Soldier Status Monitoring

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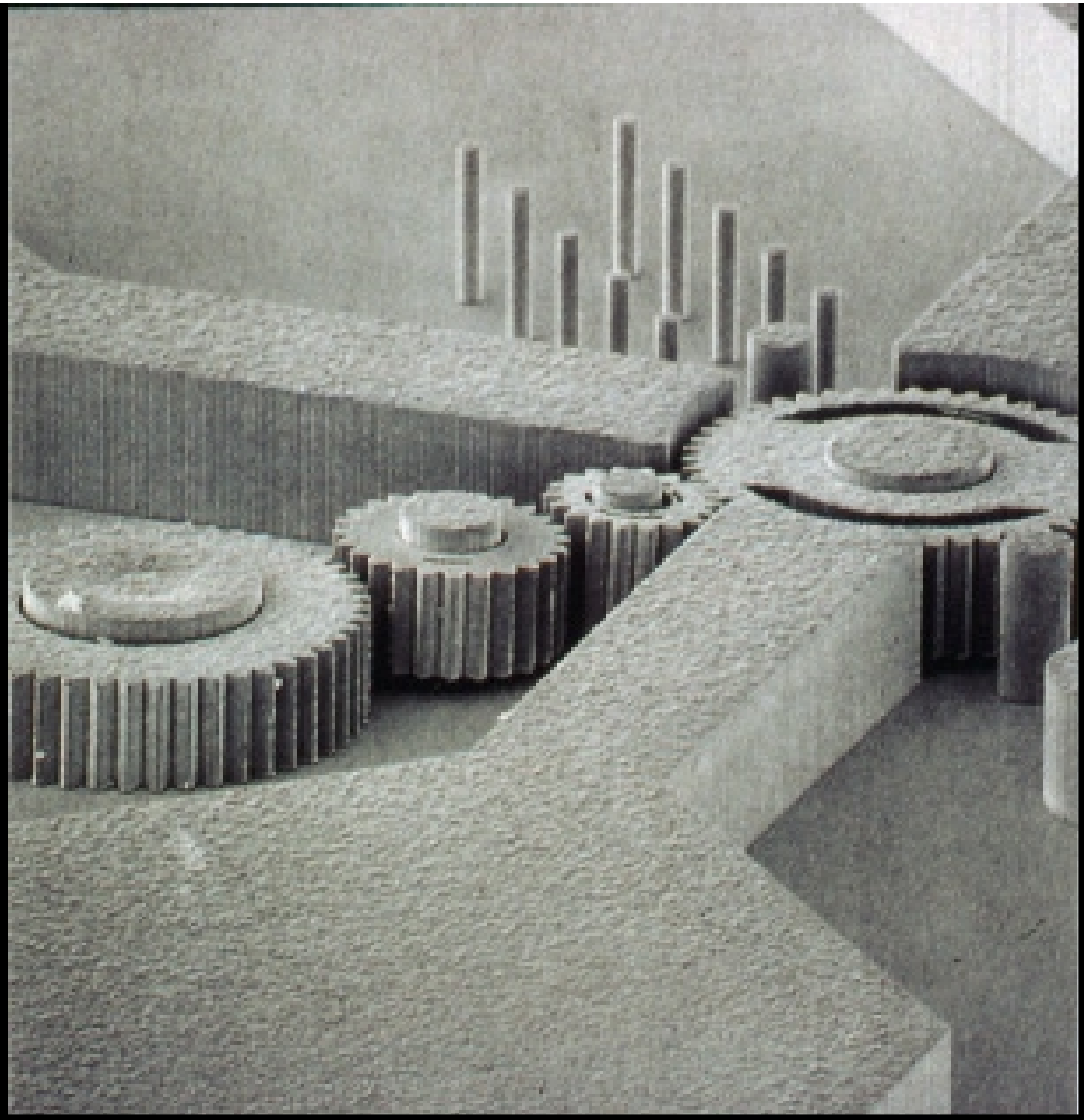
Nanoscience for the Soldier

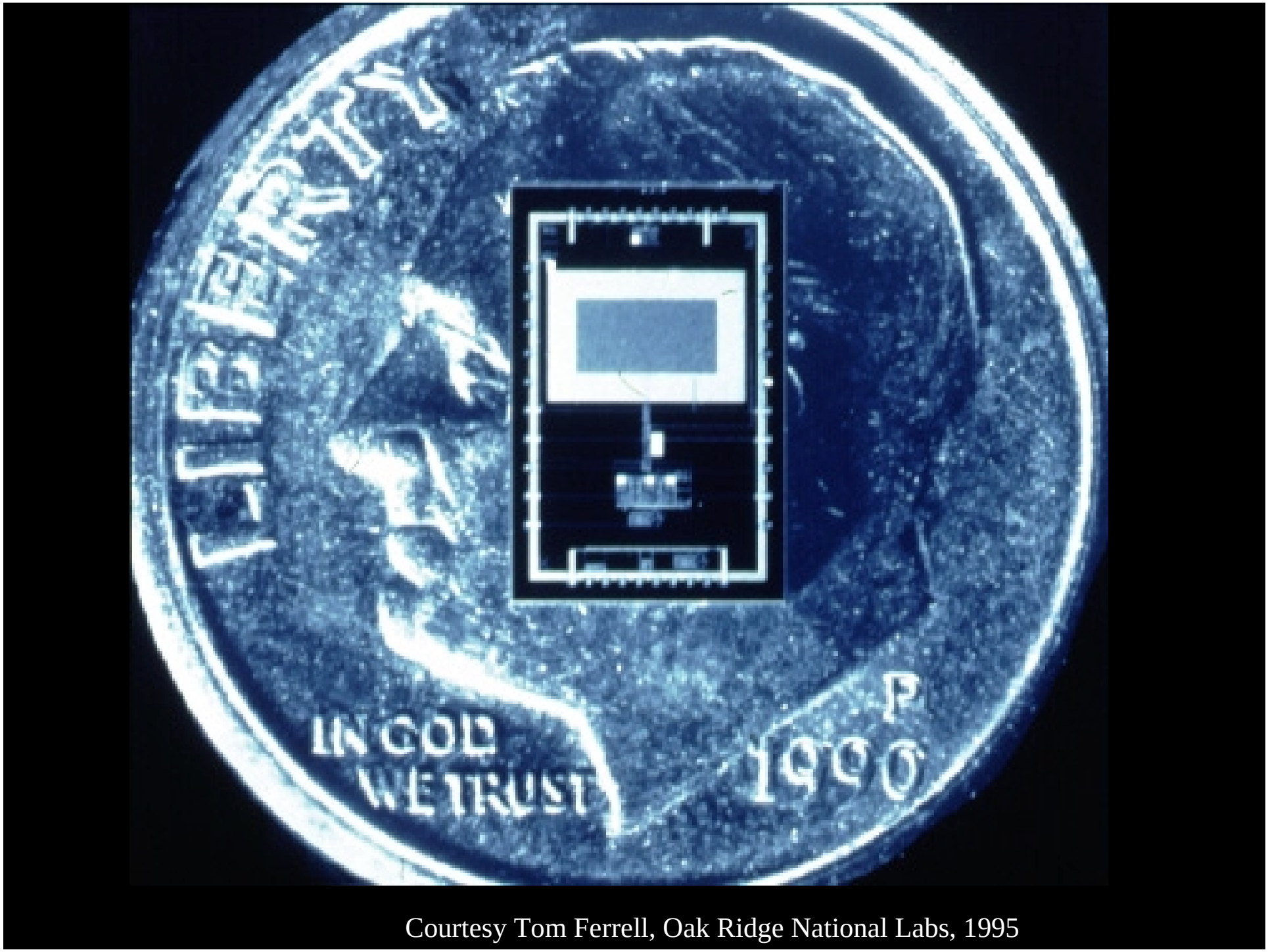
Research Triangle Institute
Raleigh-Durham, NC
February 8-10, 2001

Historical Events in Wearable Monitoring

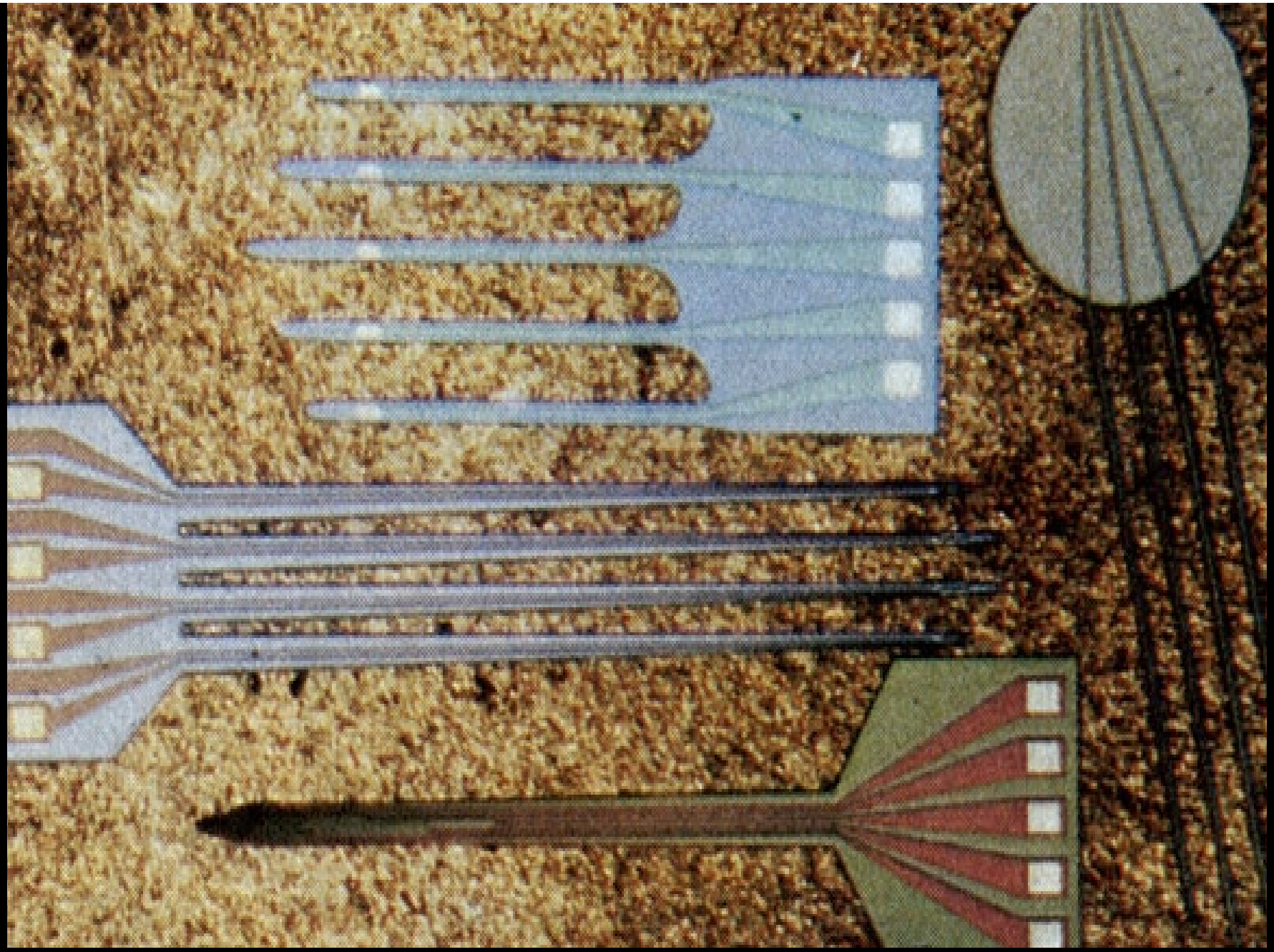
1960	**Holter**	**Holter Monitor**
1970	**Mann (MIT)**	**Wearable computers**
1986	**Shichiri**	**Glucose monitor**
1991	**Mittal**	**Pill temperature sensor**
1996	**US Army**	**PSM @ Camp Rudder**
1997	**Richey**	**Ambulatory BP (not real time)**
1997	**Montgomery**	**Vital Signs on commercial flight**
1999	**Mt. Everest**	**Everest Extreme Expedition**



