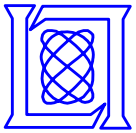

DoD Research Challenges for the Next Decade

4 September 2007

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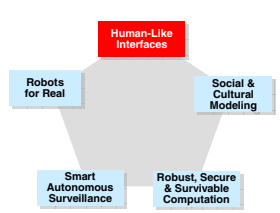
Key Technology Enablers for the Evolving Threat Space

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

From Defense Science Board 21ST Century Strategic Technology Vectors Study

Computer: Yesterday and Today



CSAIL

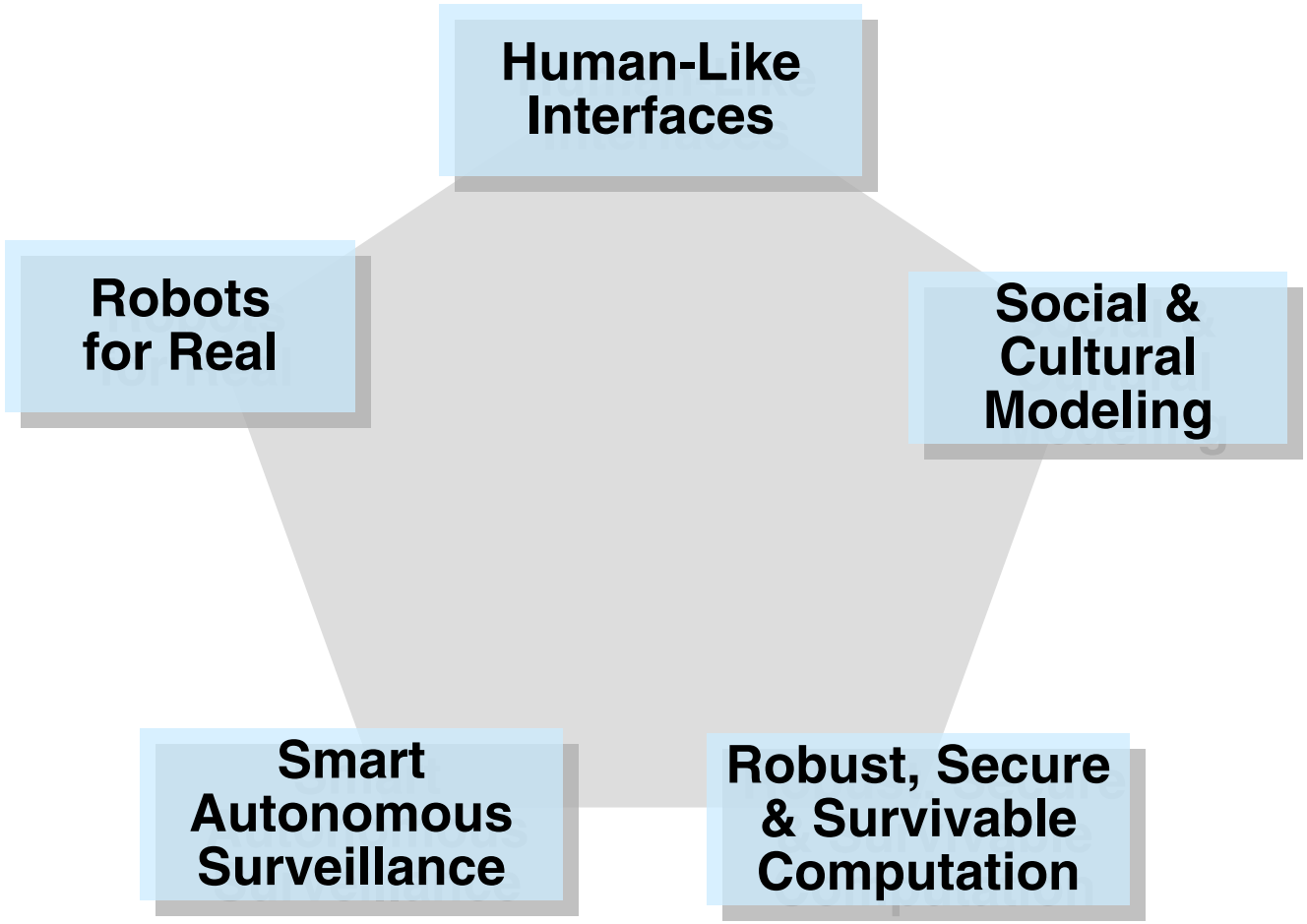
- Computation of static functions in a static environment, with well-understood specification
- Computation is its main goal
- Single agent
- Batch processing of text and homogeneous data
- Stand-alone applications
- Binary notion of correctness

