Technologies for 2020 and Beyond

Science and Technology Symposium 2004

21 April 2004

24th
Army Science Conference

Nov 29 - Dec 2, 2004
Orlando, Florida

Transformational Science and Technology for the Current and Future Force

Sponsored by the
Assistant Secretary of the Army
(Acquisition, Logistics, and Technology)

www.asc2004.com
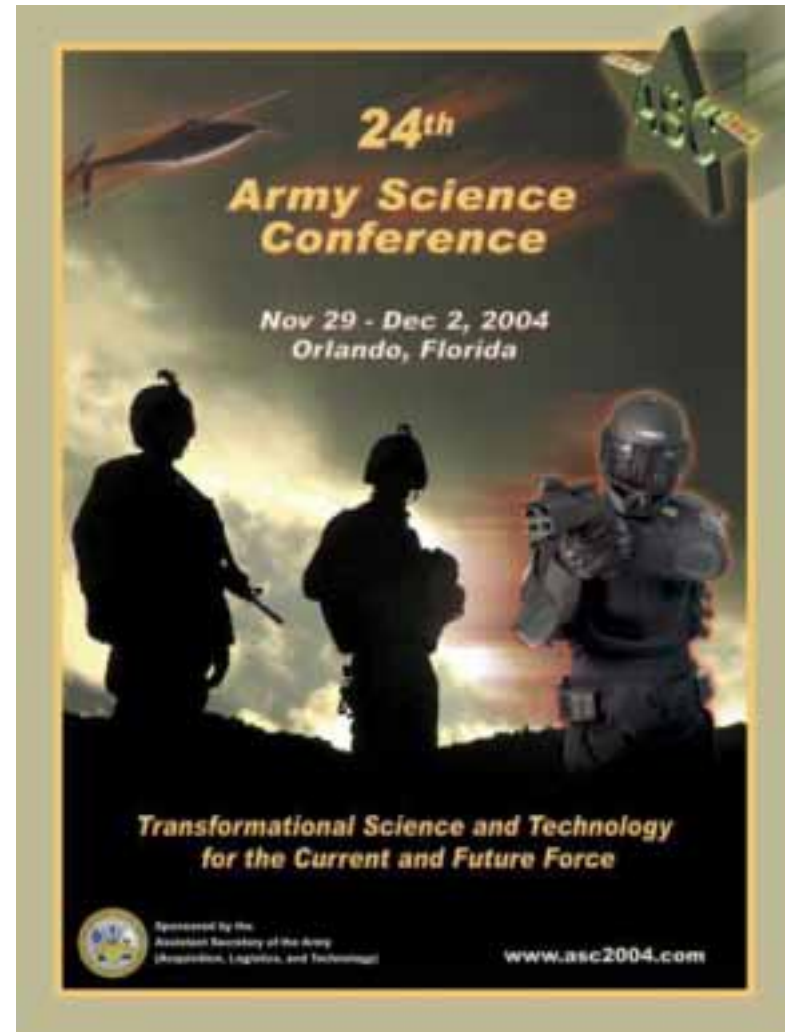
Dr. Thomas H. Killion
Deputy Assistant Secretary of the Army for Research and Technology / Chief Scientist

U.S.ARMY

Overview

- *Paradigm Shifting Technologies*

- *The Disappearing Computer*

- *Unmanned Systems*

- *Surveillance & Knowledge Systems*

- *Training & Leader Development*

Pursuing Revolutionary Technologies…
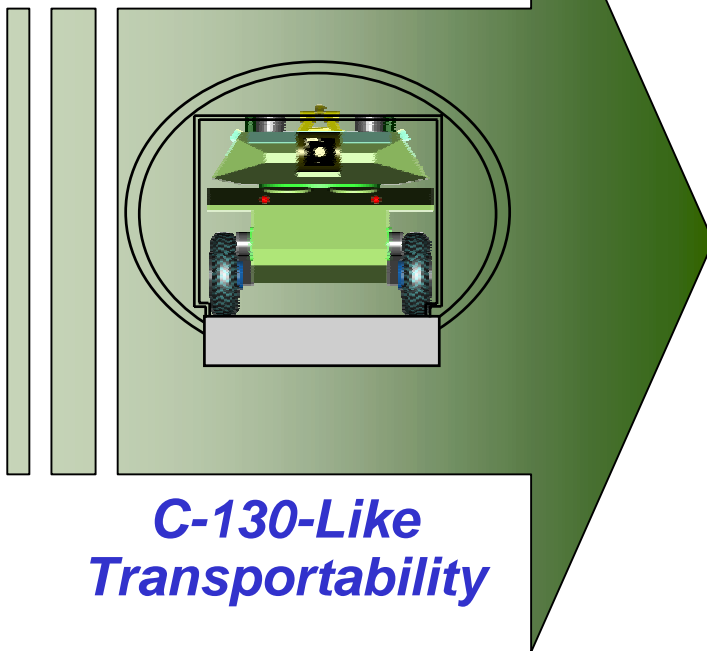## Smaller, Smarter, Lighter & Faster

Today

Future Force

~100 lb. load

From Platforms to System of Systems

< 40 lb. effective load

70+ tons

Fully networked

< 20 tons

0 mph

C-130-Like Transportability

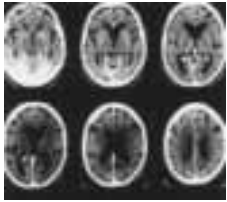> 40 mph

Accelerating Transformational Capabilities

Basic Research…
The Next Generation of Paradigm Shifting Technologies

Decade of the 1970's

Structural Imaging

1971 – First Practical X-ray Computed Tomography Image

Microprocessors

1971 – First 4 Bit Microprocessor in Production

Arcade Games

Artificial Intelligence

1970-Shakey the robot

Supercomputing

1975 – Cray I Supercomputer

Genetic Engineering
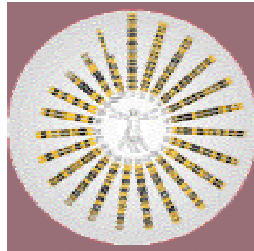
Today for 2020 and beyond…

Functional Brain Imaging
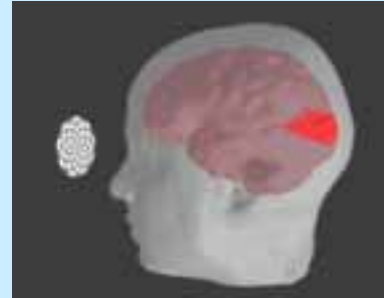
Robotics

Quantum Computing
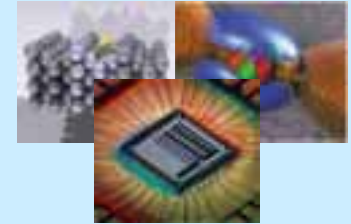
Nanotechnology

Immersive Environments
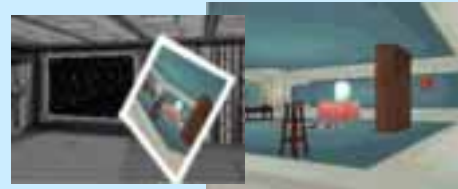
Biotechnology

The Disappearing Computer

DECREASE IN SIZE OF COMPUTERS

- Match Head-Size Web Server
- Hand-Held Devices
- First Laptop
- First Personal Computer
- Minicomputers
- Early Supercomputers

