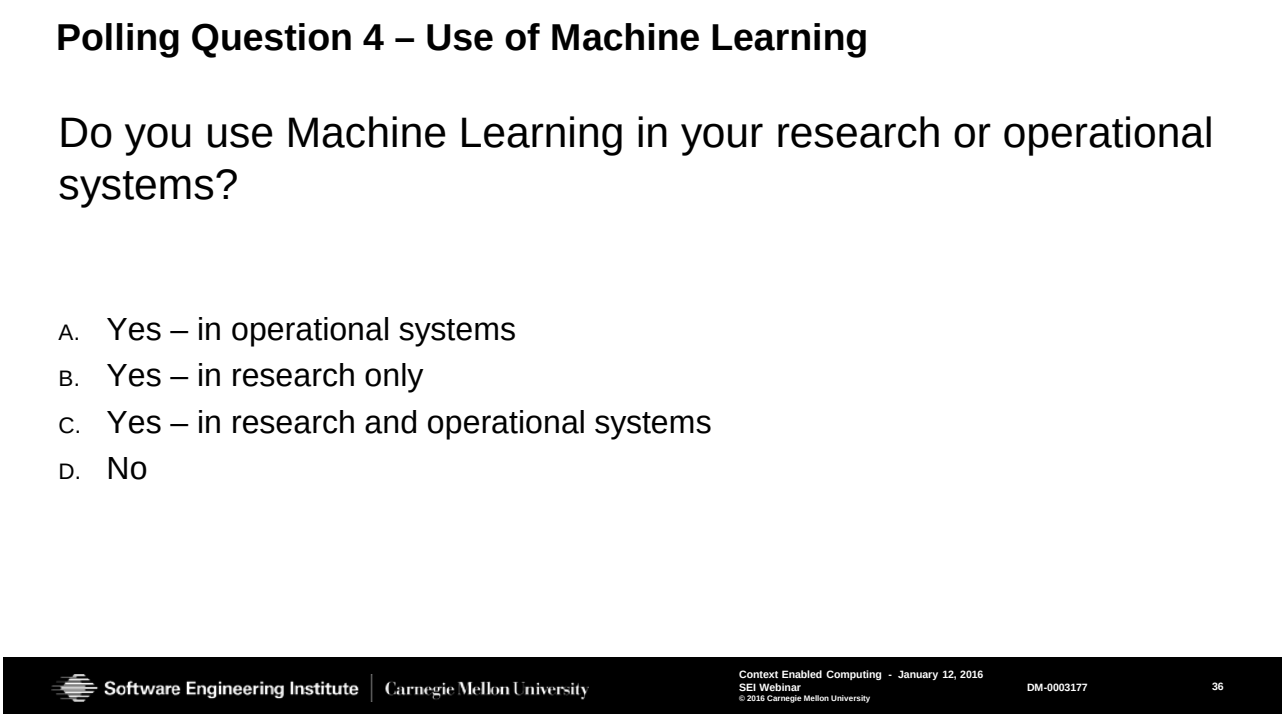
Jeff Boleng : Or, at least consider running.

Marc Novakouski : Yes, exactly.

Jeff Boleng : We don't want to be lemmings.

Marc Novakouski : That's true. That's true.

Polling Question 4 – Use of Machine Learning



**036 Shane McGraw: All right, we're going to launch another polling question. I'm going to turn it right back to you guys because I know you want to get through some slides. But the question will be up. Do you use machine learning in your research or

operational systems? And I'll turn it back to you guys.

Cooperative and Opportunistic Context

Cooperative and Opportunistic Context

- Experimentation at large music festival in PA
- Provided “assistance application” to festival volunteers
- Opportunistic Context → CMU Group Context Framework
  - http://ubicomplab.org/publications/the-group-context-framework-an-extensible-toolkit-for-opportunistic-grouping-and-collaboration/
  - Work of Adrian de Freitas and Dr. Anind Dey at CMU
- Cooperative Context – ISE
- Fuse and visualize data via MQTT message broker and web front end
- Scenarios
  - Location tracking
  - Bluetooth location
  - Noise localization
  - Lost person location
  - Cueing sensors from social media events (Edge Analytics)

**037 Jeff Boleng : Okay, so we wanted to explore cooperative versus opportunistic contexts. So, what we have in the case of ISE, the Information Superiority Edge prototype, is cooperative contexts. All of the devices in that mesh cooperatively share as much information as they need to to be able to queue context for the group and better deliver information, retask sensors, all those things that we'll do, the risk set of things that we're doing. The devices all cooperate. And it's assumed that all of the people in the set of the mesh of devices all want to share the information to each other. There's another set of research that

we've been collaborating with Anind and somebody named Adrian de Freitas, one of Anind's researchers, they wanted to look at opportunistic contexts because one of the things is hard. You hear about this wisdom of crowds. And it's great if we want to all share data. But how do you entice someone to share their context data because there's a lot of privacy associated with sharing my context data? And do I do it anonymously, or do I not do it anonymously? So, how can we create a framework that would share opportunistic contexts and then combine that with out framework that shares cooperative contexts?