- 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

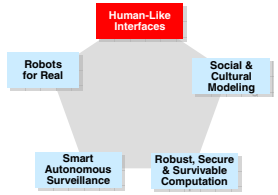
Technology Research Challenges



Environment

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

Challenge 1: *Human-like Interfaces*

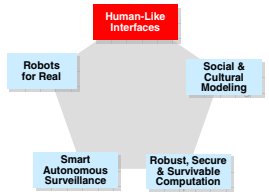


CSAIL

- **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

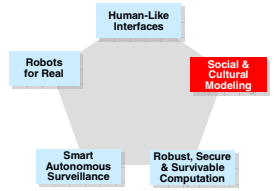
Human-like Interfaces
Today, Tomorrow, and Beyond



CSAIL

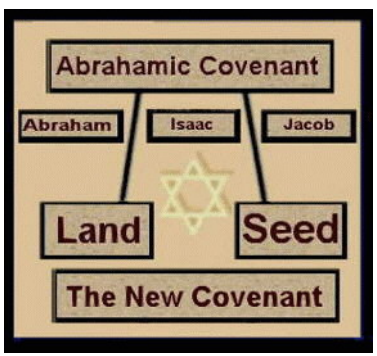
Today	3-5 years	5-10 years
individual modalities	selected combinations	multimodal interaction
controlled environments	noisy environments	uncontrolled environments
pre-specified language	learn new vocabulary interactively	learn new vocabulary by example
pre-specified multimodal interactions	opportunistic use of multimodal interaction	adapting opportunistically to modalities available
understand structured language	***understand conversation***	***non-distracting interaction with a teammate***

Challenge 2: *Operate in Foreign Cultures and Coalitions*



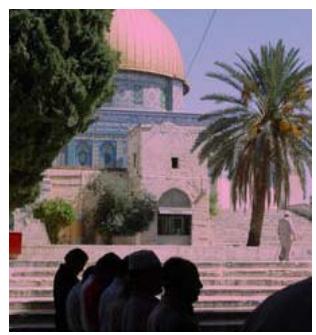
CSAIL

- … current and future military operations will require enhanced capability to understand social and cultural "terrains" as well as various dimensions of human behavior.
- Developing broader linguistic capability and cultural understanding is critical.
- The DoD has gaps in software tools and decision aids that will allow U.S. commanders to better understand different cultures.
- The Department must dramatically increase the number of personnel proficient in key languages such as Arabic, Farsi and Chinese. Source: 2006 QDR



The Binding of Isaac
The Covenant

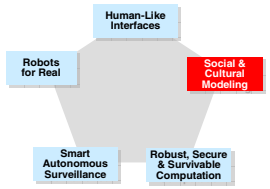
Jews Praying at
The Wailing Wall



Muslims Praying at the
Dome of the Rock

The Ascension of
Muhammad

Key Research Elements



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

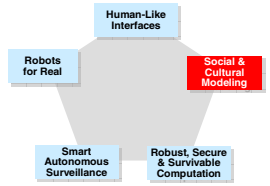
Spoken queries in mixed languages

Spoken dialog based training

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

Immersive
Human like interfaces

Social & Cultural Operations
Today, Tomorrow, and Beyond



CSAIL

Today

Limited ability to understand natural language

Retrieval based on keywords - low precision

Significant gaps in tools for modeling culture

Phraselator

Drill exercises

3-5 years

Robust natural language understanding of topic structure

Retrieval based on semantics - high precision

Models of key stories of culture

Two way translation

Activity translation

5-10 years

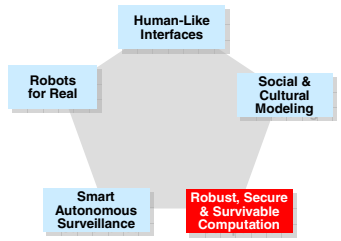
Robust understanding of causal structures