Cubic Meters

y-axis: .000001, .0001, .01, 1, 100, 10,000, 1,000,000

x-axis: 1940, 1950, 1960, 1970, 1980, 1990, 2000, 2010

EXPONENTIALSCALE
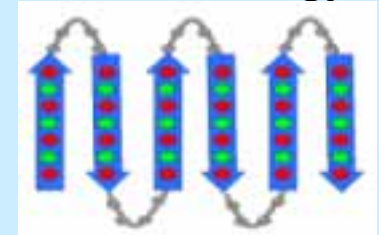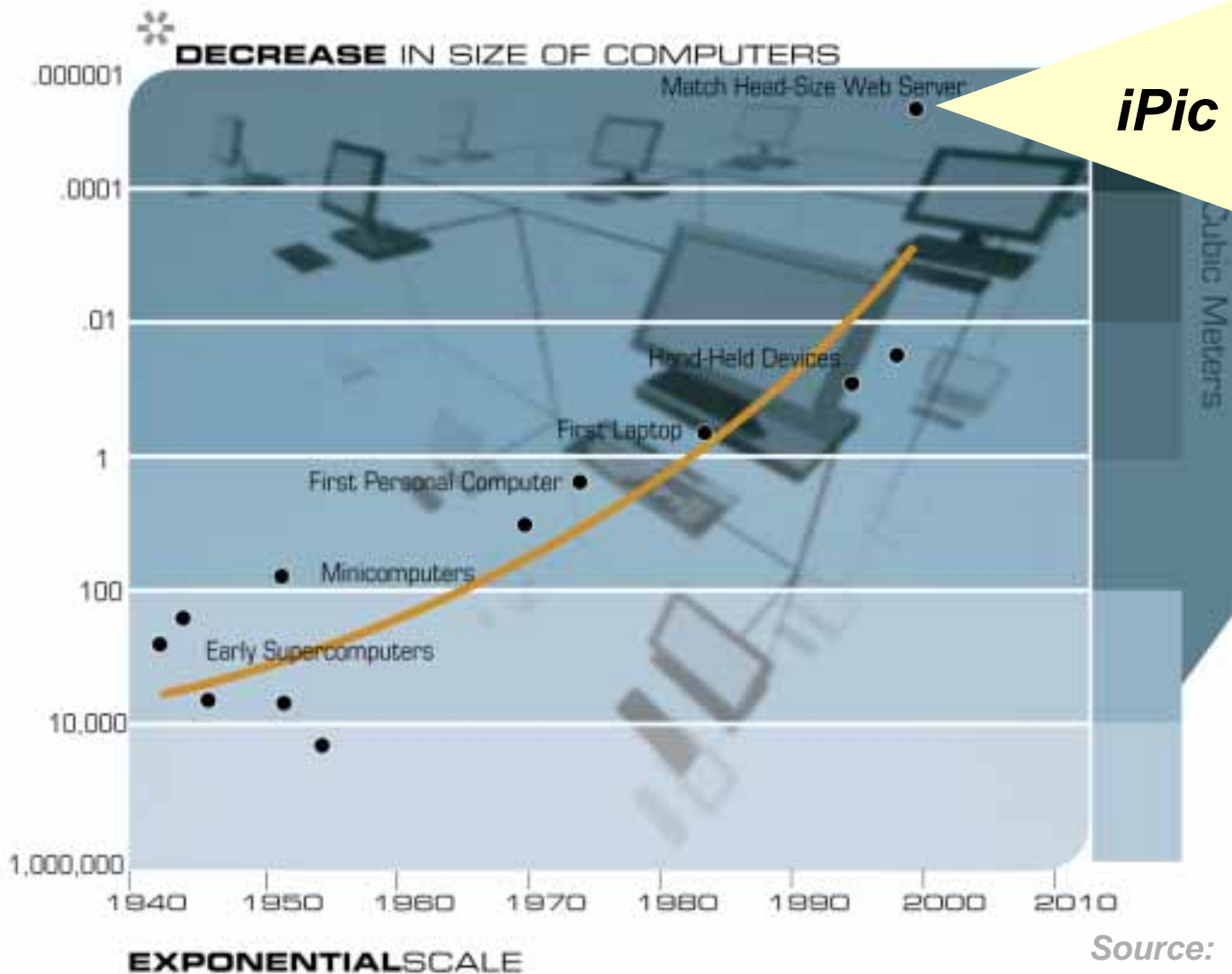
iPic

Photo courtesy of Cris Pedregal-Martin
http://www-ccs.cs.umass.edu/~shri/iPic.html

Source: Ray Kurzweil
KurzweilAI.net

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042104_Canada_Killion_Final

Growth in Computational Density

MOORE'S LAW - THE FIFTH PARADIGM

Calculations Per Second Per $1,000

1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000
ELECTROMECHANICAL   RELAY VACUME TUBE TRANSISTOR   INTEGRATED CIRCUIT