Courtesy Ken Gabriel DARPA/Carnegie Mellon 1994



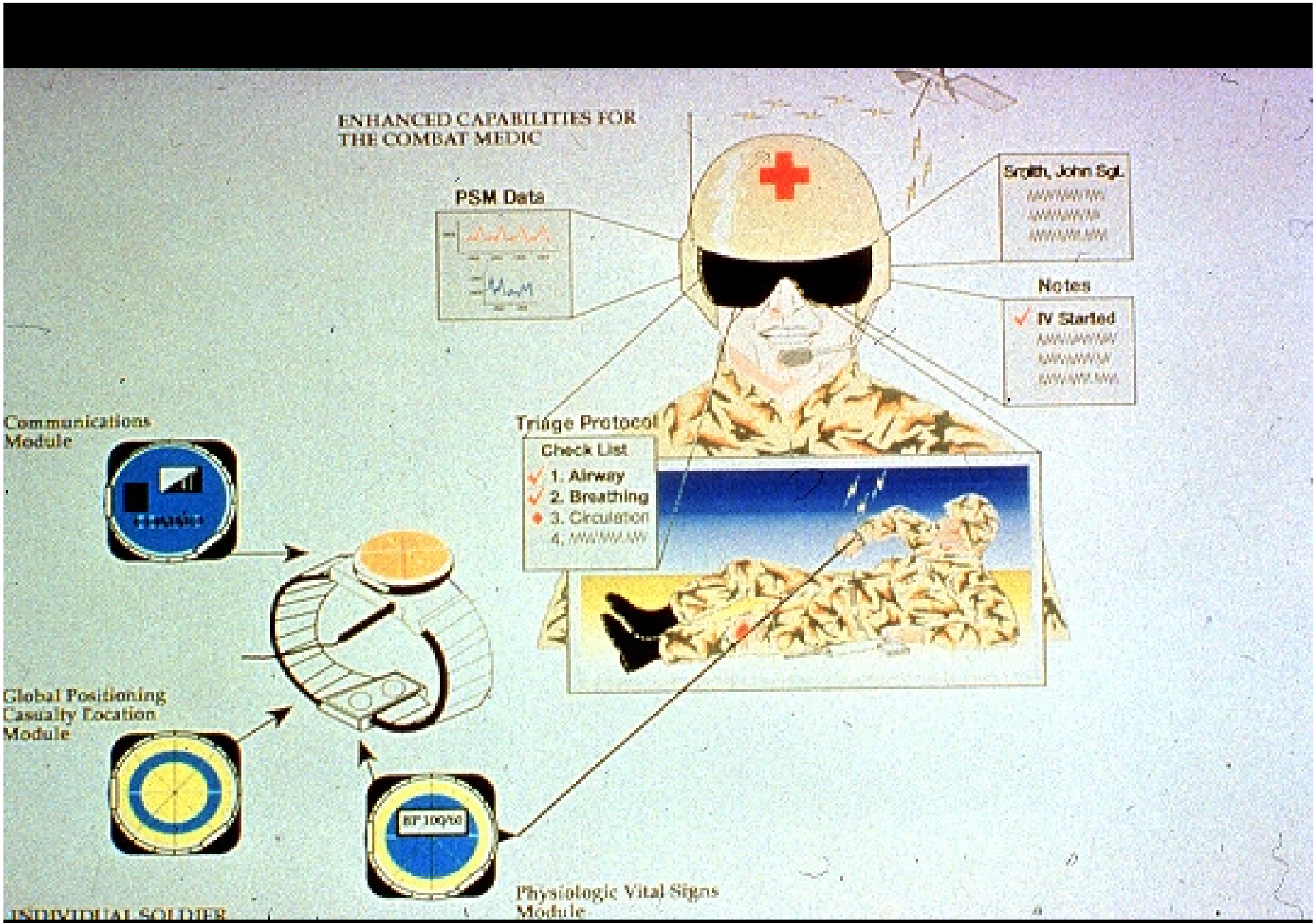
Courtesy Tom Ferrell, Oak Ridge National Labs, 1995



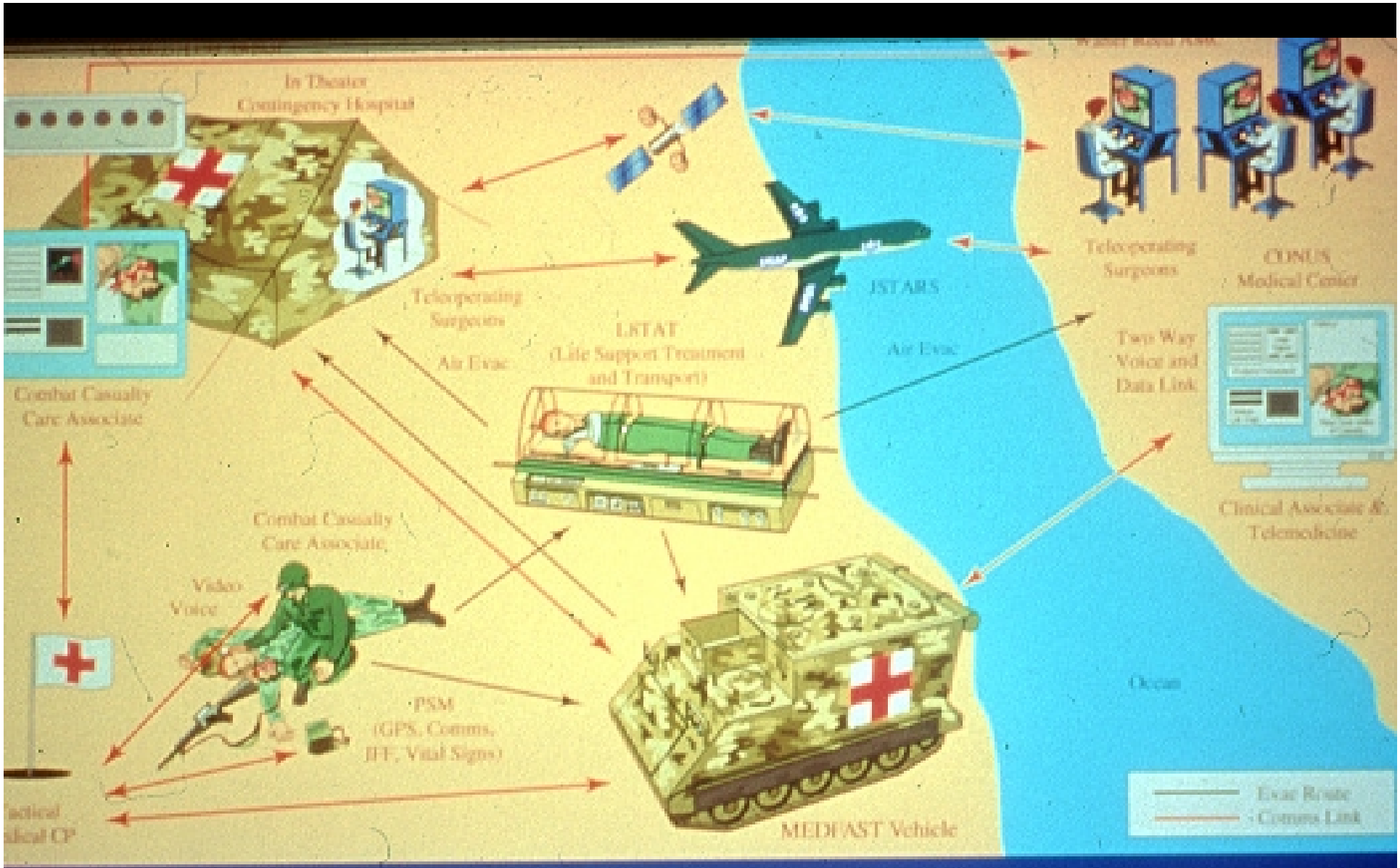
Neural micro-probes 50microns

Courtesy of Greg Kovacs, Stanford, 1990

Land Warrior 21 - 1996



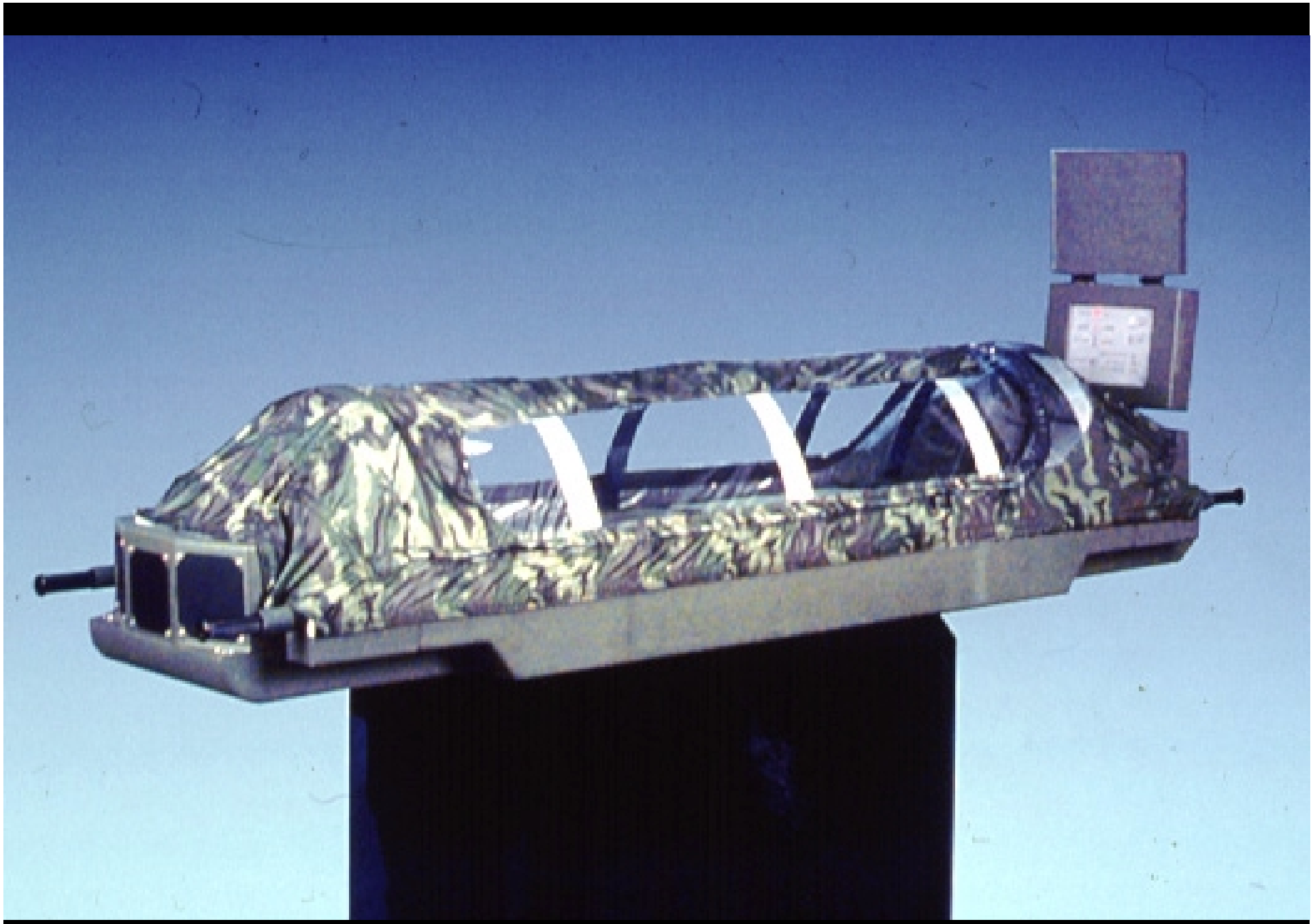
DARPA Advanced Biomedical Technologies Program, 1993-99