Continuously evolving models of culture, values, motivations, preferences

Full dialogue

Immersive, story and dialogue based interactions

Challenge 3: Make Net-Centric Systems Secure and Survivable



CSAIL

"Combat information capability" is a **critical defense weapon system.**

- Commercial information technology architecture presents **critical information assurance challenges**.
- … The system and its capabilities will always be under attack and, as a result, will be **operated in degraded or compromised mode.**
- There is ample evidence that U.S. adversaries have recognized this potential vulnerability and are now aggressively developing doctrine, tactics and technology to **attack this soft underbelly**.

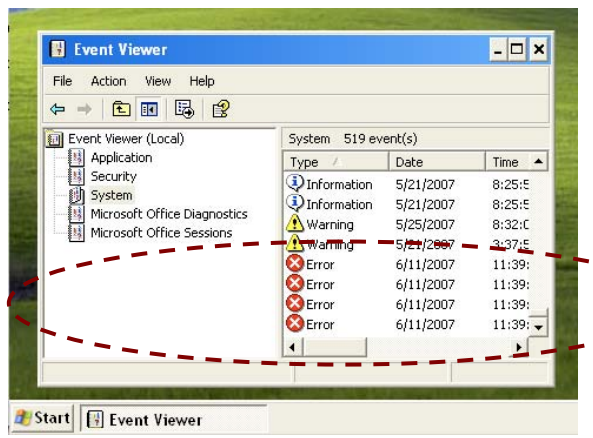
Software glitches leave Navy Smart Ship dead in the water

In 1995, the U.S. Navy, on advice Naval Research Advisory Committee (NRAC), started a program to research labor and manpower saving ideas. The results of this program, deemed the Smart Ship, are being tested aboard the USS Yorktown. The Navy quickly deemed the program a success in reducing manpower, maintenance and costs. In September of 1997, however, the Yorktown's propulsion system failed. The ship had to be towed to a Naval base at

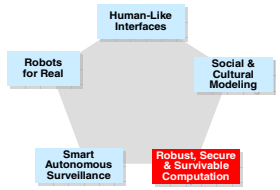
Sandia Red Team hacks all computer defenses

ALBUQUERQUE, N.M. — Over the past two years, a group at Sandia National Laboratories known informally as the Red Team has, at customer invitation, either successfully invaded or devised successful mock attacks on 35 out of 35 information systems at various sites, along with their associated security technologies

Comin' at you — Sandia's



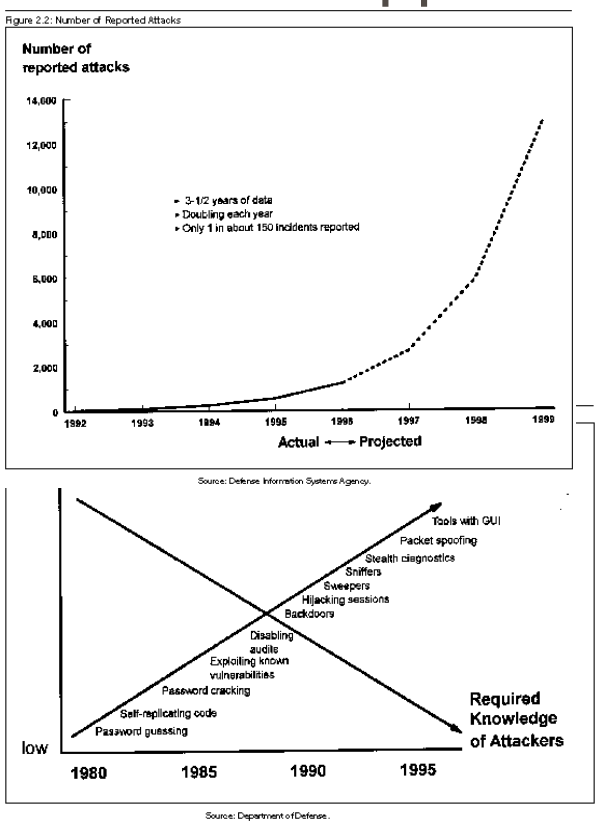
Why Is This Hard?