EXPONENTIALSCALE

MOORE'S LAW
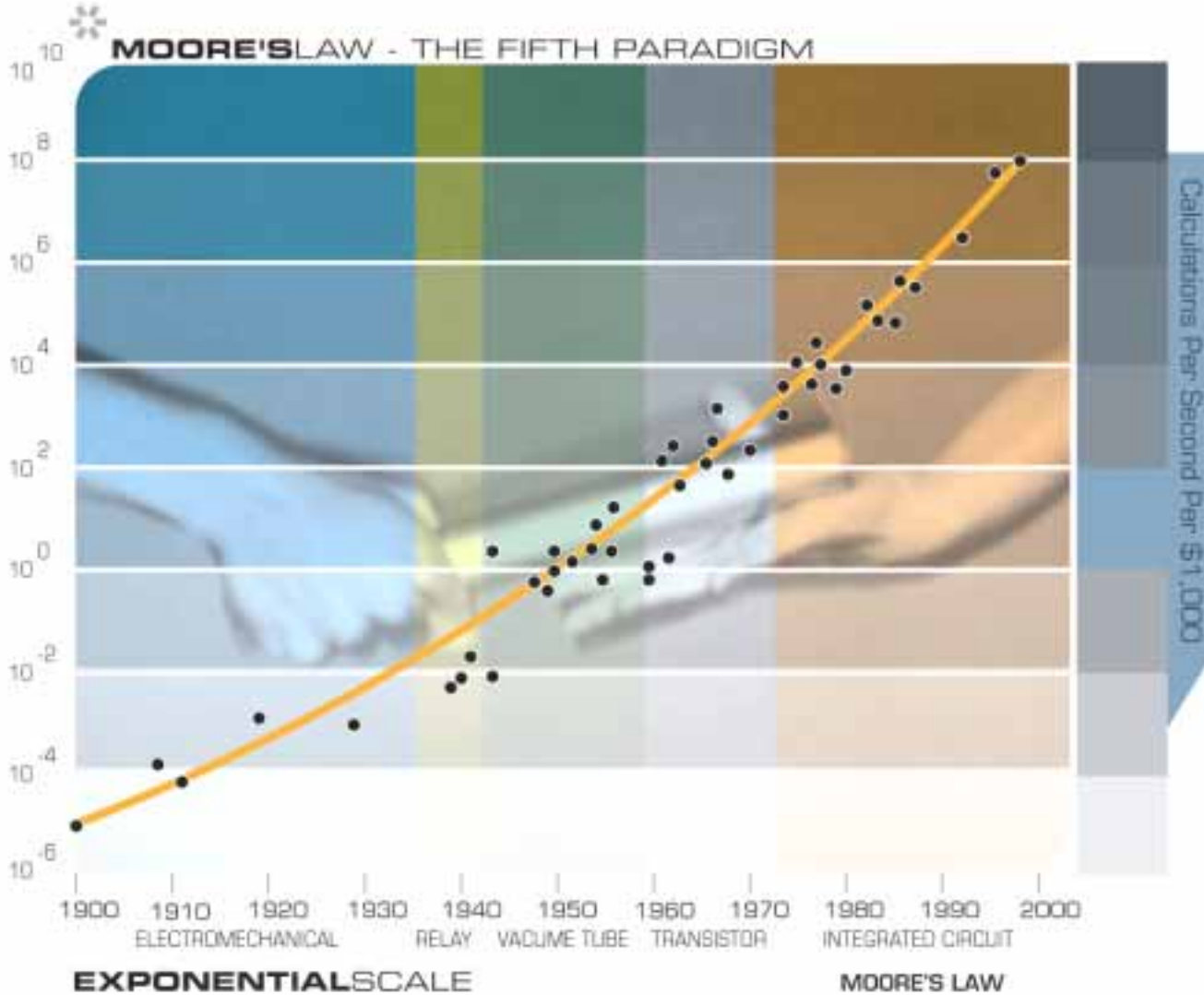
Natural vs. Artificial Intelligence
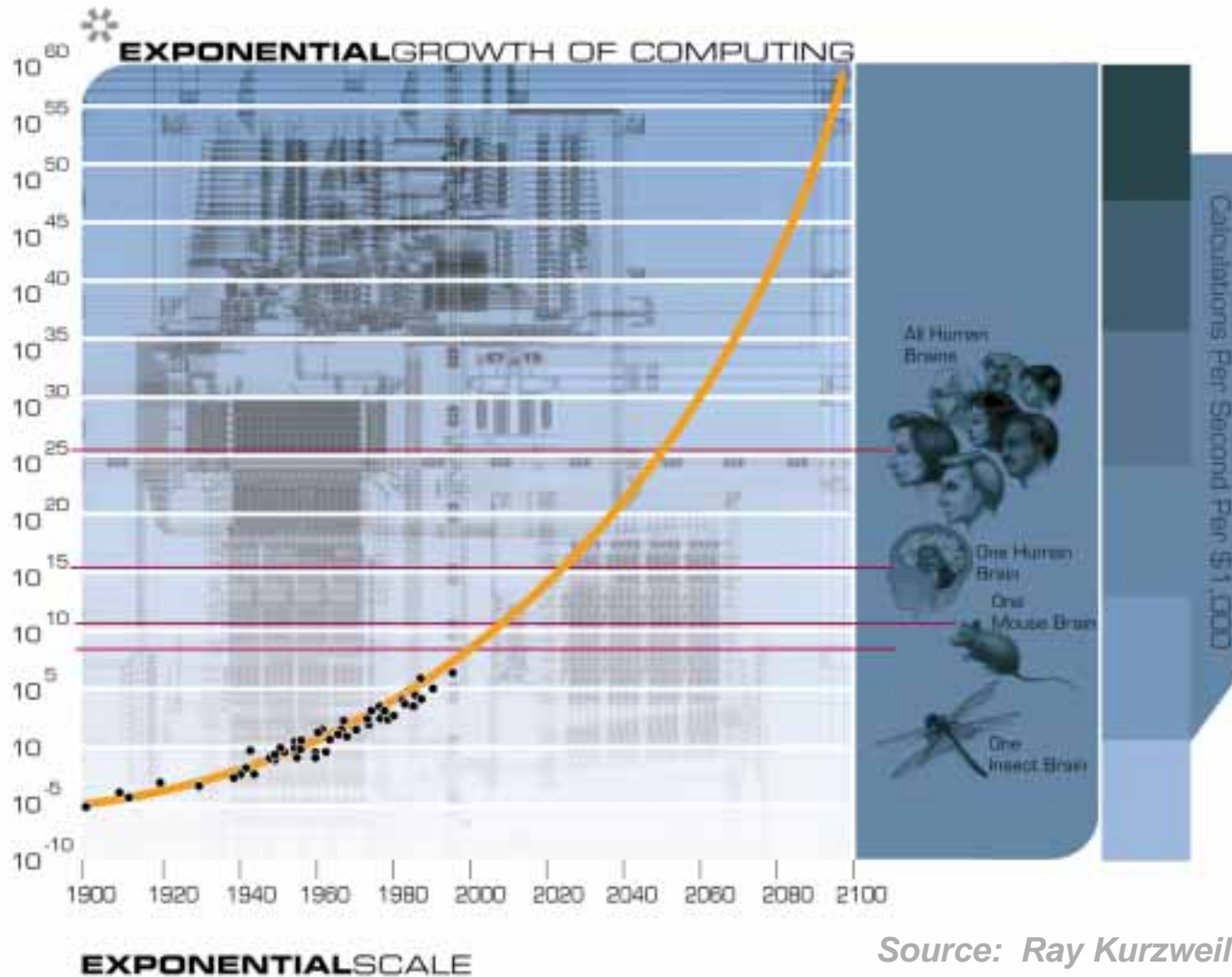
Source: Ray Kurzweil
KurzweilAI.net

2029: An intimate merger

- **$1,000 of computation = 1,000 times the human brain**

- **Reverse engineering of the human brain completed**

- **Computers pass the Turing test***

- **Nonbiological intelligence combines**
  - *the subtlety and pattern recognition strength of human intelligence, with*
  - *the speed, memory, and knowledge sharing of machine intelligence*

