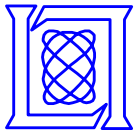


Research Challenges for the Next Decade

18 September 2007

Zachary J. Lemnios

Chief Technology Officer
MIT Lincoln Laboratory

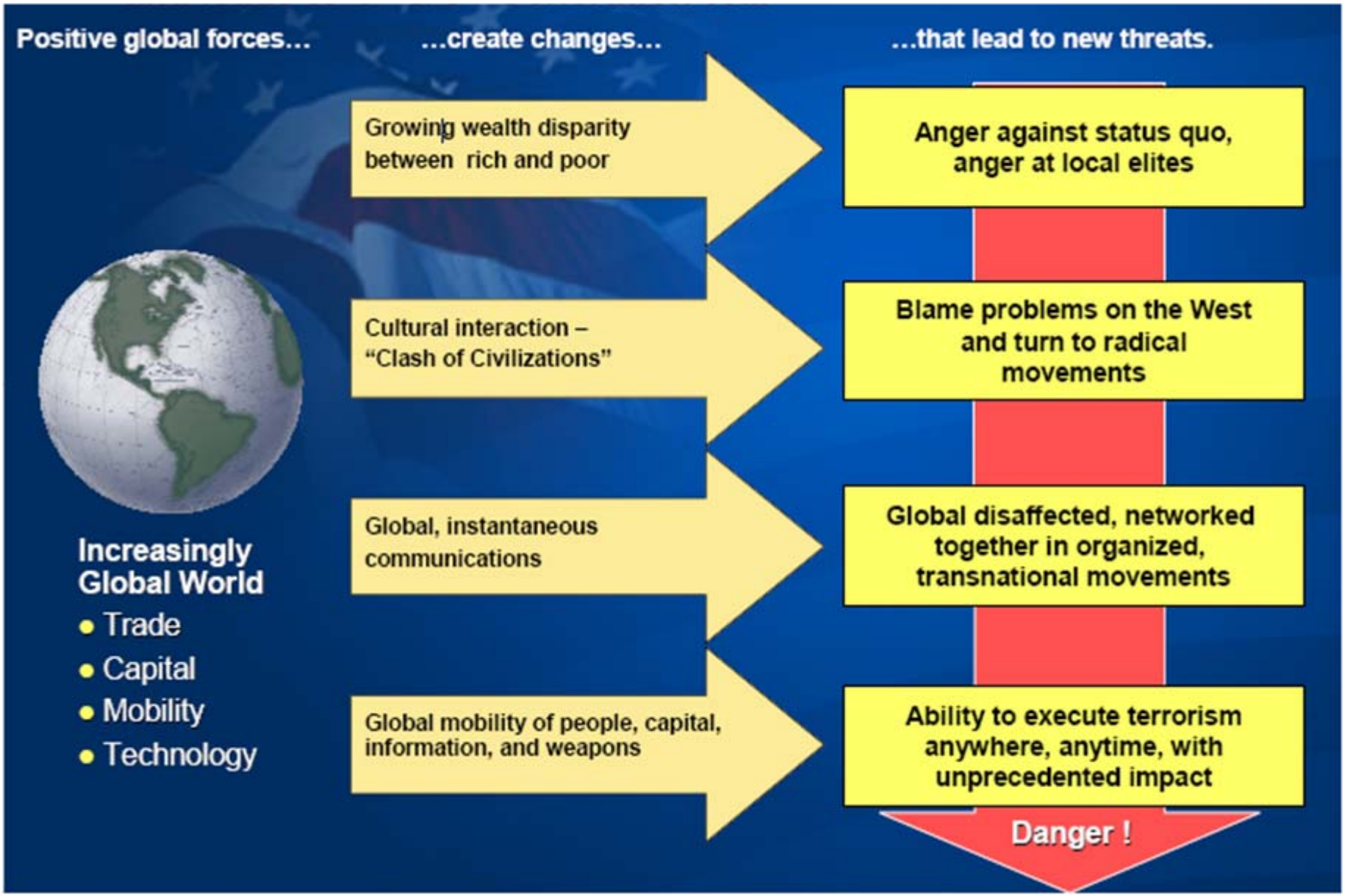
zlemnios@ll.mit.edu

Victor Zue

Director, MIT Computer Science
Artificial Intelligence Laboratory

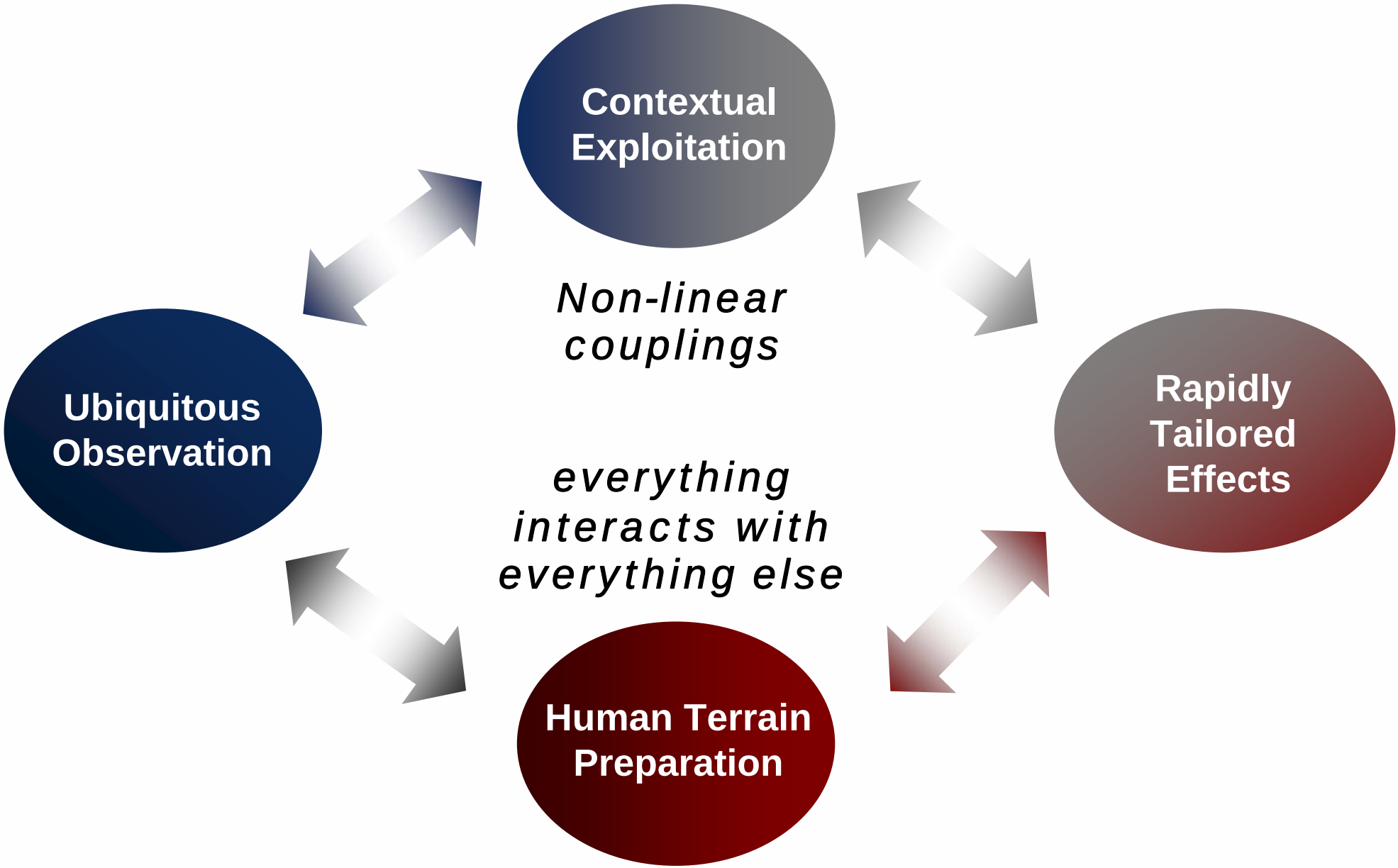
zue@csail.mit.edu

A New World has Emerged in the Last Decade



From CAPT Mark Dowd, USN(RC) JIOC/JICPAC

The Four Broad Capability Categories – an OODA-like Loop for the 21st Century



Key Technology Enablers for the Evolving Threat Space

Preparing Human Terrain

- Social/cultural dynamics modeling
- Automated language processing
- Rapid training/learning methods/aids

Ubiquitous Observation