CSAIL

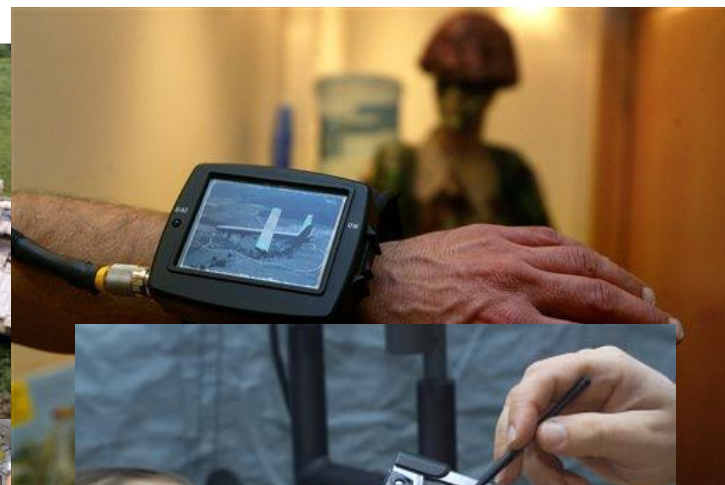
Harsh Environments

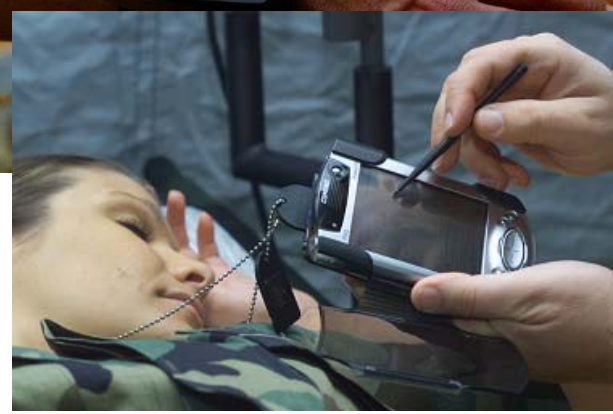
Capable and dedicated opponents



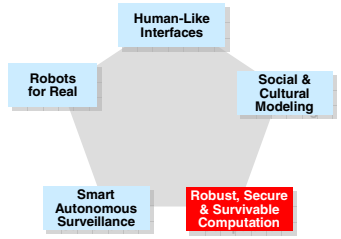
Mobile and distributed components

Heterogeneous systems





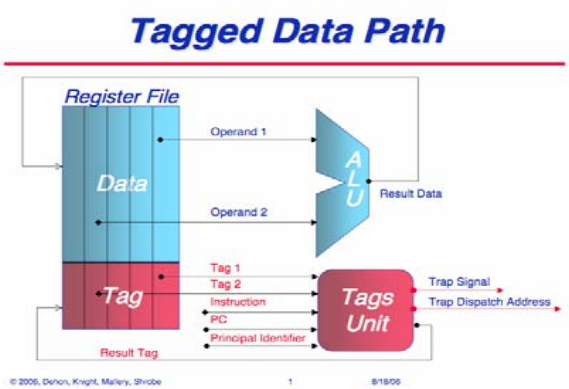
Key Research Elements



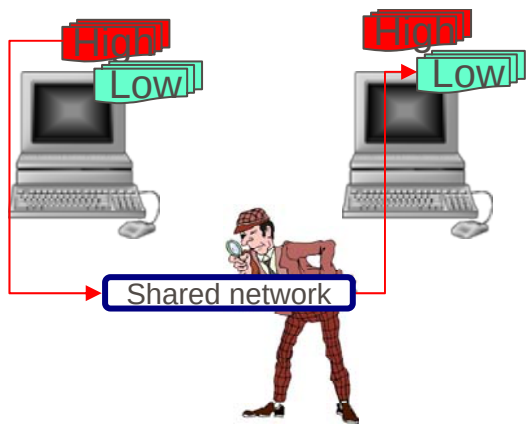
CSAIL

1. A highly secure and sustainable computer architecture
2. Model-based self checking and self-healing frameworks
3. Information flow control
4. New algorithms for dynamic distributed systems
5. High performance embedded networked security monitor
6. Abstractions and compilation for emerging multi-cores
7. End-to-end certification of critical infrastructural systems

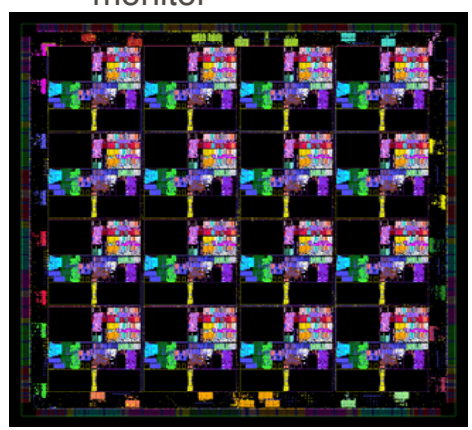
Secure and sustainable computing
Using hardware enforced integrity



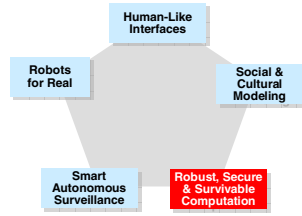
Model based self-checking &
information flow control



High performance