And we actually went out to the-- it was the second or third year in a row we've been involved with this Christian music festival in Central Pennsylvania called Christian Fest. We go out there, and we help basically provide-- I don't know what it's called, intelligence support. We help provide support to the public safety director there of what's trending on social media using the Edge analytics tool so that he can have a good feel for the event or what may be occurring at the event. And so, they allowed us to use that as sort of an experimentation venue to play around with this cooperative versus opportunistic context.

So, what we did is we created an application that was basically a reporting application for the volunteers. There are several hundred volunteers that support this

fifty or sixty thousand person multi-day con-- music concert. And we gave them an application that allowed them to report things that might need like this port-a-potty needs to be cleaned, or it needs toilet paper, or this garbage needs to be emptied, or there's a mess over here. And so, they could report those kinds of events to the public safety director in the command center.

And what we got from them running that application was all the sensors on their cellphone, all the contexts that their cellphone had. And we had to write disclaimers. And actually that was a bit of a challenge with the institutional review board making sure we had appropriate approval to use that app at this event. But we ran a bunch of scenarios. And we had some moderate successes. And we had some epic failures. And this is still sort of a thing we're looking at is how do we combine cooperative and opportunistic contexts, and how do we entice people to want to participate in a network where they share contexts so that they get at least as much as they give out of it.

Marc Novakouski : One of the kind of scenarios that we're thinking about that would be really compelling for something from the standpoint of cooperative contexts is like let's say something happens at a mall, right? so, there's an active shooter at one end of a mall. There's going to be a whole lot of noise, a whole lot of running, a whole lot of activity at one end of that mall. Maybe everything is

normal at the other end of the mall because it hasn't propagated. When the police show up, it would be really useful for them to have a general sense for what's going on over the course of that whole building so that they know where to go and where to deploy their forces and at what point to do a cutoff or something like that.

Jeff Boleng : Right, and where to evacuate first and how to respond to that event because it's a big building. I get lost when I go to the mall. I don't know which entrance to use. Every time, I'm serious.

Polling Question 5 – Context and Privacy

Polling Question 5 – Context and Privacy

How significant is the use of context to privacy?

A. Very significant
B. Significant
C. Moderately significant
D. Somewhat significant
E. Not significant at all

**038 Shane McGraw: Okay, before we launch the last polling question, I just wanted to wrap up the last one. It was a fifty/fifty split,

fifty percent yes, fifty percent no, seven percent in operational systems using machine learning, twenty-three percent in research only, and twenty percent in research and operational systems.

Marc Novakouski : Interesting.

Shane McGraw: So, we're going to launch the final polling question just is how significant is the use of context to privacy. And while we give some people a chance to vote there, we're going to work in a question here--

Context in Tactical Wireless Networks

Context in Tactical Wireless Networks

- Tactical Wireless Networks
  - DIL – Disconnected, Intermittent, Low-bandwidth
- Three broad approaches researched to increase performance

- **Application Layer** – use context to ensure the right information is delivered to the right people (device) at the right time (ISE)

- **Network Layer** – Delay Tolerant Networking and Link Awareness to ensure bandwidth is used most effectively

- **Link Layer** – NACK based UDP (vice TCP) to overcome wireless fading and the intermittent nature of tactical wireless networks

**039 From Derek. And I know we're about a minute left here. It says do you have any examples of context enabled mobile computing

with real time info in snowstorms. If so, I'd like to know some stats such as system performance, cellular network usage, and latency.

Jeff Boleng : Real time info in snowstorms specifically?

Shane McGraw: Yeah, or just--

Marc Novakouski : The only thing that occurs to me is the WEA system, the Wireless Emergence Alerts. It used to be knowns as CMAS.

Jeff Boleng : But you can actually think of Waze, the traffic application Waze, that is expanding beyond traffic. And the traffic feedback you get from Google maps and those kinds of things I think is a similar-- is in the vein of that question, I think, that is being crowdsourced now.

Shane McGraw: So, we're at 2:30 now. I'm going to give you guys the final word to wrap it up. And then we'll let the people go for today.

Jeff Boleng : Yeah, the last big thing that we didn't talk about was applying contexts to routing, delay tolerant networking, basically helping tactical military radios or just wireless tactical radios in general, operate better. The slides are out there. We invite you to contact us. There's a lot more information. We've got a-- we actually have a limited distribution technical report on some testing we did with some 117 Golf radios if anyone's familiar with those. And I think we have some great results

there. So, I apologize for not getting to it.

Shane McGraw: Sure. As Jeff and Marc mentioned, the slides are available now in the files tab on your consoles. You can walk away with them now. Any questions you have, feel free to send to info@SEI.cmu.edu. Thanks for everyone in attendance today. Marc, Jeff, great presentation. Thank you very much. See you at the next one.

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