Advanced Battlefield Casualty Care Scenario

DARPA Advanced Biomedical Technologies Program, 1993-99

Personal Status Monitor (PSM) - Courtesy Steve Jacobsen, Sarcos, Inc 1996



Life Support for Trauma and Transport (LSTAT) Courtesy Matt Hanson, IMS, Inc, Pico Rivera, CA

Non-invasive Physiologic Monitoring (6.2)

Pneumothorax on the Battlefield: Improving the Ability of the Warrior Medic to Provide Triage and Care for the Combat Casualty	**Bentley (WRAIR)**
a. Use of the Impact Ventilator (Model 754) with the Ohmeda Portable Anesthesia Complete (PAC)b. Development of Compact Volatile Anesthetic Agent Monitors	**Calkins (WRAIR)**
Development of Microimplulse Radar for Non-Invasive, Vital Sign and Cardiac Output Monitoring	**Pearce (WRAIR)**
Development of Warrior Medic Therapeutic and Non-Invasive Physiologic Monitoring System (DATAPAK)	**Lee (WRAIR)**
Development of a Wounding Event Detection System for Land Warrior/Warrior Medic	**Van Albert (WRAIR)**
Electrocardiographic Assessment of Heart Rate Variability During Acute Hemorrhage in Humans	**Cancio (ISR)**
Evaluation of Lower Body Negative Pressure as a Surrogate Model of Hemorrhagic Schock	**Convertino (ISR)**

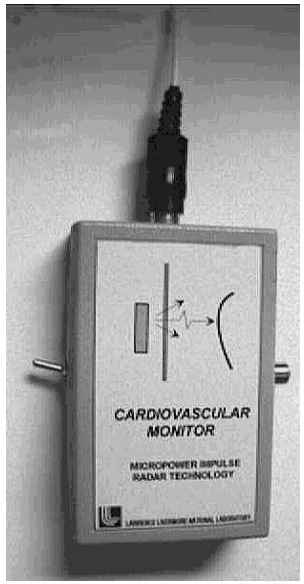
Field Diagnostic Device (6.2)

Micro-impulse Radar Vital Signs Monitor

- **Problem:** Due to the high acoustic noise and high vibration environments of the battlefield , traditional non-invasive vital sign and blood pressure measurement devices do not work well. A highly reliable and non-invasive alternative is required which is capable of continuous measurement which will allow a better assessment of stability and responsiveness to therapy. This information impacts both triage and evacuation decision making.
- **Approach:** Investigate range-gated and range finder versions of microimpulse radar for life signs detection
- **Development:** Collaborative development with Lawrence Livermore National Lab. Targeting hand-held for medic and body worn versions for LW. Coordinated with STO H, WPSM activity.
- **Results to Date:** Have demonstrated “through clothing” vital sign detection and improved HR detection in high vibration helicopter environment..
- **Future Plans:** Demonstrate sensitive life signs detection in all body types and position compared to manual pulse detection.

Other Potential Applications

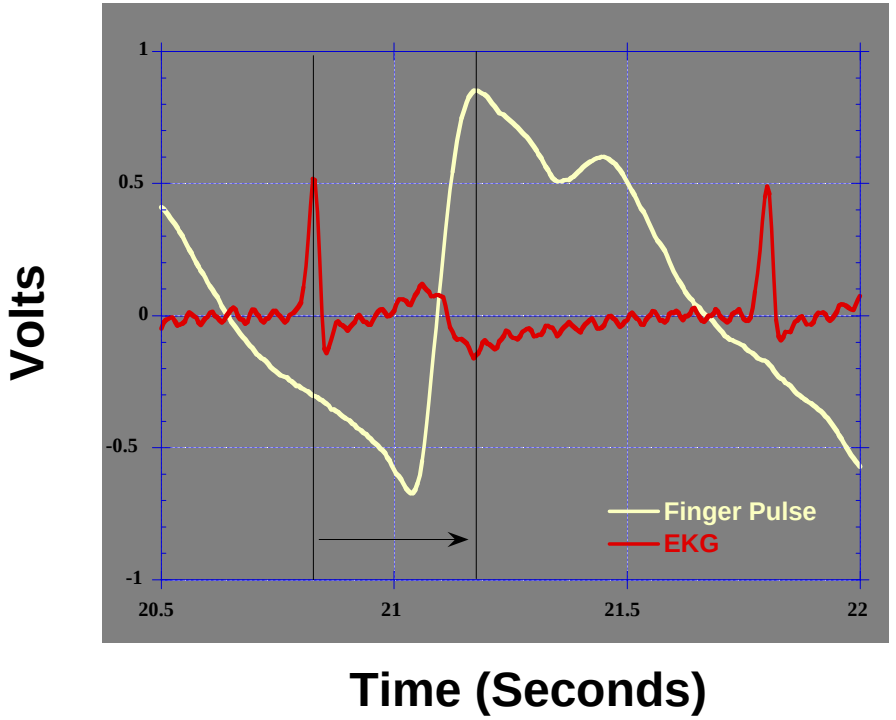
- Cardiac output
- Intra-abdominal fluid detection
- Subdural hematoma detection
- Pneumothorax detection
- Hemothorax detection
- Limb edema detection



Field Diagnostic Device

Physiologic Monitoring

- **Problem:** Develop cuffless blood pressure monitoring suitable for continuous assessment (5/min) and feedback control of fluid infusion
- **Approach:** Investigate the potential for using the pulse wave transmission technique to measure blood pressure down to 40 mm Hg
- **Development:** Intramural
- **Results to Date:**
- **Milestones:**



Medic Physiological Monitoring (DataPac)

(Non-DTO)

Physiologic Monitor

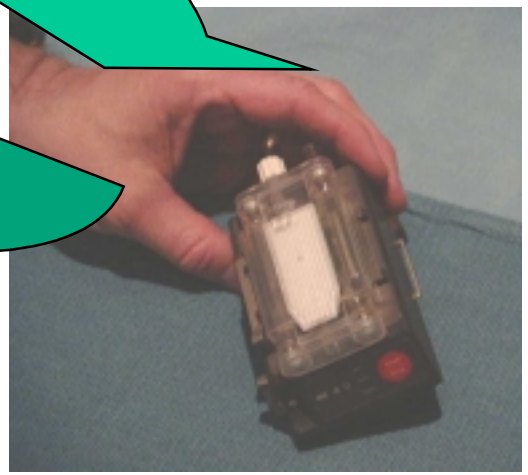
- Blood Pressure
- Pulse Oximetry
- Cardiac Output
- Core/Skin Temp.
- Heart Rate
- Respiratory Rate
- Circulatory Volume
- Pneumothorax detection
- CNS assessment
- Drive voltage to IV pump
- Data Logging
- Comms to WM Computer

Computer Assisted Resuscitation Algorithm CARA

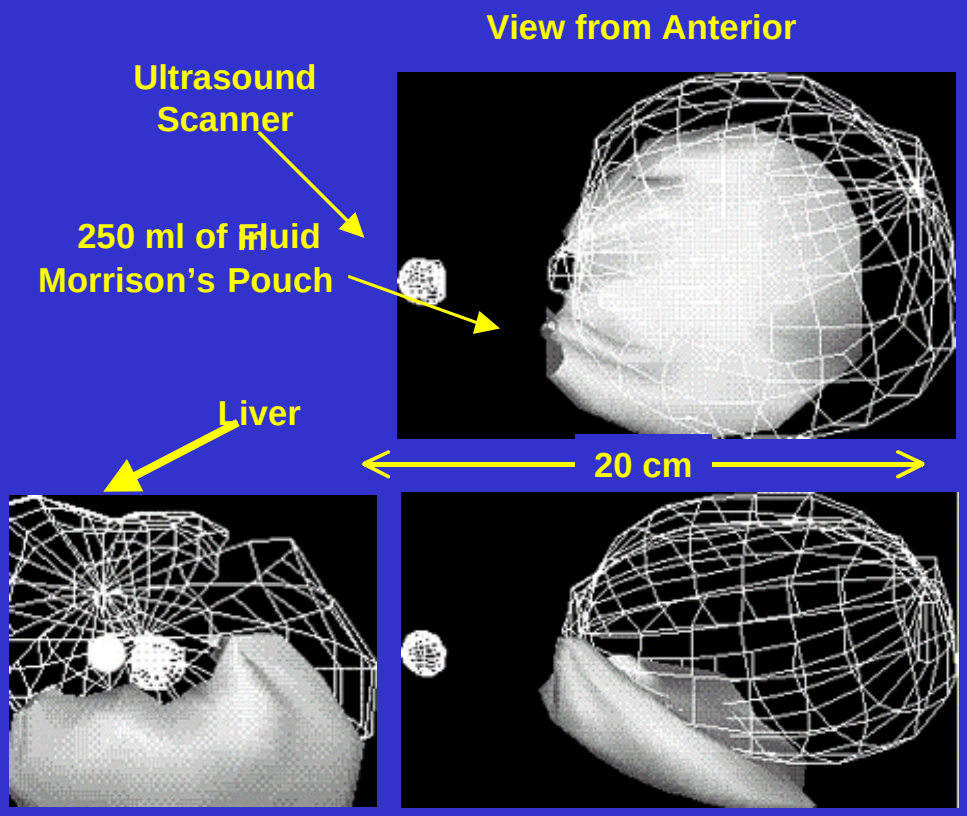
Resuscitation Pump

Max Flow Rate	**6 L/hr**
Weight	**243 g.**
Battery Life	**5 - 17 hrs. (continuous)**
Battery Shelf Life	**5+ years**

Servo-controllable using NIBP



Internal Bleeding Can Be Detected with Portable Diagnostic Ultrasound Scanners



Peritoneal fluid (surface rendered) and liver (wire frame) taken with a prototype palm-size 3-D ultrasound imager