- **Nonbiological will continue to grow exponentially whereas biological intelligence is effectively fixed**

*Alan Turing's notional test for determining when a system is "intelligent"

Source: Ray Kurzweil
KurzweilAI.net

Unmanned Systems
Paradigm Shifts in Warfighting Capability

Acting First…Extending the Battlespace

Autonomous Teaming
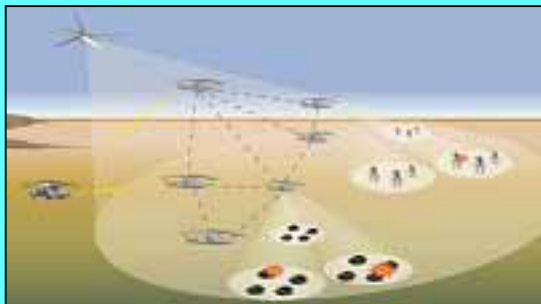
Unmanned Ground Vehicles

Unmanned Combat Armed Rotorcraft

Autonomous Combat Operations with Unmanned Systems

1,000 lbs and 8 hrs

Armed Reconnaissance Vehicles

Assured comms and situational awareness

A-160 Hummingbird	Organic Air Vehicle (OAV)	Micro Air Vehicle (MAV)
1,000 lbs and 40 hrs	**~10 lbs and 1 hr**	**<1 lb and 30 mins**

Really Micro UAVs

Goal:

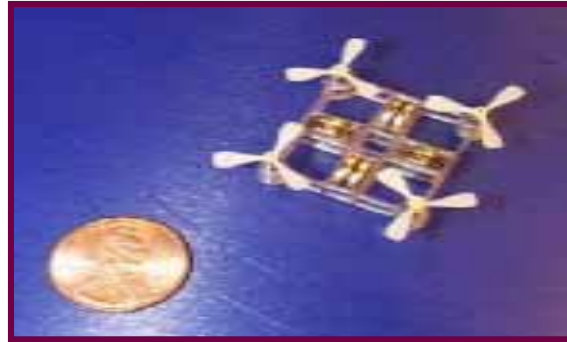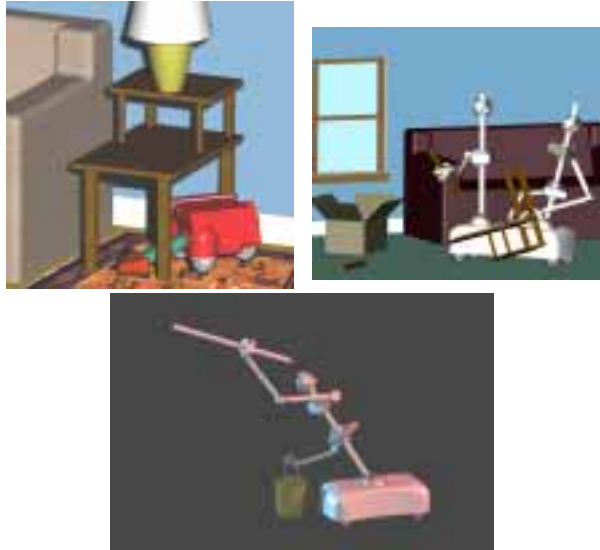- *Control systems that sense environmental instabilities and adjust their airfoils and propulsion to stabilize in real time*

- *Navigate to arrive and land on demand*

**Increasing focus on biologically-inspired flight systems**

Technology Forecast for General Purpose Robots*

MIPS (Million Instructions Per Second)

4th Gen Universal Robots
Processing power: 100M MIPS (human-scale)
Key Features: Reasoning

3rd Gen Universal Robots
Processing power: 3M MIPS (monkey-scale)
Key Features: Task "visualization" for fast learning

2nd Gen Universal Robots
Processing power: 100,000 MIPS (mouse-scale)
Key Features: Adaptive behavior ("on-the-job learning")

1st Gen Universal Robots
Processing power: 3000 MIPS (lizard-scale)
Key Features: General-purpose perception, manipulation & mobility; pre-programmed task functions

- **1B**
- **10M**
- **100K**
- **1K**

- **2010**
- **2020**
- **2030**
- **2040**

Assumptions:

- **Continued miniaturization of electronic elements**

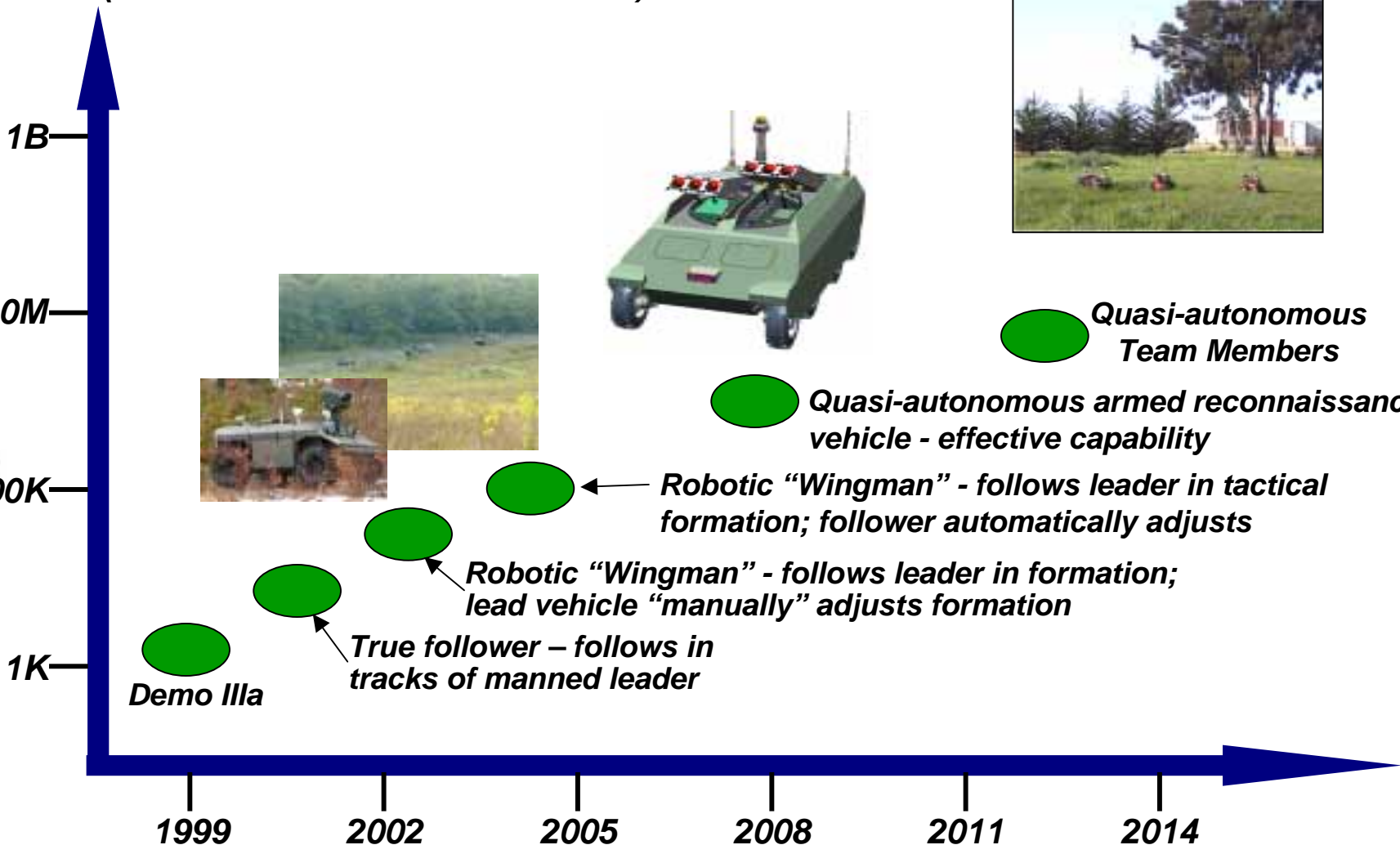- **Automated, plug'n'play software development**
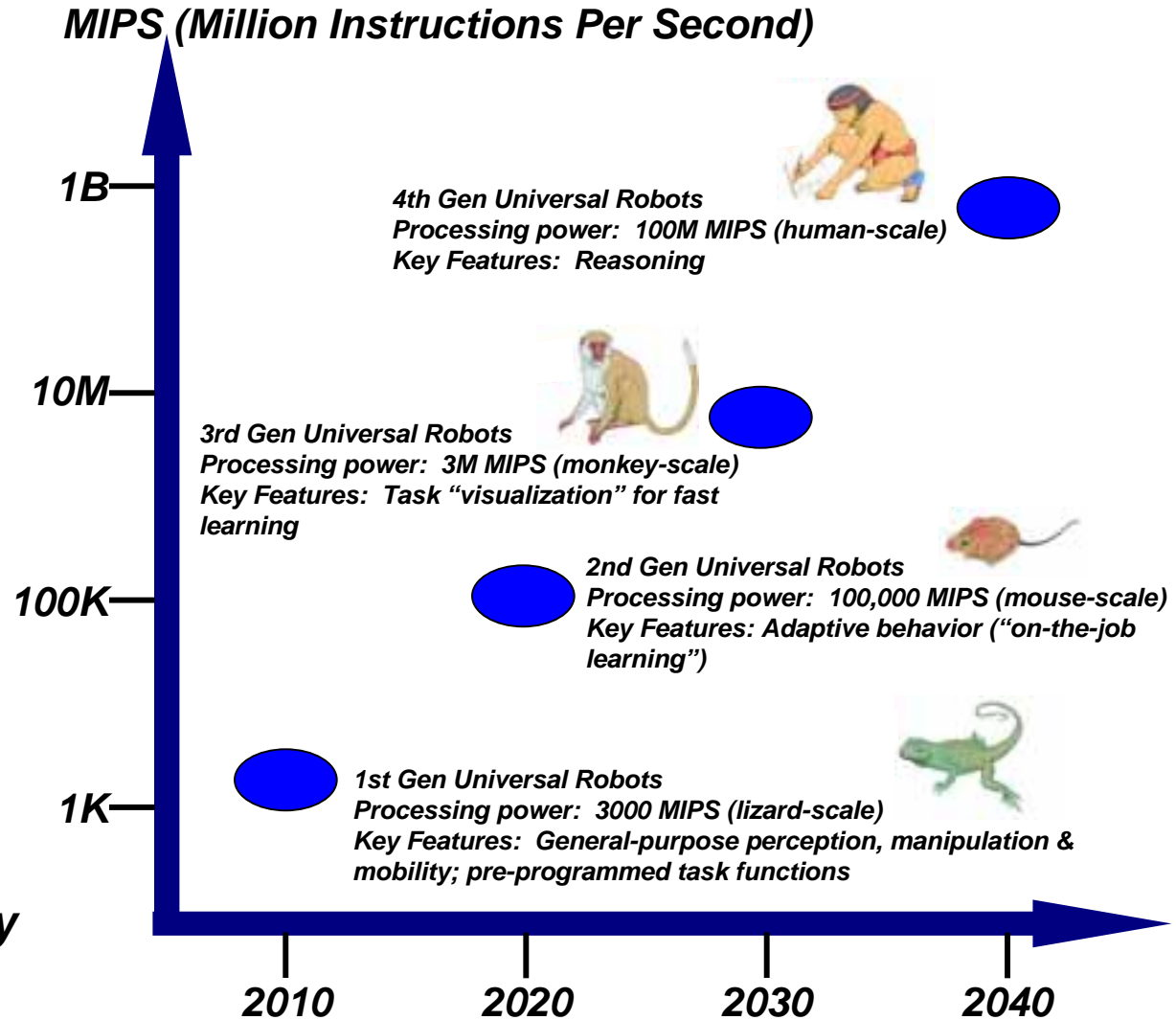
Adapted from Hans Moravec, "Robot: Mere Machine to Transcendent Mind", Oxford, 1999.

Way Ahead for Army UGVs

MIPS (Million Instructions Per Second)

1B —

10M —

Quasi-autonomous Team Members

100K —

Quasi-autonomous armed reconnaissance vehicle - effective capability

Robotic "Wingman" - follows leader in tactical formation; follower automatically adjusts

Robotic "Wingman" - follows leader in formation; lead vehicle "manually" adjusts formation

1K —

True follower – follows in tracks of manned leader

Demo IIIa

1999   2002   2005   2008   2011   2014
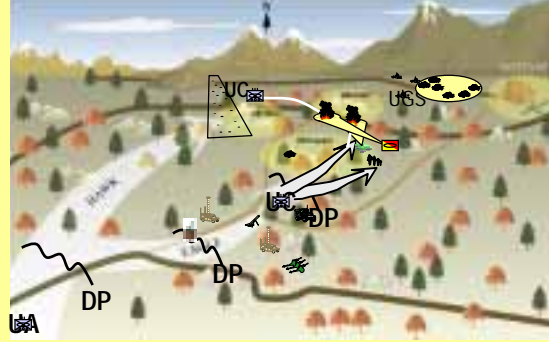
Surveillance and Knowledge Systems
C2 + C2 + ISR