- Day/night all-weather wide area surveillance
- Close-in sensor and tagging systems
- Soldiers-as-sensors

Contextual Exploitation

- Mega-scale data management
- Situation dependent info extraction
- Human/system collaboration

Scalable Effects Delivery

- Consequence-modeled decision making
- Information ops
- Time critical fires
- WMD mitigation

Key Technology Enablers for the Evolving Threat Space

Algorithmically and Computationally Rich

- **Social/cultural dynamics modeling**
- **Automated language processing**
- **Rapid training/learning methods/aids**

- Day/night all-weather **wide area surveillance**
- Close-in sensor and tagging systems
- **Soldiers-as-sensors**

- **Mega-scale data management**
- **Situation dependent info extraction**
- **Human/system collaboration**

- **Consequence-modeled decision making**
- **Information ops**
- Time critical fires
- WMD mitigation

A Revolution in Capabilities for DoD

(from DARPA presentation at HPEC 2002)

INFORMATION PROCESSING TECHNOLOGY OFFICE

DARPA

More Aggressive Threats → Adaptive and Intelligent Data-Fused Sensors

- Threats are more dynamic and in deeper hide (collapsing time lines)
- System performance is outpaced by changing threat environments
- Cooperative battle management requires robust information backbone

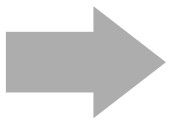
Sensor Data Flow Overwhelming Human Analyst → Cognitive Information Exploitation

- Sensor bandwidth is increasing faster than processor capability
- Target classification has become a multi sensor