Everest Extreme Expedtion (E^3)
Parameters Monitored

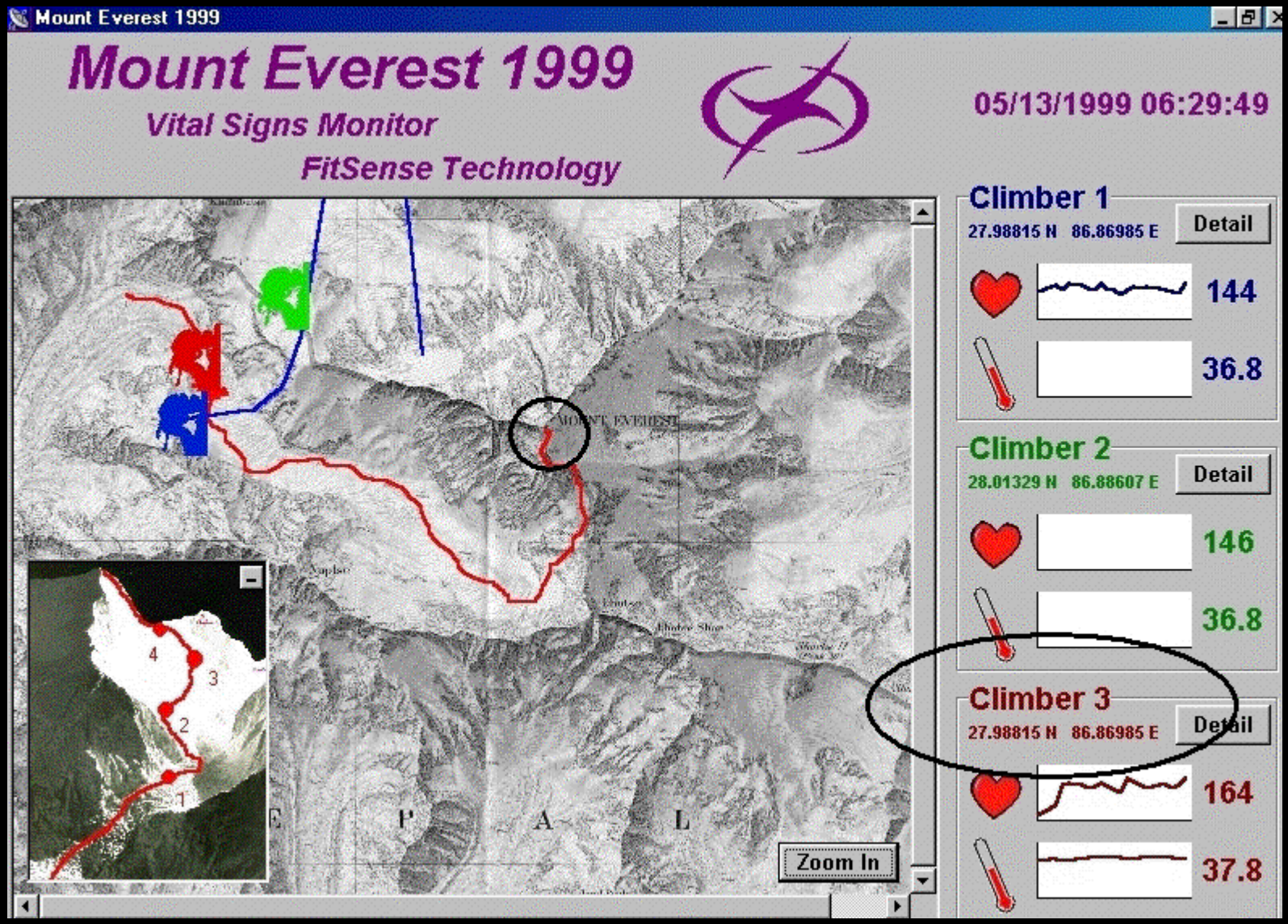
Parameter	Accuracy
Heart Rate	4 bpm
EKG	3 Lead
Activity	accelerometer
Skin Temp	0.01°C
Core Temp	0.04°C
GPS	0.75meters

Results - Vital Signs

Heart Rate	86-164 bpm
Skin Temp	22.1 - 34.3^{o}C
Core Temp	36.7 - 39.6^{o}C
Activity	11-64 pm

Skin temp	4-7^{o}C of Core body temp
Core temp	varied with drinking
Activity	not correlated

Terrain Display on Monitor

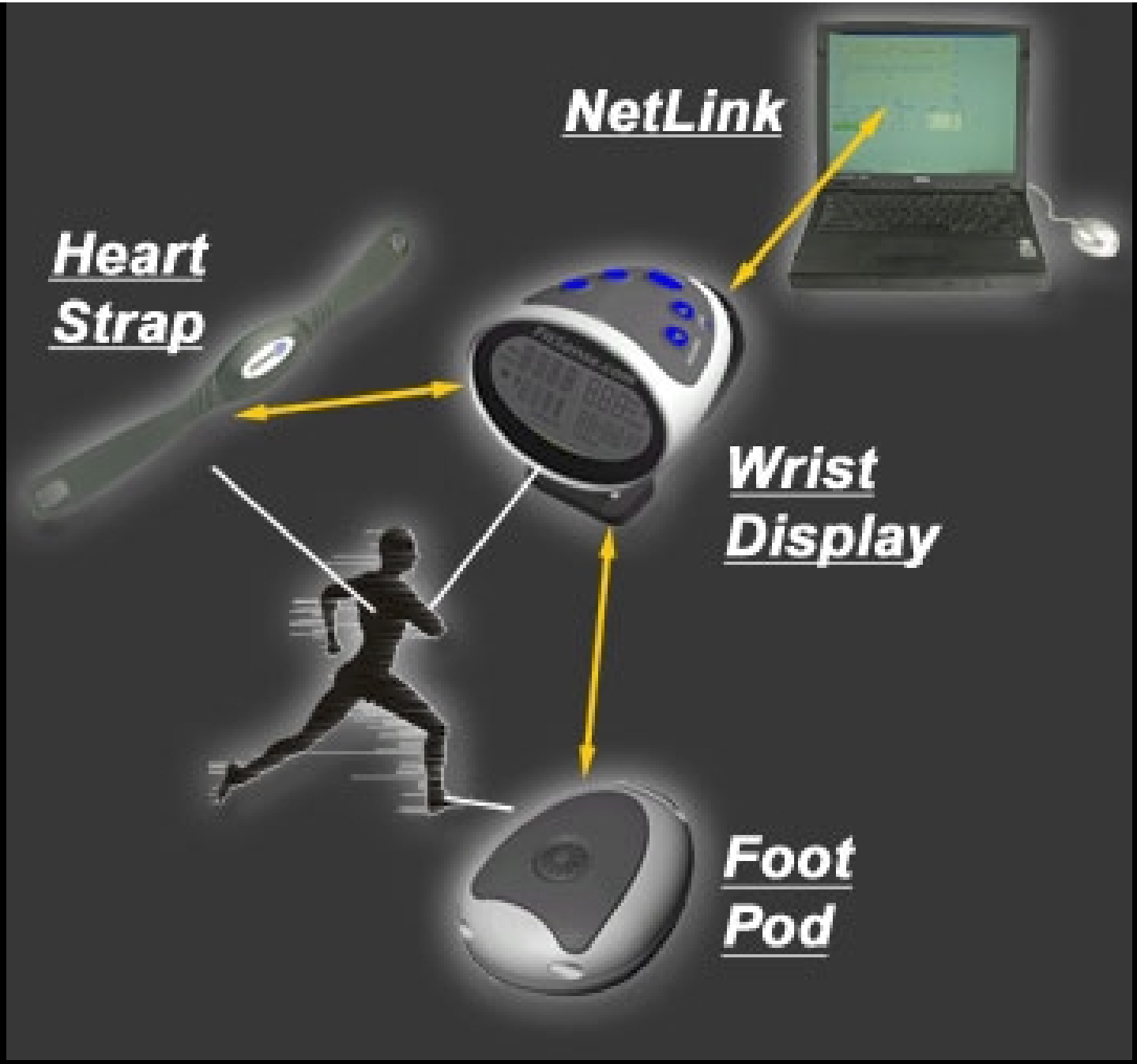


Courtesy Tom Blackadar, Fitsense Technologies, Boston, MA - 1999

Courtesy Tom Blackadar, Fitsense Technologies, Boston, MA - 1999

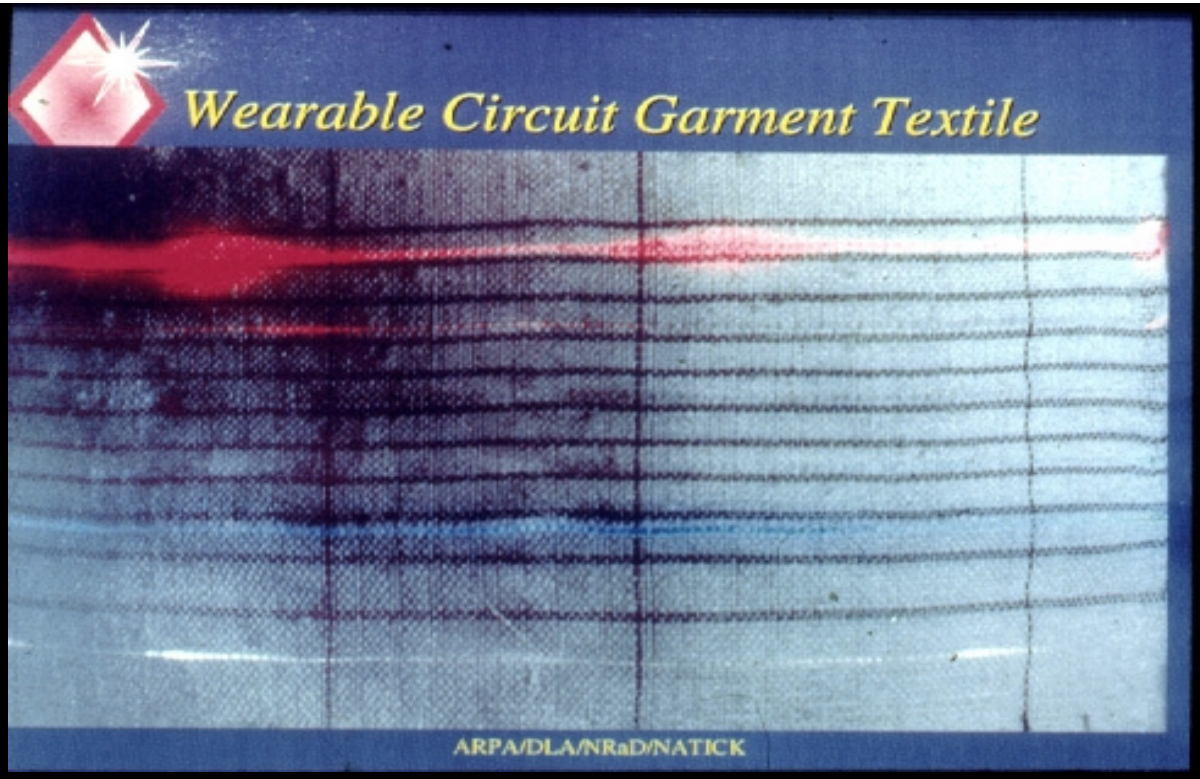
Typical Data From Vital Signs Monitors

Data ID #	Time (GMT)	Latitude	Longtitude	Heart Rate	Activity	Skin Temp	Core Temp
3380	23:22:43	28.00658	86.86138	96	16	22.11	37.36
3381	23:35:47	28.00725	86.86089	84	27	24.11	37.12
3382	23:40:35	28.00704	86.86126	84	48	25.16	37.27
3383	23:45:47	28.00716	86.85998	148	44	25.85	37.95
3384	23:50:47	28.00625	86.86282	128	36	26.55	37.67
3385	0:00:01	-37.3914	122.0376	128	37	27.68	37.61
3386	0:00:01	26.63363	29.78837	124	48	29.7	37.53
3387	0:05:47	28.00522	86.86506	100	18	31.19	37.45
3388	0:10:47	28.0039	86.86366	160	44	31.71	37.36
3389	0:15:47	28.00399	86.86554	168	49	32.36	37.53
3390	0:20:47	28.00293	86.86737	172	38	32.86	37.8
3391	0:25:47	28.00216	86.86763	172	30	33.05	37.95
3392	0:30:47	28.00199	86.86862	176	37	33.18	38.13
3393	0:35:47	28.00154	86.86896	172	35	33.25	38.21
3394	0:40:47	28.00136	86.86934	180	38	33.34	38.23
3395	0:45:47	28.00012	86.87052	176	32	33.16	38.26
3396	0:50:47	27.9993	86.8708	172	26	33.16	38.23
3397	0:55:47	27.99964	86.87203	172	31	33.13	38.26
3398	1:00:41	27.99952	86.87135	172	26	33.01	38.26
3399	1:05:46	27.99786	86.87095	172	31	32.94	38.15
3400	1:10:46	27.99752	86.87148	168	26	32.96	38.08
3401	1:15:47	27.99665	86.87207	156	37	32.74	38.02
3402	1:20:47	27.99625	86.87303	164	29	32.64	38.06
3403	1:25:47	27.99513	86.87352	168	33	32.46	38.26
3404	1:30:45	27.99513	86.87316	168	35	32.28	38.04
3405	1:35:44	27.9941	86.87302	152	32	31.93	38.08