Command & Control

Flexible Displays
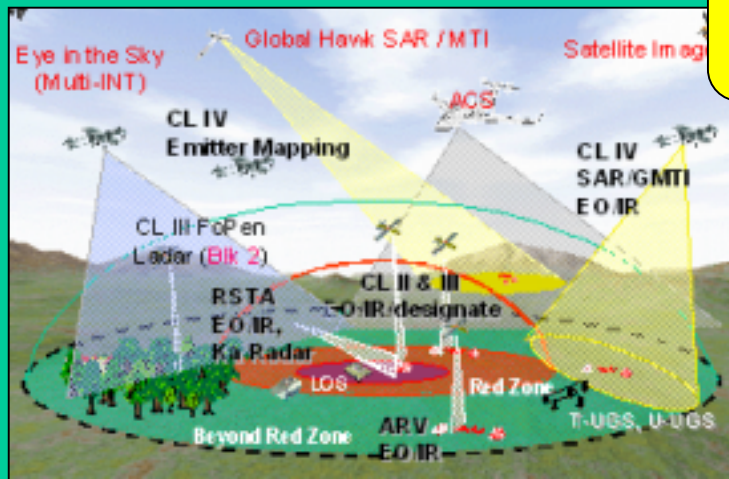
Knowledge Fusion
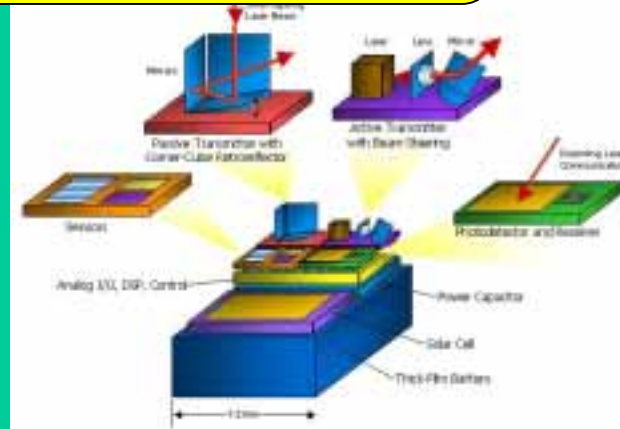
System of Systems Demos

Networked Comms

Conformal Antennas

- *Find the Enemy*
- *Assured Comms*
- *Battle Command*
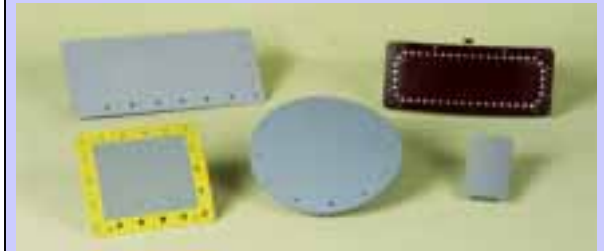
Persistent Sensor Coverage

Eye in the Sky (Multi-INT)

Global Hawk SAR /MTI

Satellite Image

CL IV Emitter Mapping

ACS

CL IV SAR/GMTI EO IR

CL III FoPen Ladar (Blk 2)

RSTA EO IR, Ka Radar

CL II & III EO-IR designate

LOS

Red Zone

Beyond Red Zone
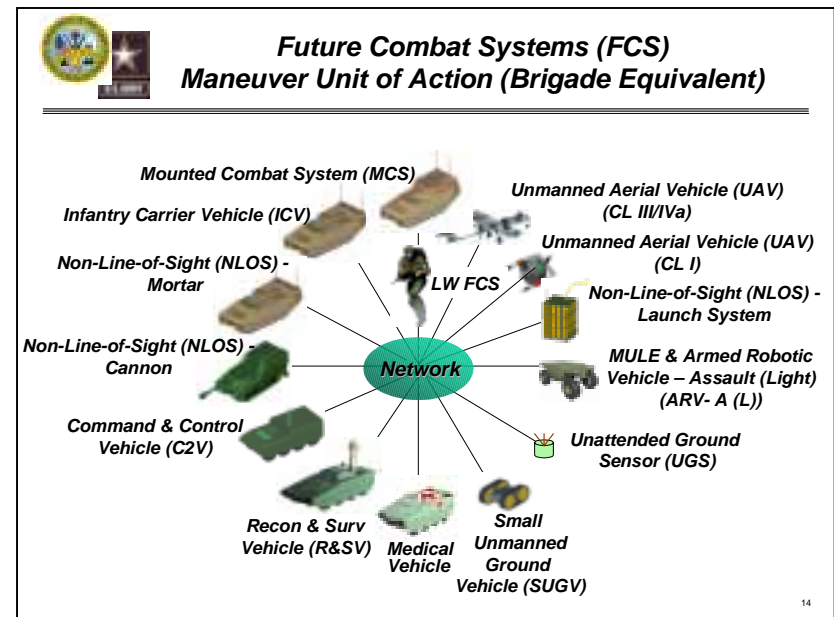
ARV EO IR

T-UGS, U-UGS

Unblinking "Eye"

Ubiquitous Sensing - Smart "Dust"

FCS Network Characteristics

- *Self-organizing and self-configuring*
- *Assured communications (continuous)*
- *Secure communications (encryption, LPI, LPD)*
- *Knowledge of where everyone is (friend and foe) in space and time*
- *Distribution of common operating picture (COP) to users of information*
- *COP that minimizes latency*
- *Conduct complex operations with great precision and speed to devastate an adversary*

**Future Combat Systems (FCS)
Maneuver Unit of Action (Brigade Equivalent)**

Mounted Combat System (MCS)
Infantry Carrier Vehicle (ICV)
Non-Line-of-Sight (NLOS) - Mortar
Non-Line-of-Sight (NLOS) - Cannon
Command & Control Vehicle (C2V)
Recon & Surv Vehicle (R&SV)
Medical Vehicle
Small Unmanned Ground Vehicle (SUGV)
Unattended Ground Sensor (UGS)
MULE & Armed Robotic Vehicle – Assault (Light) (ARV- A (L))
Non-Line-of-Sight (NLOS) - Launch System
Unmanned Aerial Vehicle (UAV) (CL I)
Unmanned Aerial Vehicle (UAV) (CL III/IVa)
LW FCS
Network

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All on the move!

Some Complex Networks

- *Internet*
- *Power grid*
- *Transportation*
- *C³ (FCS Unit of Action)*
- *Social (friends, tribes, organizations, towns, cities, countries, global village)*
- *Insect (bees, ants, wasps and other swarms)*
- *Ecosystems*
- *Cellular (neuronal)*
- *Molecular (metabolic, nanobiotechnology)*
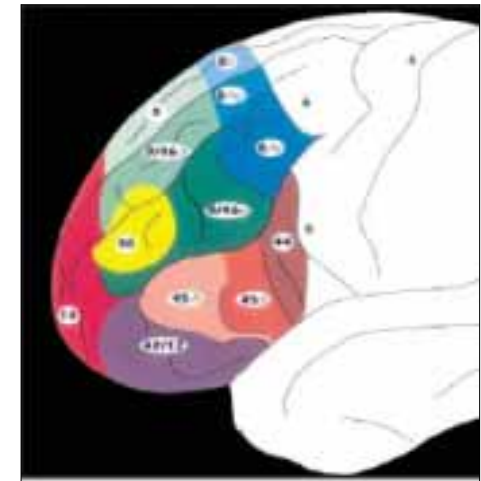

Fundamental understanding of complex networks is still lacking

Network Science and Technology

Research challenges involve the development of

– *An understanding of the principles and rules that govern the behavior of complex network systems at a local level*

– *A corresponding language that is insightful and efficient in describing the underlying phenomena*

– *A mathematical framework that incorporates the above to facilitate the systematic study of such complex systems*
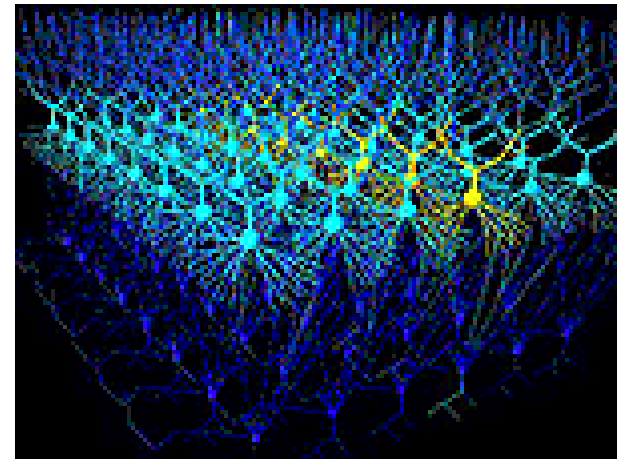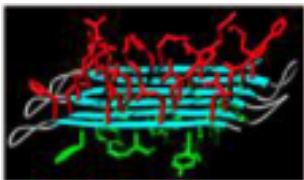

Goal for Army C^3 is to develop control systems to mitigate uncertainties and instabilities to improve performance

Institute for Collaborative Biotechnologies
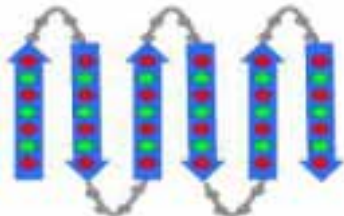
Binary code strategy to enable biologically-based production

Facial amphiphile

- *University-led center to integrate biosciences with the physical and engineering sciences*
  - *22 August 2003 Contract award of ICB –*
    Lead: University of California at Santa Barbara (UCSB)
    Partners: California Institute of Technology (Cal Tech)
    Massachusetts Institute of Technology (MIT)

- *Understanding of biological construction of novel materials to include:*
  - *Biologically-derived functional electronic, magnetic and optical materials*
  - *Integrated multi-modality sensing*
  - *Biologically-derived power and energy*
  - *Sense and respond actuation capabilities*

- *Army payoffs:*
  - *Precision strike*
  - *Signature management*
  - *Network design*

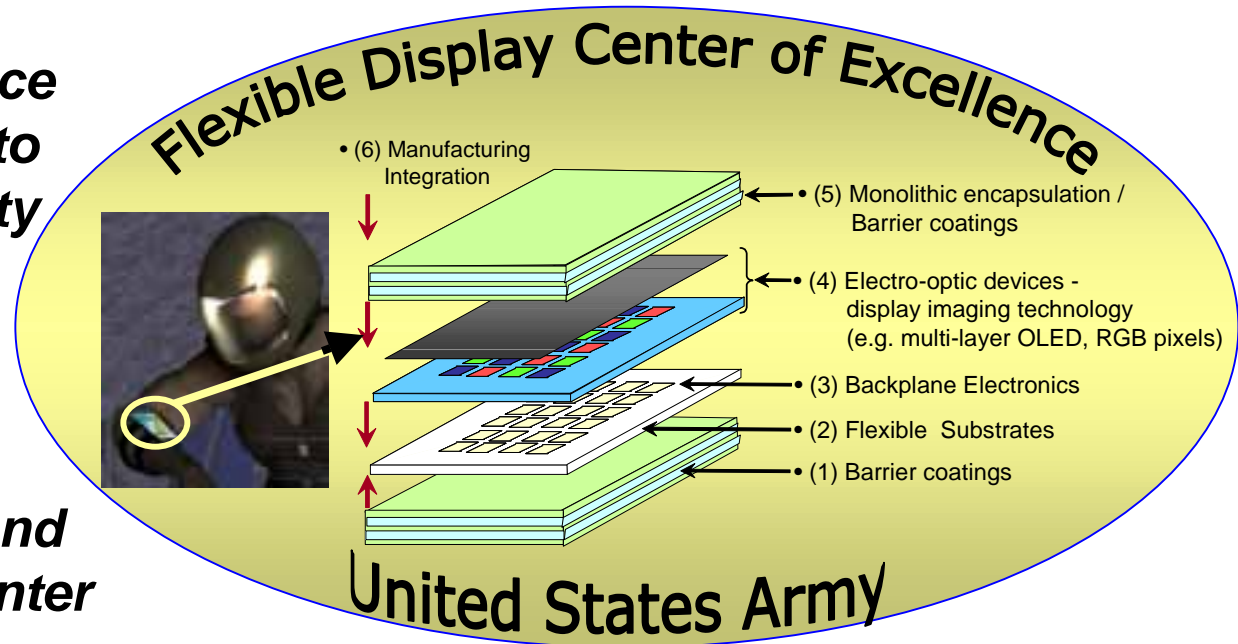*Opportunities in Biotechnology for Future Army Applications*
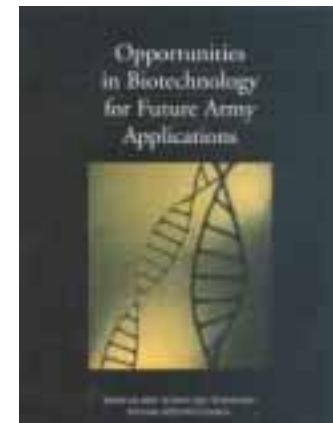
Gain insight from nature … for design principles, performance capabilities, and manufacturing possibilities

Flexible Display Initiative

- *FDI Center of Excellence awarded Feb 10, 2004 to Arizona State University*
- *ASU currently in negotiations with Dow and other potential industrial partners*
- *Shared technologies and IP generated by the center*

Flexible Display Center of Excellence

- (6) Manufacturing Integration
- (5) Monolithic encapsulation / Barrier coatings
- (4) Electro-optic devices - display imaging technology (e.g. multi-layer OLED, RGB pixels)
- (3) Backplane Electronics
- (2) Flexible Substrates
- (1) Barrier coatings