Computer: Yesterday and Today

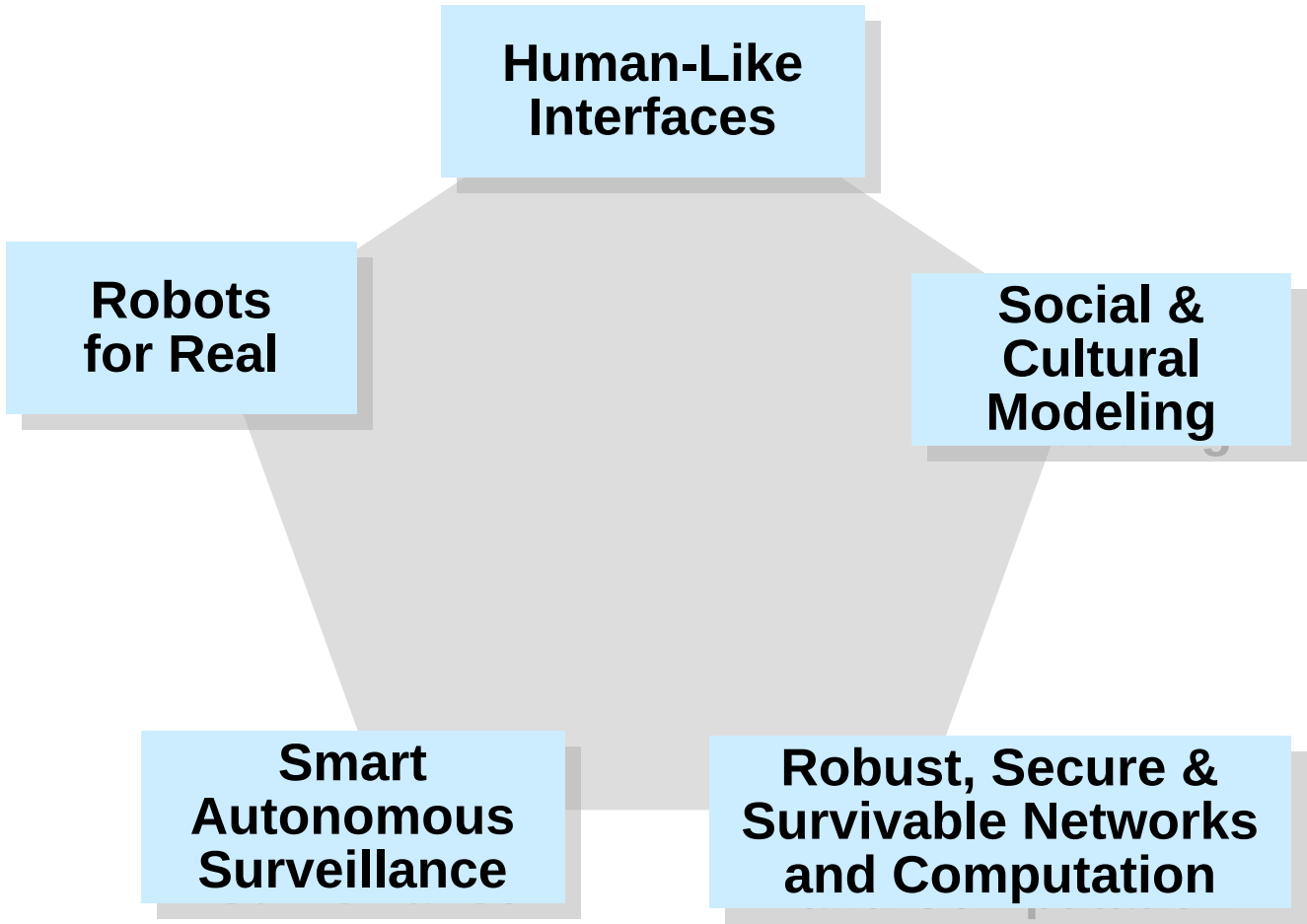
- Computation of static functions in a static environment, with well-understood specification
- Computation is its main goal
- Single agent
- Batch processing of text and homogeneous data
- Stand-alone applications
- Binary notion of correctness

- Adaptive systems operating in environments that are dynamic and uncertain
- Communication, sensing, and control just as important
- Multiple agents that may be cooperative, neutral, adversarial
- Stream processing of massive, heterogeneous data
- Interaction with humans is key
- Trade off multiple criteria

Today's World 

Ubiquitous communication, cheap computation, overwhelming data, and scarce human resource

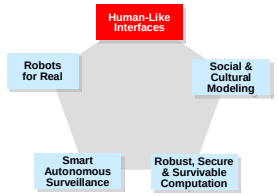
Technology Research Challenges



Environment

- High tempo
- Enormous data loads
- Civilian clutter
- Deep hide threats
- Wicked problems
- Unstructured environments
- Cultural interaction
- High consequence

Challenge 1: *Human-like Interfaces*

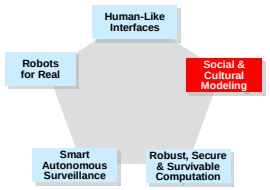


CSAIL

- **Interacting with computation should be as natural as interacting with people.**

- **Human-like interfaces need to be:**
  - **modality-opportunistic**
  - **modality-agnostic**
  - **non-distracting**
  - **symmetrically-multimodal**
  - **mixed-initiative**
  - **multi-lingual**