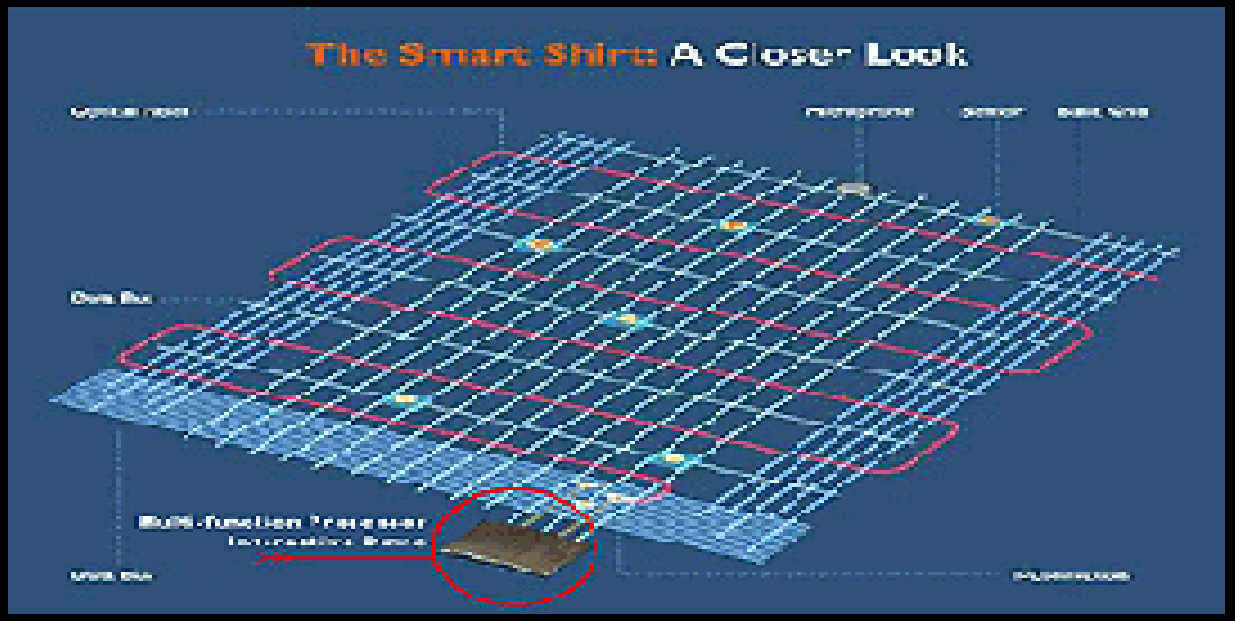
Courtesy Tom Blackadar, Fitsense Technlogies, Boston, MA

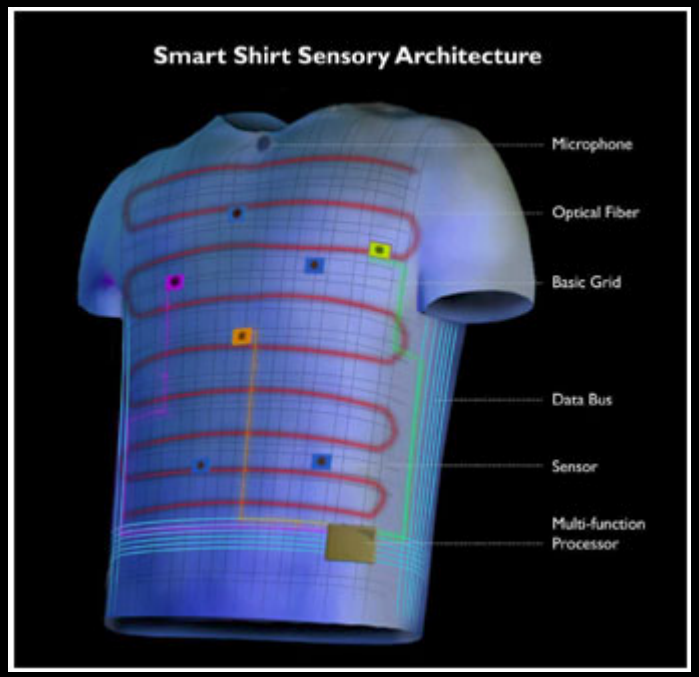
Smart Tee-Shirt

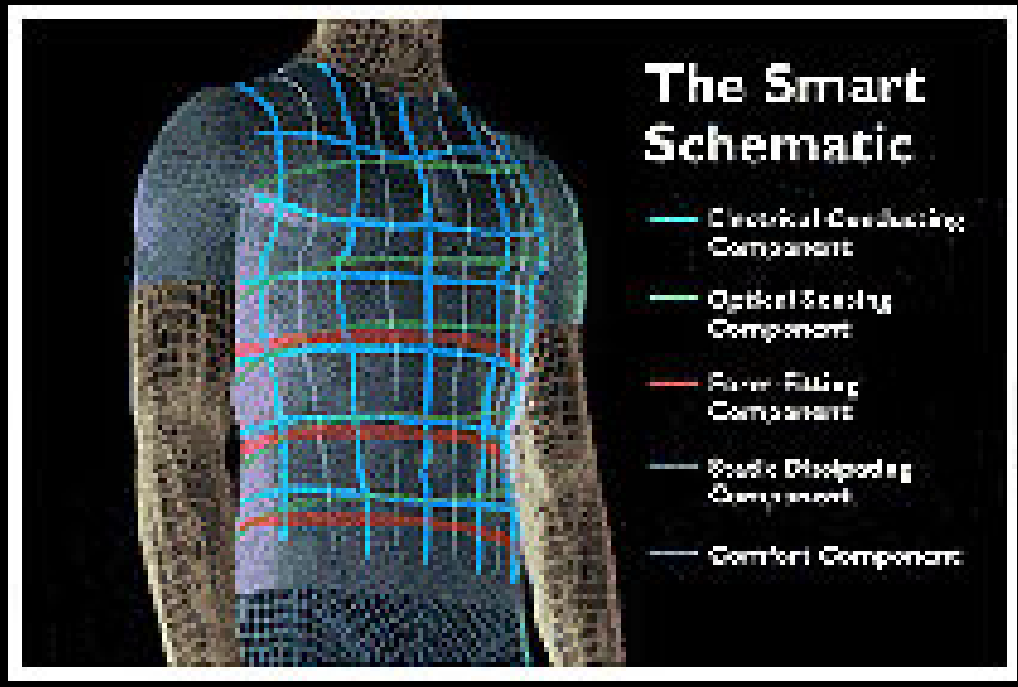


Courtesy Sundaresan Jayaraman, Georgia Tech - 1996

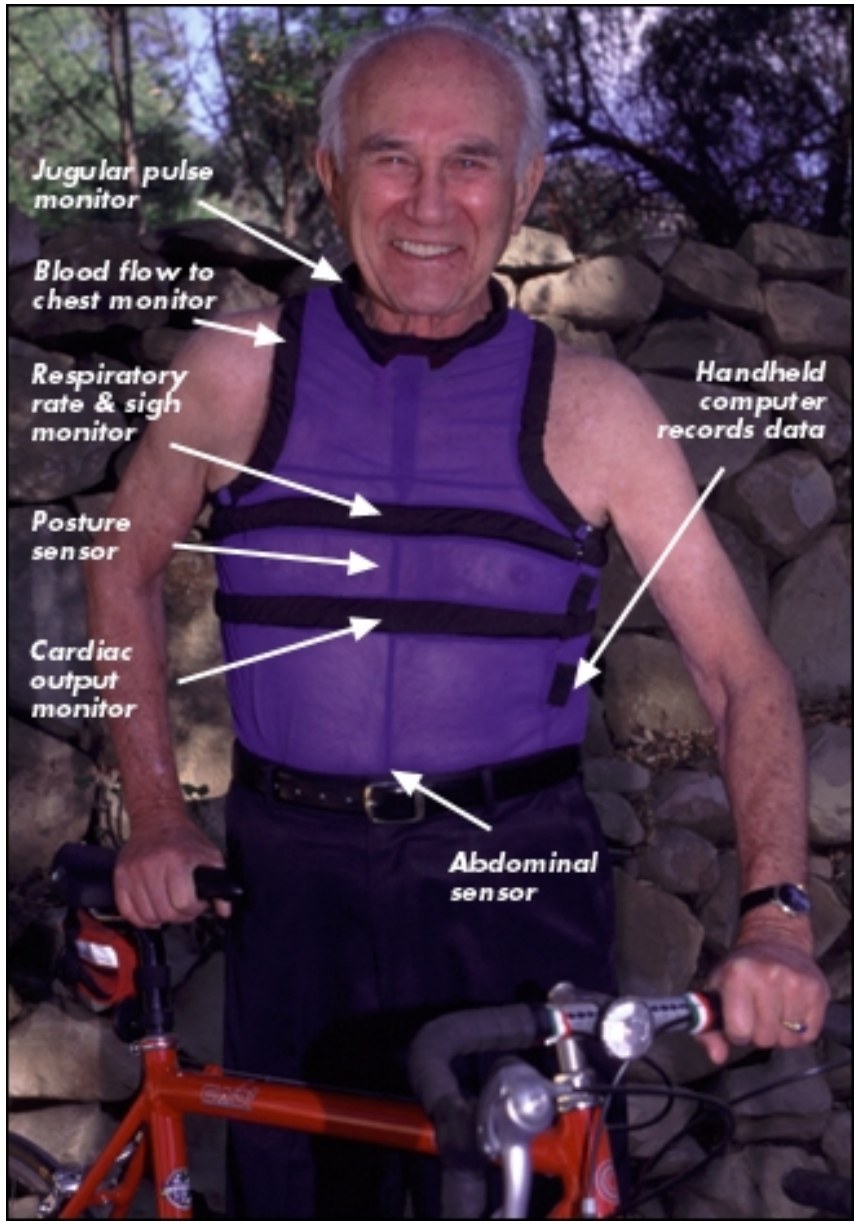
Smart Tee-Shirt







Courtesy Sensatex Technologies, New York, NY



The LifeShirt System

- a comfortable garment that can be worn under normal clothing.
- automatically and continuously monitors over 40 physical signs.
- data are stored on Handspring PDA for daily upload to LifeShirt.com's website.
- patients may enter their symptoms, mood, and activities on PDA and get medication alerts.