United States Army

- *Establish core capability to address the development of flexible displays*
- *Perform applied research and development to achieve larger displays, 4-6 inches*
- *Manufacturing "proofing" facility simulates manufacturing production lines*

Training & Leader Development

Scenario Based Decision Making

"Think Like A Commander"

Game Based Training

Immersive Environments

- **Compelling Scenarios**
- **Intelligent Avatars**
- **Virtual "Face-to-Face" Dialogue**
- **Avatar Directed After Action Review**

Speech Recognition Software

	1985	1995	2000	2010?
Price	$5,000	$500	$50	$5
Vocabulary Size (# Words)	1,000	10,000	100,000	1,000,000
Continuous Speech?	No	No	Yes	Yes
User Training Required (Minutes)	180	60	5	<1
Accuracy	Poor	Fair	Good	Excellent

Source: Ray Kurzweil KurzweilAI.net

# 24th Army Science Conference

"Transformational Science & Technology for the Current and Future Force"

- **Briefings and exhibits from world-class scientists and technologists**

- **Focus on joint aspects of Transformation**

- **November 29 - December 2, 2004**

- **J.W. Marriott Orlando - Grande Lakes**

- **2,000 government, industry, academia and foreign conferees**

- **Website: www.asc2004.com**

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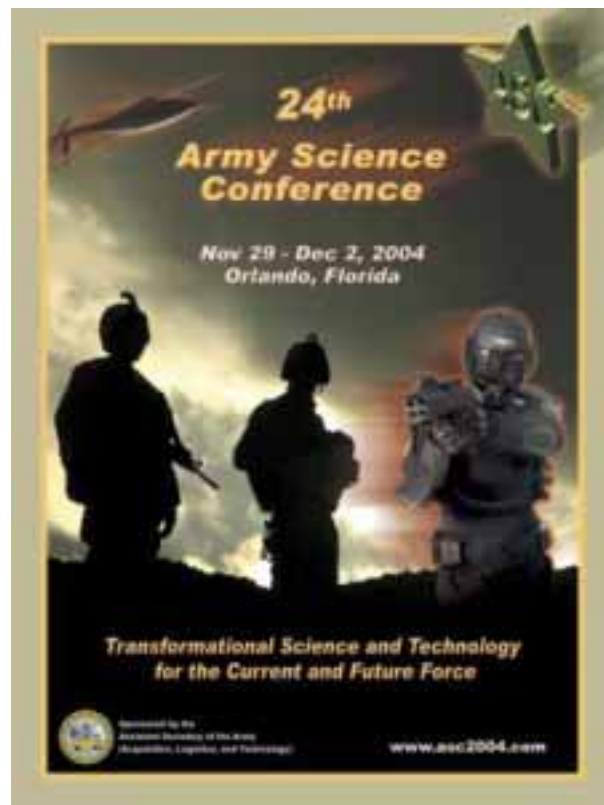
Call for papers, posters and exhibits

The Army…
On the Fast Track to Transformation

Future Force

This Decade

U.S. Army Training and Doctrine Command

TRANSFORMATION PLANNING GUIDANCE

APRIL 2003
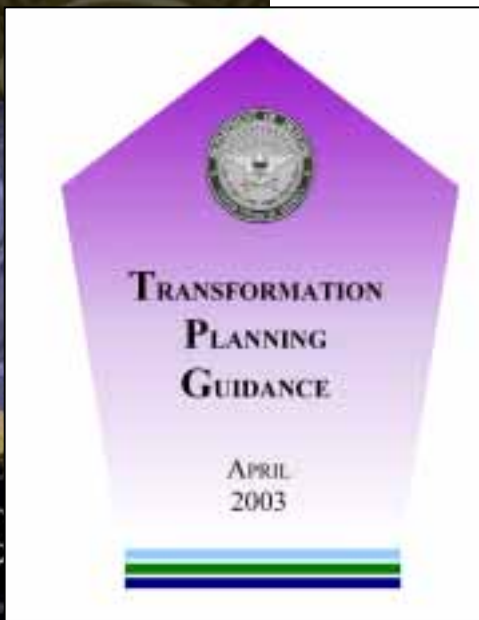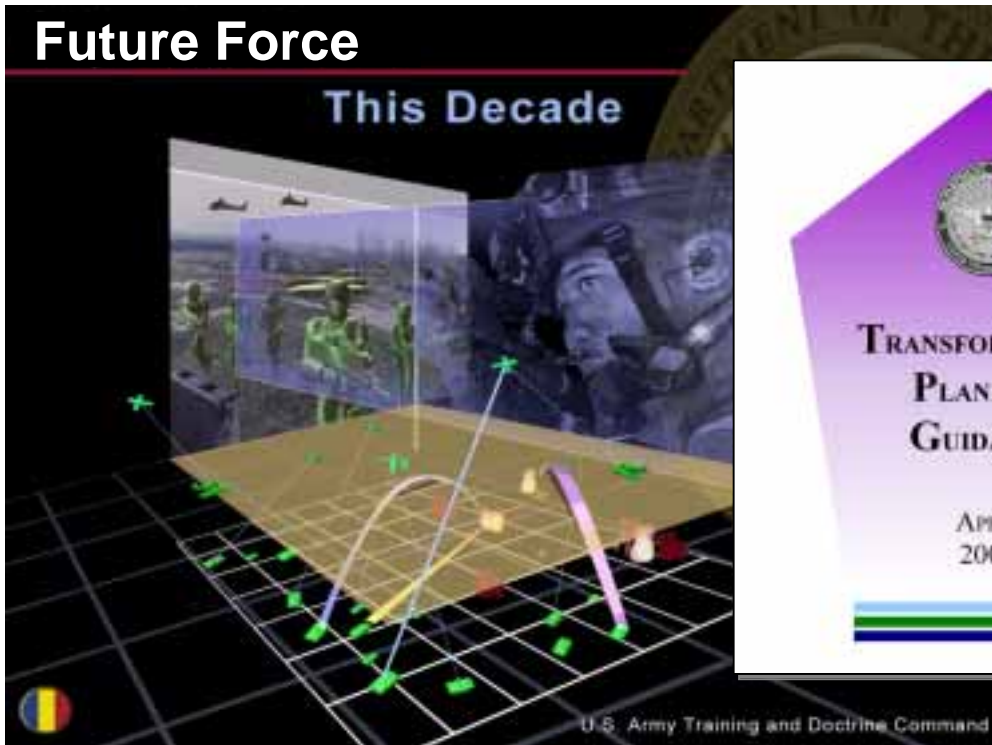
"…we must achieve: fundamentally joint, network-centric, distributed forces capable of rapid decision superiority and massed effects across the battlespace."

Secretary Rumsfeld

"…a future force that is defined less by size and more by mobility and swiftness, one that is easier to deploy and sustain, one that relies more heavily on stealth, precision weaponry and information technologies."

George W. Bush