Challenge 2: *Operate in Foreign Cultures and Coalitions*



CSAIL

Cultural data

Electronic media

Story understanding & Indexing

Models Of culture

Culture sensitive analogical information retrieval

Match-making Information push Argument structure capture

Analysts Workbench

Immersive Language & culture training system

Recovering topical structure

Core natural language processing

Universal speech understanding

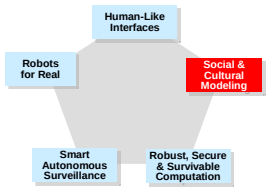
Spoken queries in mixed languages

Spoken dialog based training

Emotions & motivations
Sub-cultures
Preferences, value systems
Individual decision making
Allegiance and desertion

Immersive
Human like interfaces

Challenge 2: *Operate in Foreign Cultures and Coalitions*



CSAIL

Cultural data

Electronic media

Story understanding & Indexing

Recovering topical structure

Models Of culture

Core natural language processing

Universal speech understanding

Spoken queries in mixed languages

Culture sensitive analogical information retrieval

Spoken dialog based training

Match-making Information push Argument structure capture

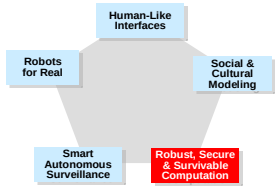
Analysts Workbench

Immersive Language & culture training system

Immersive Human like interfaces

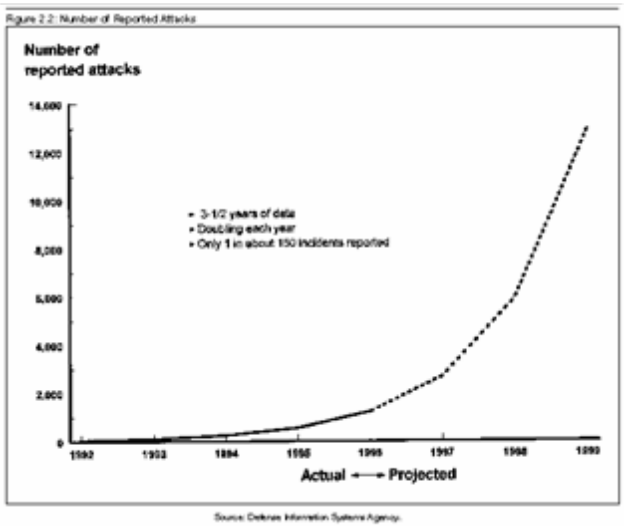
Emotions & motivations
Sub-cultures
Preferences, value systems
Individual decision making
Allegiance and desertion

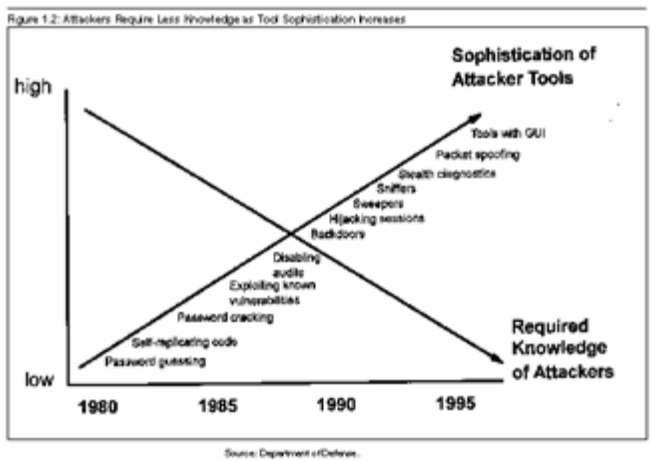
Challenge 3: Make Net-Centric Systems Secure and Survivable



CSAIL

Capable and dedicated opponents

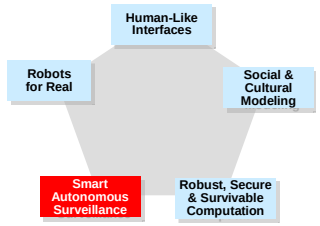




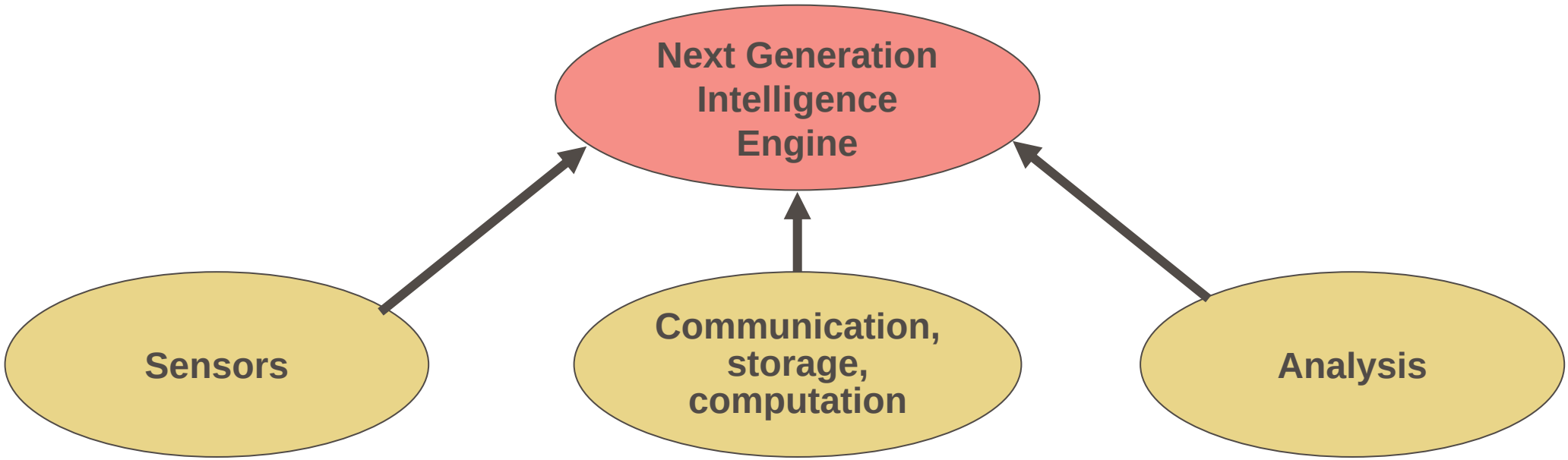
Mobile and distributed components

Heterogeneous systems

Challenge 4: Smart Autonomous Surveillance



CSAIL

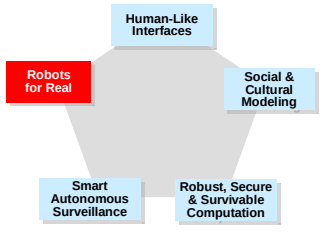


- Computational cameras
- Coded aperture sensors
- Queuing sensors

- Power and content-aware networking.
- Fusion across modality, time, place, and source

- Change detection
- anomaly alerts
- contextual analysis, integration with historical data,
- prediction

Challenge 5: Robotics for Real



CSAIL

- **Military "robots" today lack autonomy**
  - Currently, many soldiers operate one robot
  - Want few soldiers working with a *team* of *agile* robots, to achieve *force multiplication* even in *harsh* environments
  - Put fewer soldiers in harm's way

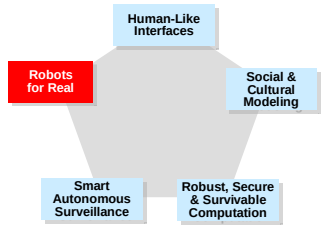
RQ1-Predator GCS

- **Better robots for monitoring**
  - *Enable* soldiers w/ persistent and pervasive ISR, including from hard to reach places (e.g., inside buildings/caves/bunker networks)

Supply-chain task

- **Better robots for logistics**
  - *Replace* soldiers in the supply chain with capable autonomous robots and vehicles

Key Research Elements



CSAIL

Logistics:
- Packing
- Loading
- Transportation

Monitoring:
- Surveillance
- Patrol
- Observation

Perception and Awareness	Planning and Reasoning	Manipulation and Control	Communication and Coordination
Vision	Uncertainty	Grasping	Teaming
Speech	Dynamic world	Rolling, legged, flying mobility	Coordinated motion
Gesture	Scale		
Localization	Prediction		
Surround awareness			

Enabling Technical Areas

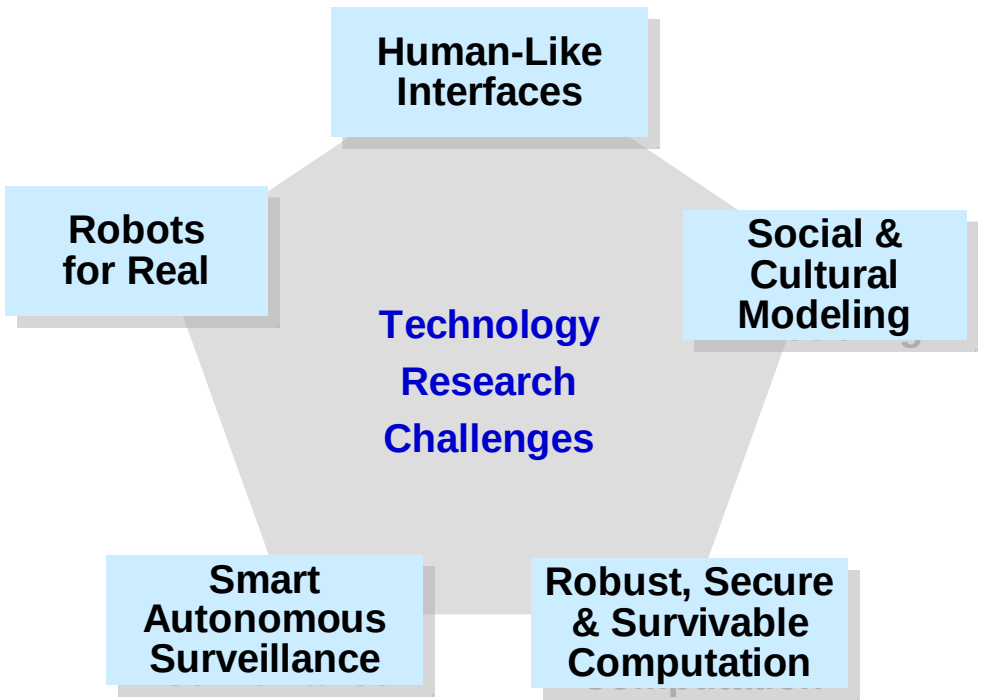
10 year Vision: Exploiting Algorithms and Computation in Human-Like Ways

CSAIL

Human-like Interfaces	*Social & Cultural Operations*	Secure and Survivable Systems	Autonomous Robotics	Smart Autonomous Surveillance
multimodal interaction uncontrolled environments learn new vocabulary by example adapting opportunistically to modalities available ***non-distracting interaction with a teammate***	Robust understanding of causal structures Continuously evolving models of culture, values, motivations, preferences **Full dialogue** **Immersive, story and dialogue based interactions**	Systematic survivability, defense in depth Auditable assurance cases, formal methods and self-checking software and hardware together **High confidence that failures and security attacks have not and will not occur**	Autonomous vehicles require minimal supervision, and outperform the best human pilots Robotic supply chain improves efficiency and surge response, greatly reducing the danger to humans **Humans interact with robots as partners and capable team-mates**	Computational cameras Queuing sensors Change detection Power and content-aware networking. Fusion across modality, time, place, and source contextual analysis, integration with historical data **prediction**

Summary

- We are in a much more challenging threat environment
- Success will depend on operating;
  - in high tempo unstructured environments
  - against asymmetric adversaries in deep civilian hide
- A new set of research challenges are before us:



The Power of a New Initiative

The New York Times

October 9, 1903

"The flying machine which will really fly might be evolved by the combined and continuous efforts of mathematicians and mechanicians in from one million to ten million years"

"We started assembly today"

Orville Wright's Diary
October 9, 1903

December 17, 1903