network security
monitor



Secure and Survivable Systems Today, Tomorrow, and Beyond



CSAIL

Today

All COTS systems are vulnerable

Isolated components, serious problems with dynamic distributed systems

No ability to assess overall exposure, low confidence that deployed systems have worked correctly

3-5 years

Modest survivability provided by hand-crafted solutions at single level

Data tagged with provenance and credibility; accountable flow of information.

Reasonable confidence that systems have worked correctly

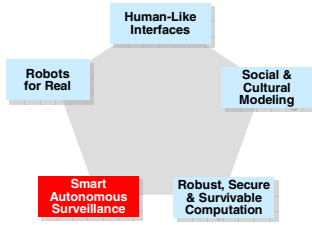
5-10 years

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

Challenge 4: Smart Autonomous Surveillance (SAS)



CSAIL

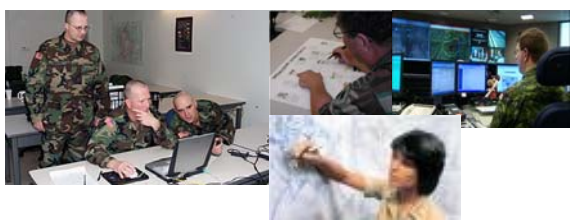
Mexico City

NGA's High-Resolution Terrain Information (HRTI) Test Range

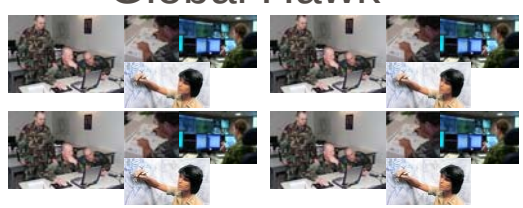
Predator

Global Hawk

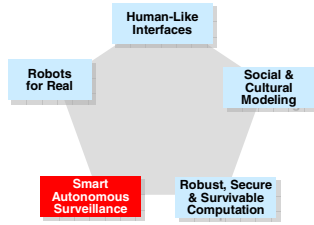
Avg. 6 people needed to interpret data from 1 Predator