Courtesy Paul Kennedy, VivoMetrics, Inc., Ojai, CA

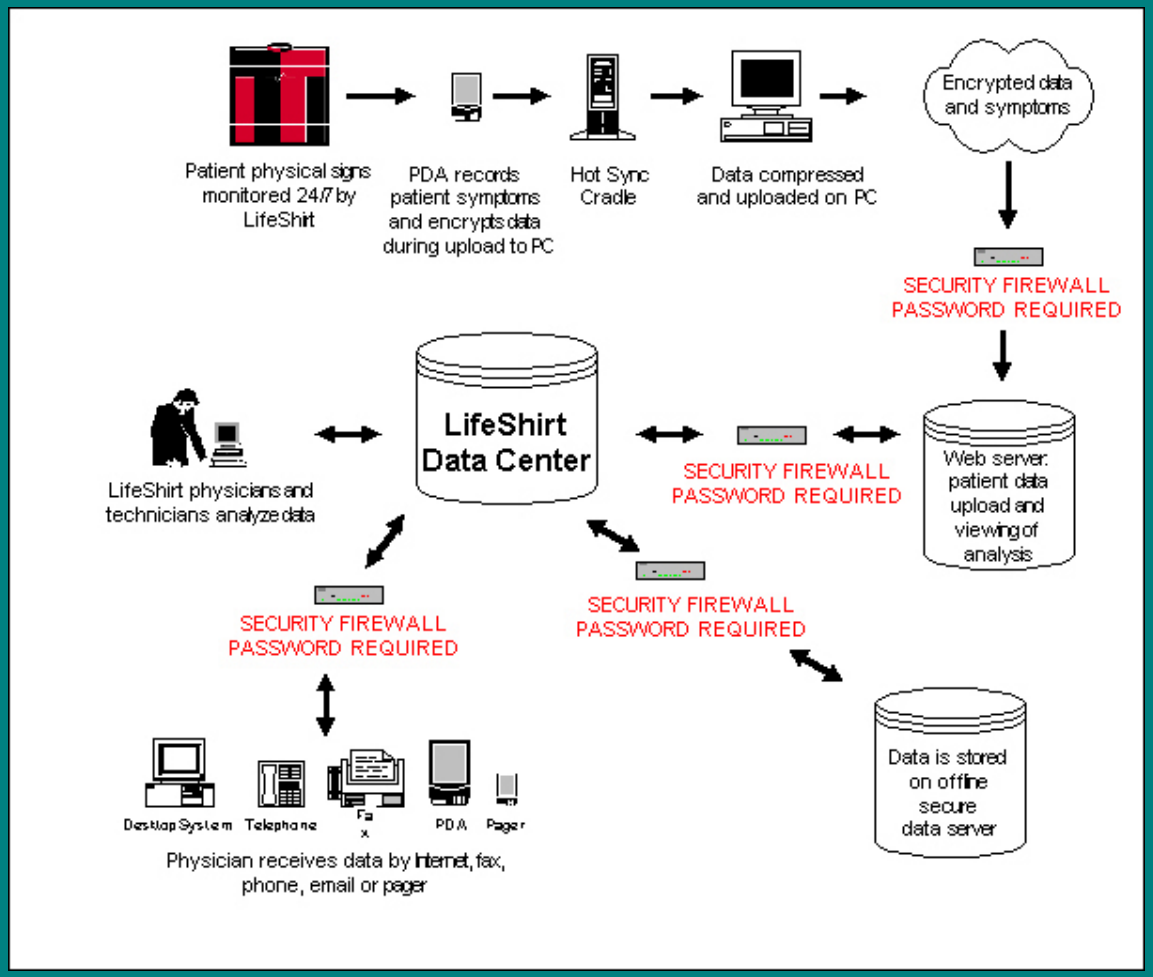
Over 40 Physical Signs

- Respiratory rate
- Tidal volume
- Ventilation
- Sigh count
- Peak inspiratory flow
- Ventilation/peak inspiratory flow
- Peak inspiratory flow/mean inspiratory flow
- Peak expiratory flow/mean expiratory flow
- Phase relation
- %RC/Vt
- Apnea/hypopnea detection
- Apnea/hypopnea classification
- MPer
- Changes of VtFRC
- Peak expiratory flow
- Volume expired in one sec
- Right minus left hemithoracic tidal volume

▪Right versus left hemithoracic phase relation
•Respiratory efforts
•Pre-ejection period/Left ventricular ejection time (PEP/LVET)
•Central venous pressure
•Jugular venous pulse trace
•Swallow counts
•Pulse wave transit time
•Amplitude of cardiac pulsation
•Amplitude of cardiac pulsation times heart rate
•PEP/LVET
•Deceleration time from mathematical derivative cardiac pulsation
•Heart rate
•Arrhythmias
•Respiratory sinus arrhythmia
•Counts method (sNN50)
•Arterial oxygen saturation
•Arterial pulse wave

LIFESHIRT•COM
vital signs online

The Data Flow



Courtesy Paul Kennedy, VivoMetrics, Inc., Ojai, CA

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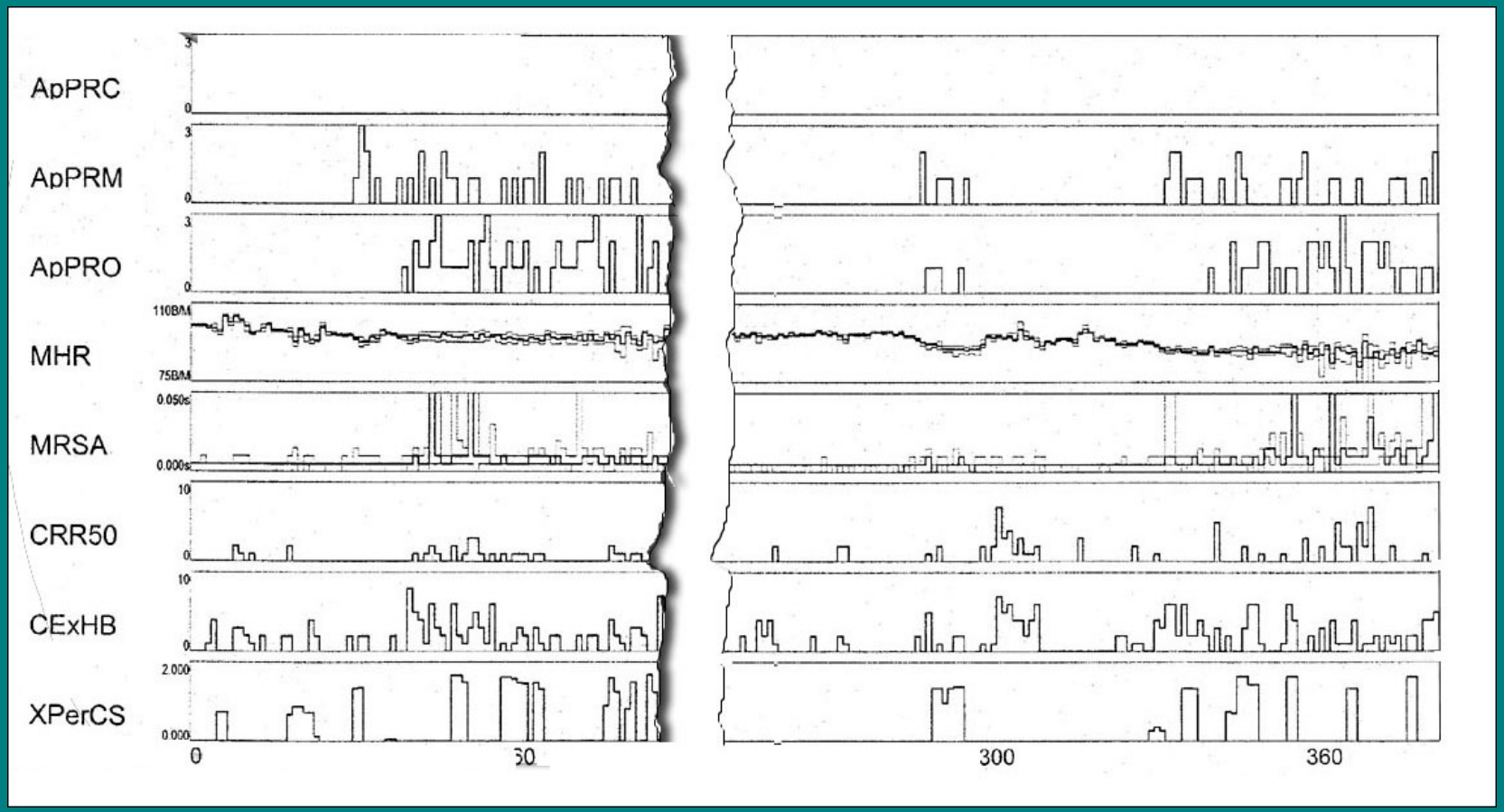
vital signs online

Sample LifeShirt Report

Graphical Components--B



Courtesy Paul Kennedy, VivoMetrics, Inc., Ojai, CA

Thoracocardiograph

Systolic Function

29) Amplitude of ventricular volume trace Equivalent to stroke volume (SV) but reflects changes from baseline not absolute values since it cannot be independently calibrated to volume

30) Amplitude of ventricular volume trace times heart rate Equivalent to cardiac output but reflects changes from baseline not absolute values since it cannot be independently calibrated to volume

31) PEP Reflects myocardial contractility, with lower values consistent with good contractility and high values poor contractility

32) 1st 1/3 ejection/SV Measure of systolic function; higher the value, the better the function

Diastolic Function

33) E/A ratio Peak of **E**arly rapid filling of ventricle wave divided by peak of filling of ventricle wave from **A**trial contraction. High values consistent with restrictive myocardopathy as well as elevated pulmonary capillary wedge pressure; low values consistent with low pulmonary capillary wedge pressures; E/A ratio is highly specific but not sensitive

Electrocardiogram

38) Heart rate Sensitive but non-specific sign of cardiac function

39) ECG waveform Needed to interpret cardiac arrhythmias; in some instances, requires addition of jugular venous pulse to distinguish atrial contraction to diagnose type of tachyarrhythmia

40) Respiratory sinus arrhythmia Instantaneous heart rates timed with Respitrace® inspiratory and expiratory tidal volumes; direct correlates with parasympathetic nervous system activity; low values reflect emotional stress

41) Counts method (sNN50) Counts # RR intervals of ECG where successive beats exceed 50 msec; low values consistent with impaired parasympathetic nervous system activity

Posture and Activity

42) Posture Two, dual axes accelerometers, one over sternum and other on lateral aspect of upper thigh give indications of standing, sitting, supine, prone, and lateral decubitus

43) Activity Two, dual axes accelerometers, one over sternum and the other on lateral aspect of upper thigh indicate activity through measurement of accelerations during walking and running.

Pulse Oximeter (option during sleep)

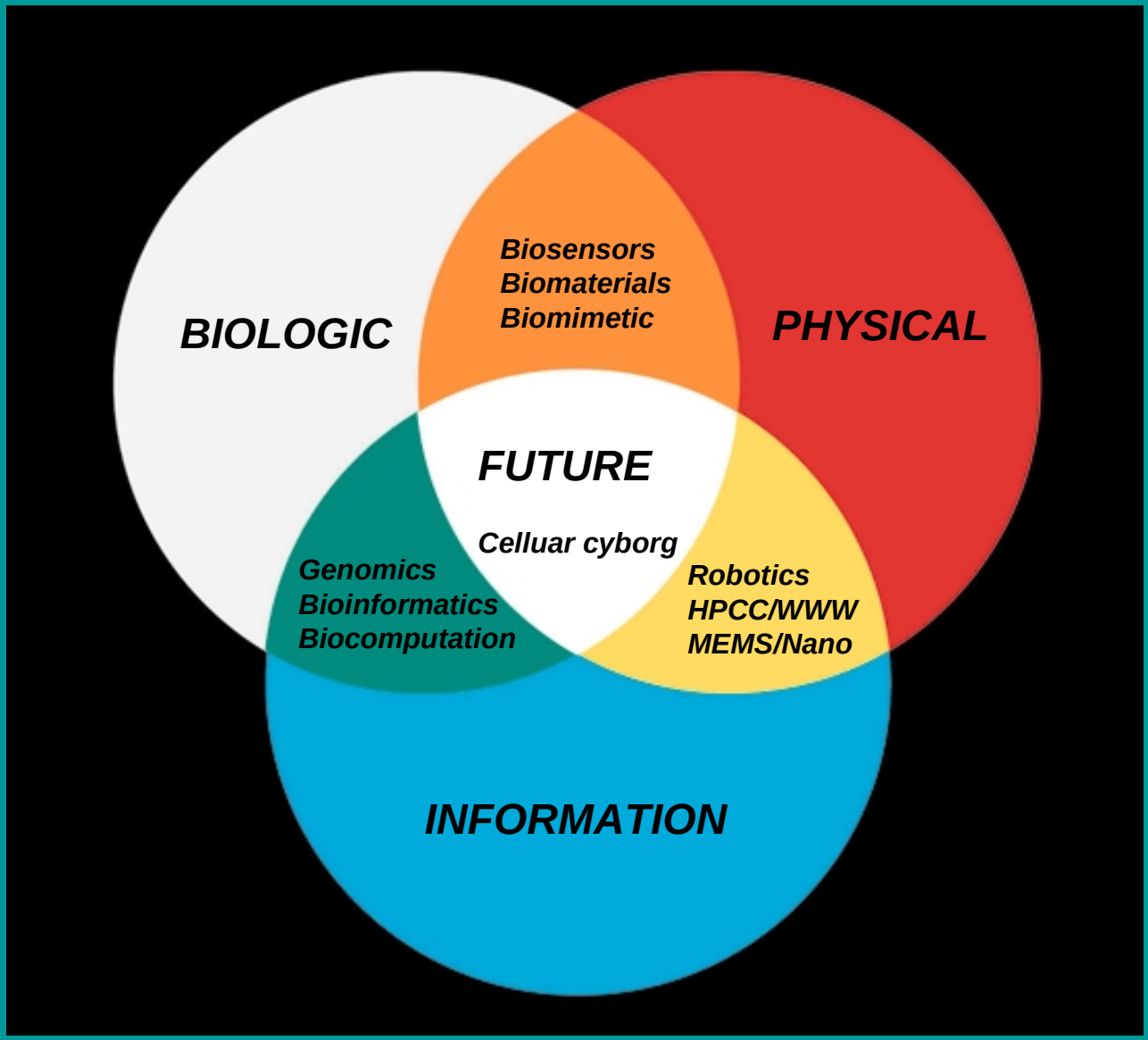
44) Arterial oxygen saturation Assesses amount of oxygen in arterial blood & is component of sleep study

45) Arterial pulse wave Validates accuracy of arterial oxygen saturation reading values by measurement of pulse upstroke time

46) Pulse bad indicator Artifactual pulse as indicated from upstroke times outside of normal range; also serves as a movement indicator for wake state

47) Pulse transit time Time from R wave to pulse oximeter wave upstroke; brief transient decreases signify microarousals from sleep because pulse transit time decreases with elevation of blood pressure

BIO INTELLIGENCE AGE



Satava 2 Feb 1999

DARPA: The 7 Focus Areas

1 Modeling of Biologic behavior (Virtual Human)

2 Biological Computers (DNA, cells)

3 The Language of Biology (decoding genes)

4 Interfacing biotic to abiotic world (cellular cyborg)

5 Mimicking the brain (molecules to cognition)

6 Biology on the move (how biology creates work)

7 Biomaterials (unique properties, self assembly)

DARPA Controlled Biological Systems Program

Animats **Machine** **Living** **Animals**

Biomimetic Systems

- Integration of biological design for sensorimotor function
  - neural control architecture
  - biomechanical self-stabilization
  - sensor/performance
- Autonomous navigation
- Modular design/fabrication of fault tolerant mobile sensor platforms

Biohybrid Organisms

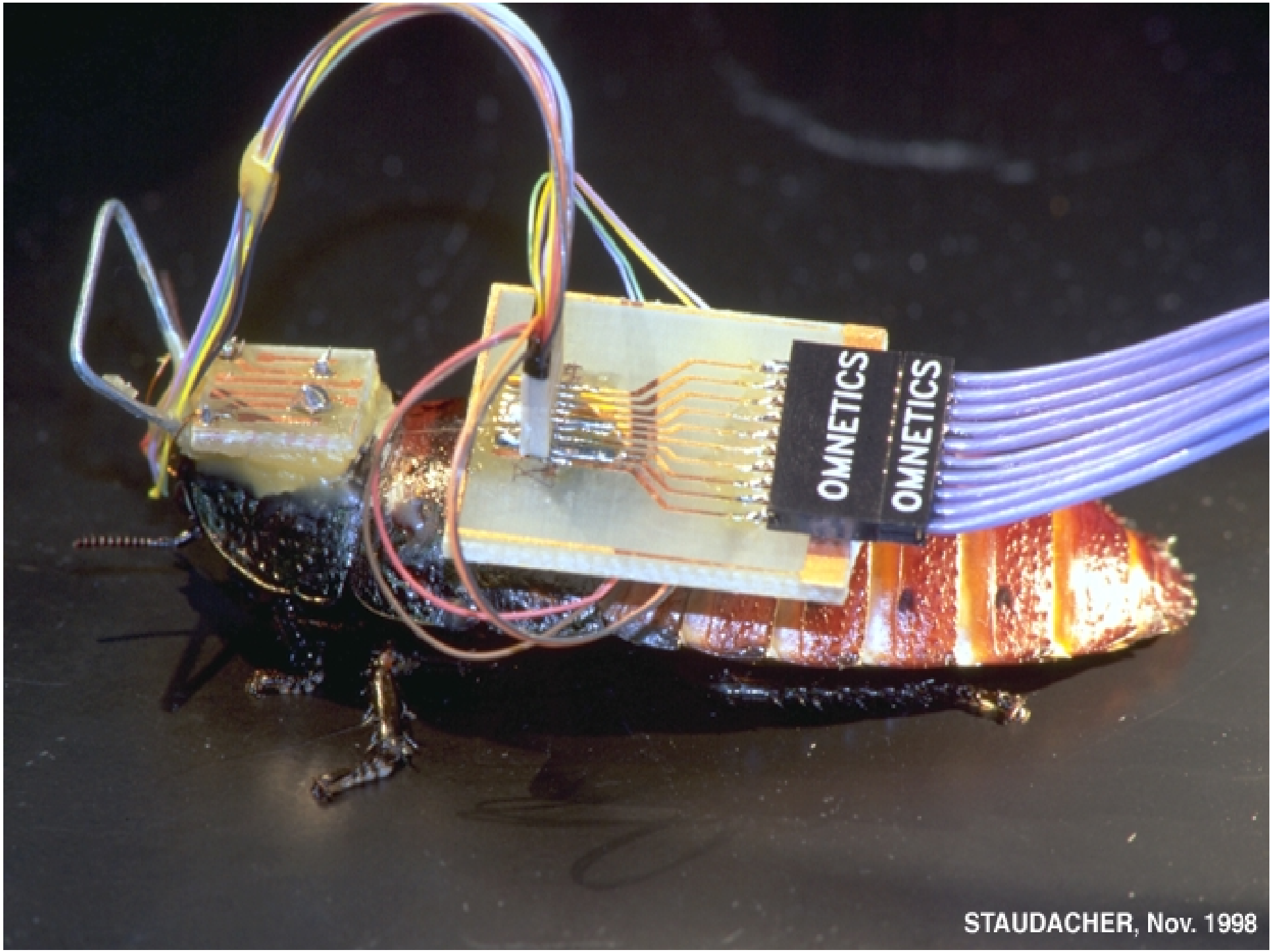
- New interfaces for measuring neural-muscular outputs sensorimotor control in freely moving/sensing behaving biological systems
- Stimulation of neural and muscular systems to influence sensorimotor function
- Inexpensive attachment of sensors (chem/bio)

Biological Systems

- Pheremone control of sensorimotor output - plume tracing
- Plasticity of associative learning to threats of interest (conditioned training)
- Investigate behavior with sensor motor architecture

Courtesy Alan Rudolph, Program Manager, 1999

University of Montana, 1999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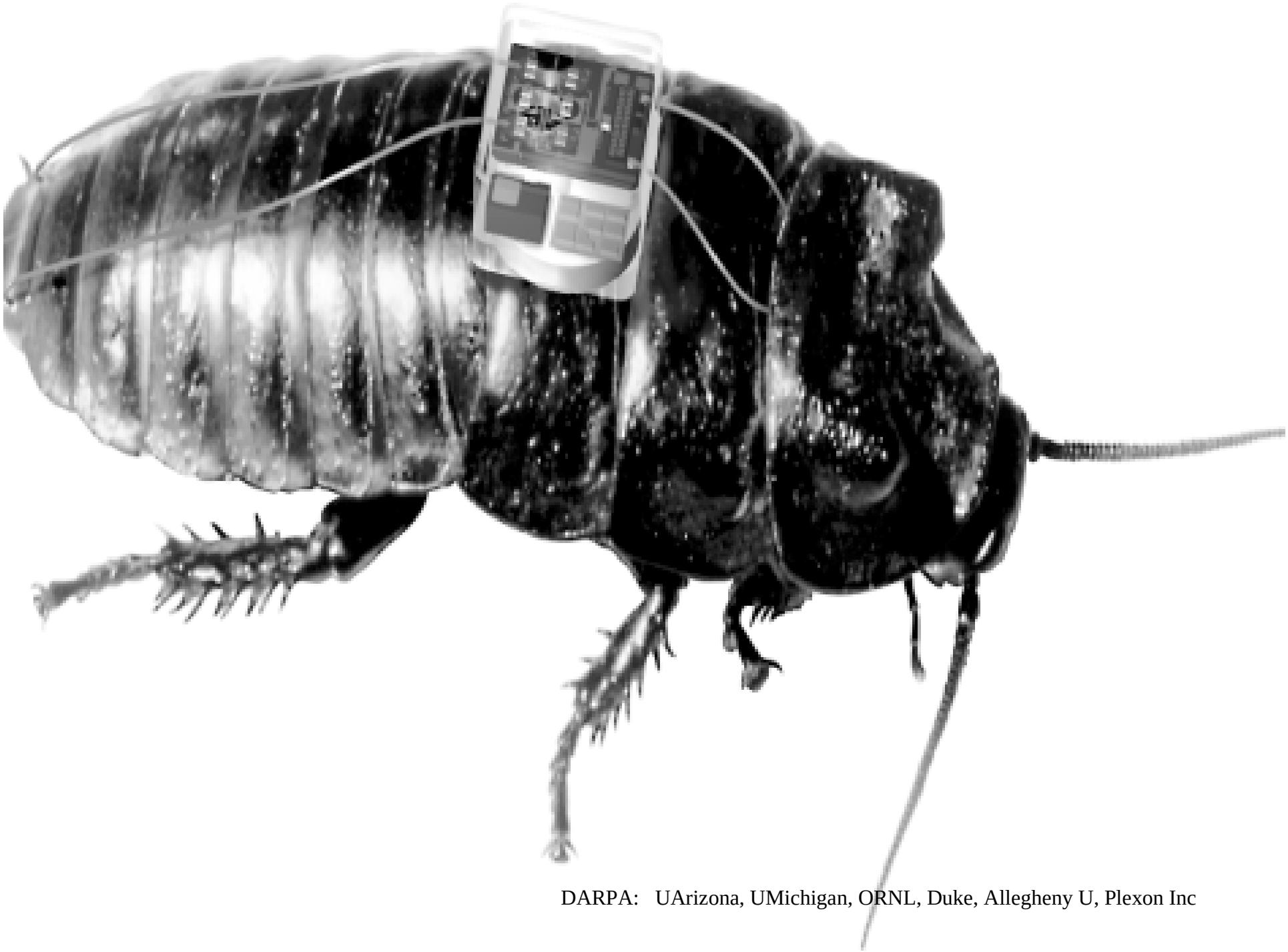
OMNETICS
STAUDACHER, Nov. 1998



DARPA: UArizona, UMichigan, ORNL, Duke, Allegheny U, Plexon Inc

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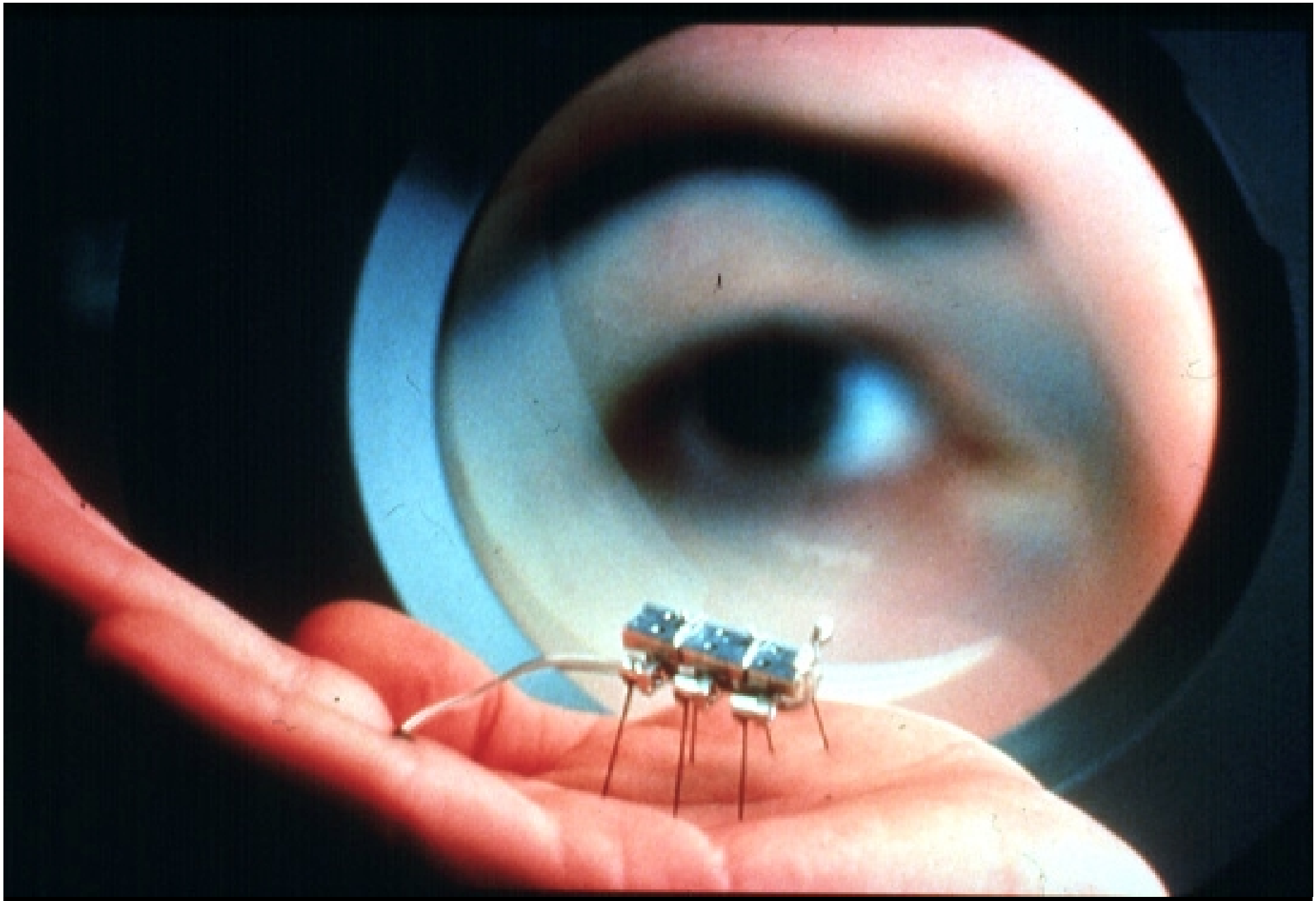
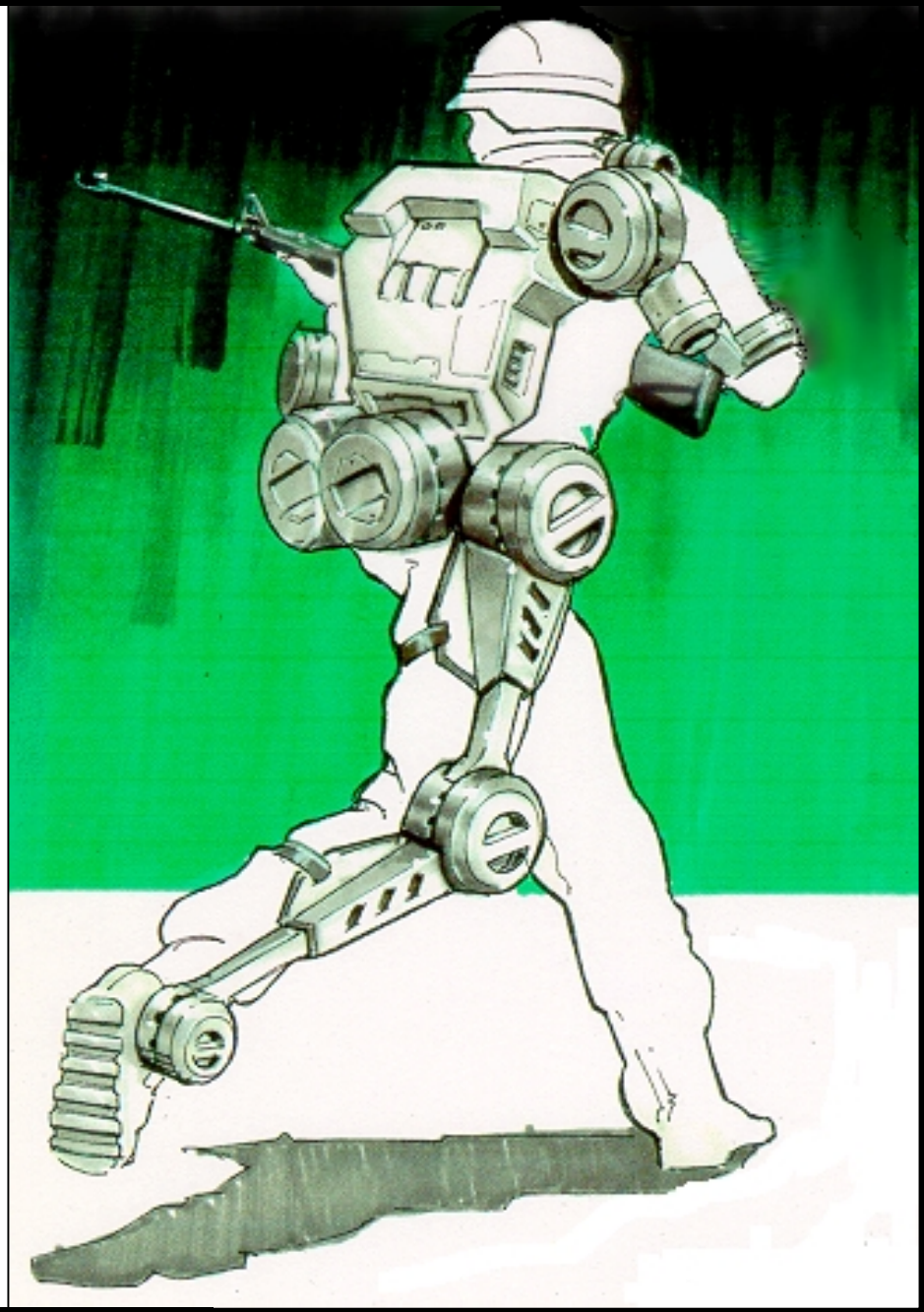


Micro-robot with micro-video Anita Flynn, MIT 1994

Biomimetic Micro-robot

Courtesy Sandia National Labs



E Garcia DARPA Jan, 2000

The 5 P's
of the
Future of Soldier Health Support

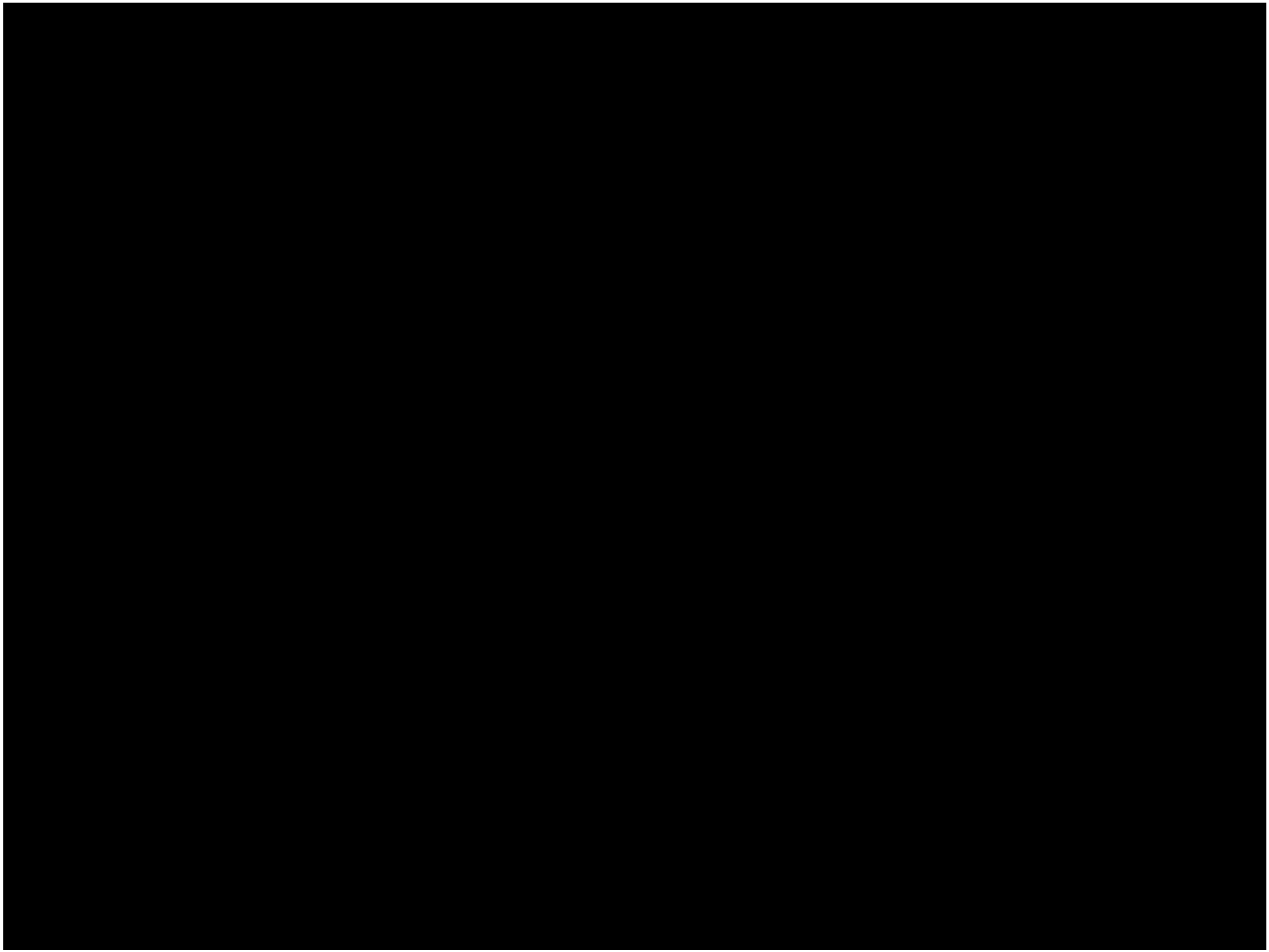
Predictive - Genetics, allergies, specific medications

Preventive - Acting proactively with preventive medicine

Point of care - Mobile communications & ubiquitous computing
Local intelligence

Parametric - Multiple parameters, over time, referenced to patient's own baseline, compared to standard model

Personalized - Individual treatment for each patient



PSM needs for monitoring

Thermal
Hydration
Fatigue
Physiologic status