Avg. 24 people needed to interpret data from 1 Global Hawk



Smart Autonomous Surveillance: from Forensic to Prediction Tools



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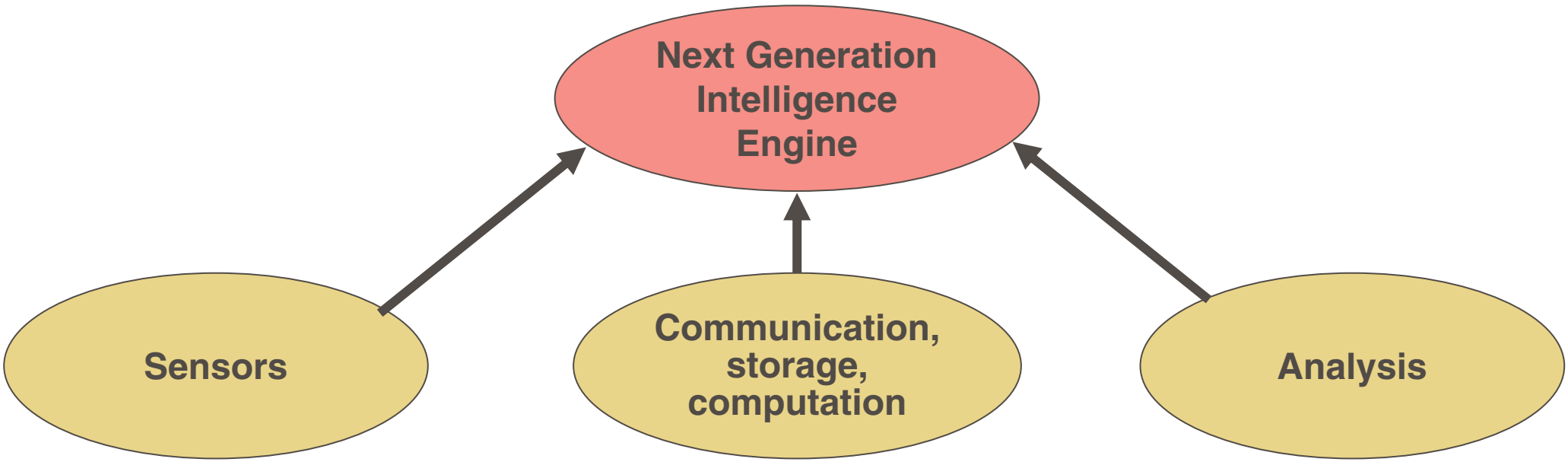
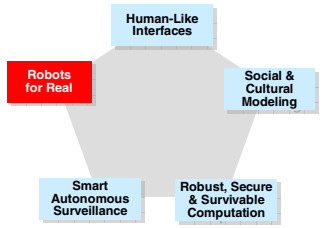


- Computational cameras
- Coded aperture sensors
- Queuing sensors

- 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

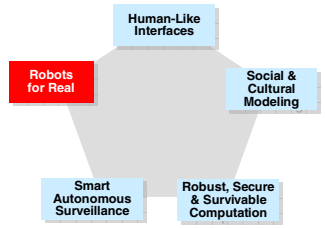
RQ1-Predator GCS

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

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

Supply-chain task

Key Research Elements



CSAIL

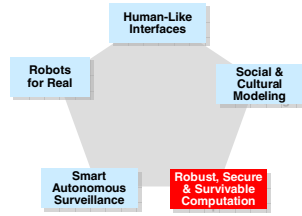
Logistics:
- Packing
- Loading
- Transportation

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 →

Robotics
Today, Tomorrow, and Beyond



CSAIL

Today

Tele-operated, unmanned vehicles used effectively by special forces

Supply chain implemented by human pilots/drivers and loaders/unloaders

Humans interact with robots through joystick interfaces

3-5 years

FCS vehicles in common use, but still require teams of trained personnel

Robotic ground vehicles perform routine supply runs in friendly areas

Humans interact with robots using restricted speech and gesture commands

5-10 years

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

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: