Overview of Cognitive Science and Technology
Sandia National Laboratories

Dr. Chris Forsythe

Distinguished Member Technical Staff

Cognitive and Exploratory Systems and Simulation

Sandia National Laboratories

jcforsy@sandia.gov

Where human-machine systems are today

- **Basic science of human performance > human factors engineering guidelines**

- **Design processes and methods for testing and evaluation**

- **User modeling/profiling, is it a convenience or a threat?**

- **Advanced interface technologies filling their respective niches, eg Virtual Reality**

The current path promises many years of <u>incremental</u> improvement in human-computer interaction

People are drowning in data

Only 1.6 x 10⁻⁹ of data bombarding the operator used in real time!

Source: Steinbuck, 1962

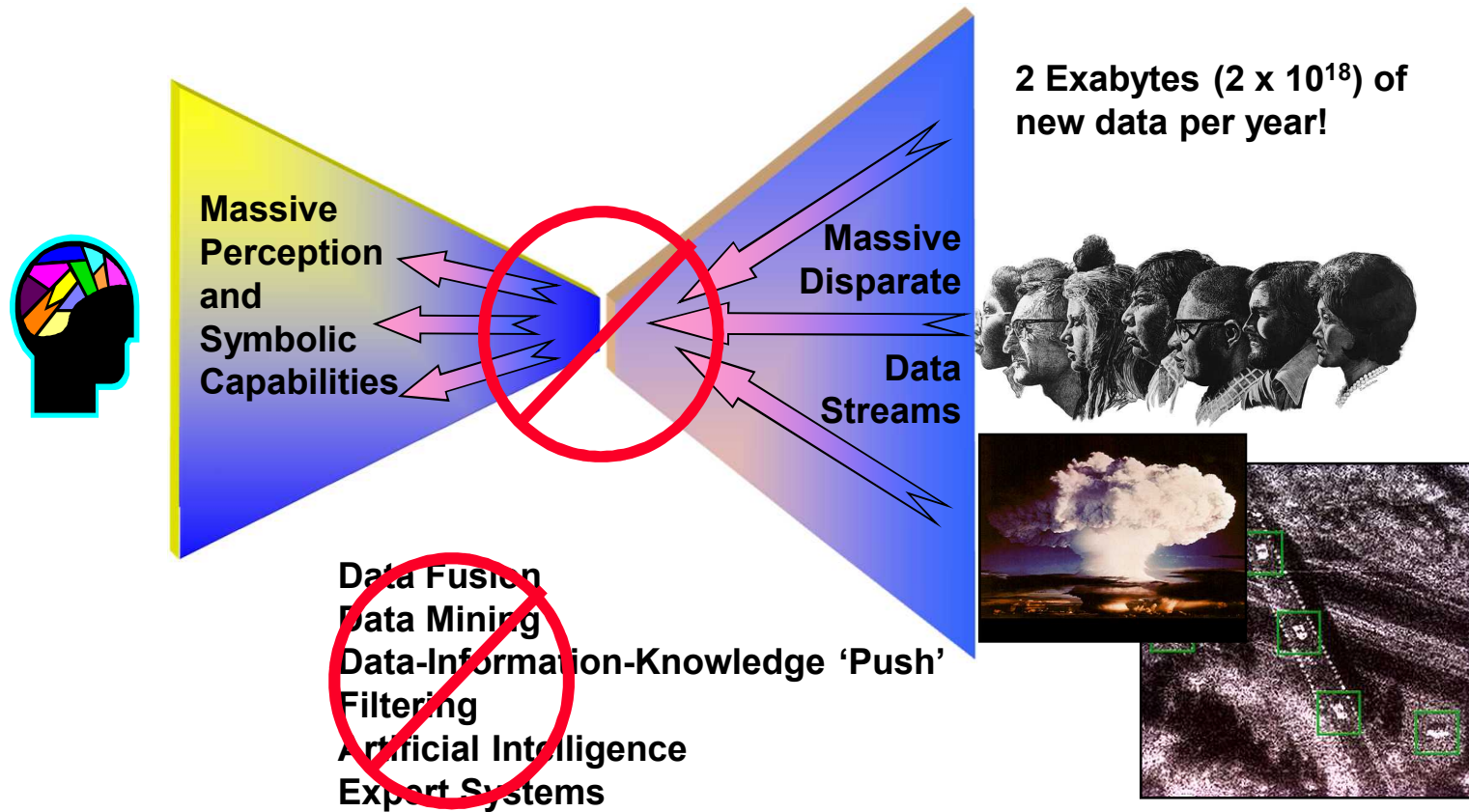## Estimates of Human Processing Capabilities
Filtering Algorithms

Process	Flow (Bits/Sec)	% Filtered	% Orig. Filtered
Sensory	1 Billion		--
Neural Coding	3 Million	0.003	--
Cognitive	16	0.000005	.0000000016
To Perm. Store	0.7	0.04	.0000000014

- A TV quality movie every second → Sensory
- A high resolution photo every second → Neural Coding
- Two words every second → Cognitive
- One character every second → To Perm. Store

Total volume of information generated worldwide annually = 2 Exabytes
Exabyte [1,000,000,000,000,000,000 bytes OR 10^{18} bytes]

Sources: *Lyman and Varian, How Much Information?, 2000; and Schmorrow, Augmented Cognition, 2000.*

More of the same has not worked

Massive Perception and Symbolic Capabilities

Massive Disparate

Data Streams

2 Exabytes (2×10^{18}) of new data per year!

Data Fusion
Data Mining
Data-Information-Knowledge 'Push'
Filtering
Artificial Intelligence
Expert Systems

**The technology meant to solve the problem has made the problem worse
-- human strengths have been disabled!**

Fundamentally rethink the human-machine interface
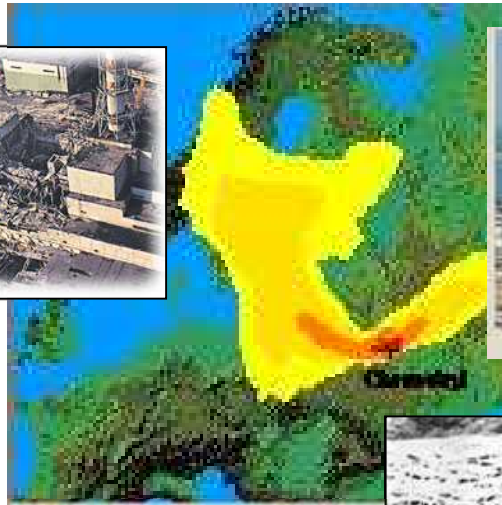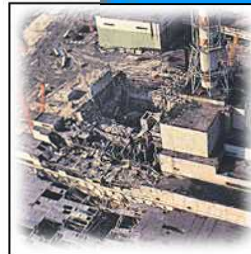
NOT redesign Human-Machine Interfaces, yet again

Nuclear Station at Chernobyl, Ukraine

Three Mile Island nuclear accident

HOMELESS AND HUNGRY... Please Help.

STOP RAISING INTEREST RATES

JOBS

ENRON

The challenge is to learn to swim in a sea of information

5

Cognitive systems offer the needed paradigm shift

- Embed within machines **individualized** computer models of cognitive processes vital to human communication, cooperation and collaboration.

- Provide software that **acquires accurate models of an individual's knowledge** of a domain or task by observing their day-to-day system interactions.

- **Create systems that interact with users in a knowing cognitive manner:**

    (1) know what you know, what you don't know, what you do, how you do it,

    (2) can place current events in the context of past experiences and

    (3) make readily accessible the knowledge and experience of diverse experts.

Transform the human-machine interaction to become more like an interaction between two cognitive entities

The Neuro/Cognitive Revolution is upon us and it will be disruptive

- Digital Revolution
   Maturing – probably another 10 years of progress
   Biggest impacts are being realized right now
   - A few still to come – medicine, security, governance

- Bio Revolution – early stages
   Beginning to realize some impacts
   Biggest impacts are 10-30 years out

- NanoTech Revolution – early stages
   Realizing some impacts in nano-materials and simple devices
   Biggest impacts are 15-20 years out

- Neuro/Cognitive Revolution – very early stages
   First impacts are in demo/test now
   Significant impacts in less than 10 years [large capital investment not required]
   Biggest impacts yet unknown

- Multi-disciplinary Revolution
   Will happen in parallel to the others
   Will be the source of greatest impact

From "Neuro and Cognitive Futures" by Michael Swetnam, CEO & Chairman Potomac Institute for Policy Studies

Changes are on the horizon that will make the paradigm shift brought about by the GUI seem modest in comparison

Cognitive Science and Technology has been targeted as core competency of Sandia

June 2005, Cognitive Science and Technology (CS&T) become a Technology Focus Area, deserving sustained investment and support.
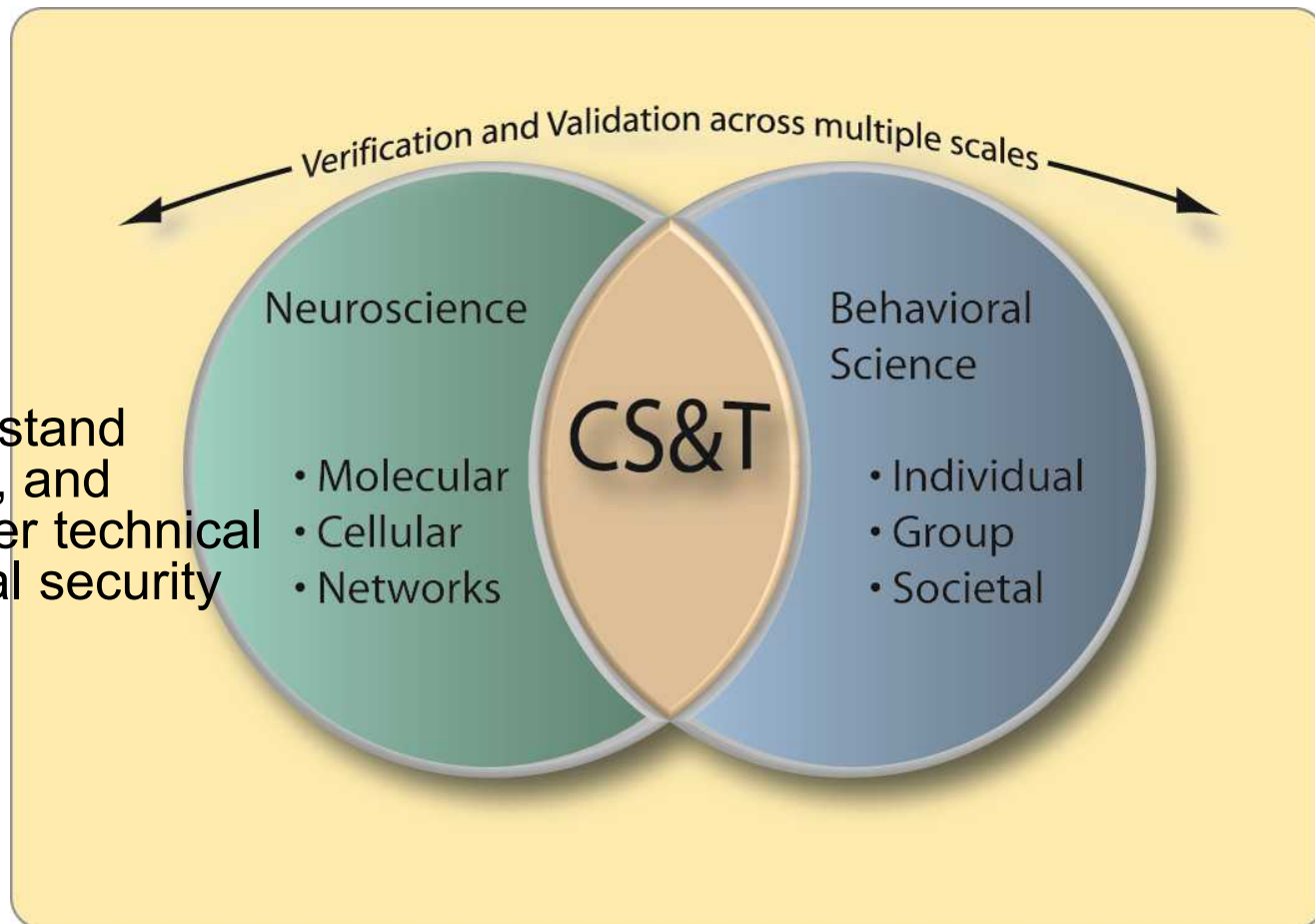
CS&T exists at the Intersection of Neuroscience and Behavioral Science

CS&T vision

Scientifically understand human brain, mind, and behavior to engineer technical solutions to national security problems


Verification and Validation across multiple scales

Neuroscience
- Molecular
- Cellular
- Networks

CS&T

Behavioral Science
- Individual
- Group
- Societal

CS&T's breadth is intended to bridge traditionally isolated disciplines across scales to drive innovation

Cognitive framework and automated knowledge capture provide basis for integrated products

Cognitive Framework
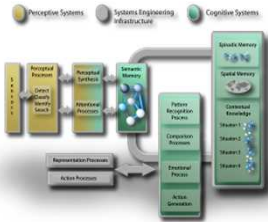
Generic cognitive engine employed with each product

Automated Knowledge Capture

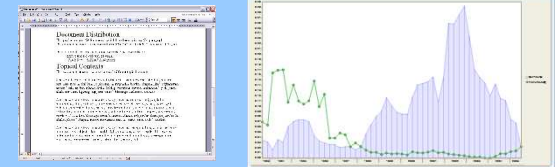**Text Sources**
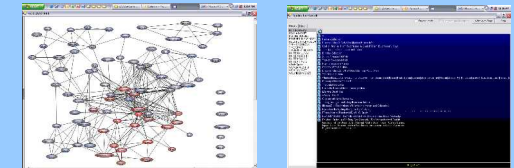
Machine Transactions

Spatial Domains

Acquire model of individual through observation of everyday activities

CS Products

Understand the Model
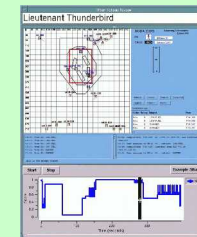
Use the Model

Dynamic Adaptation

Automated After Action Review

Simulation Human Behavior
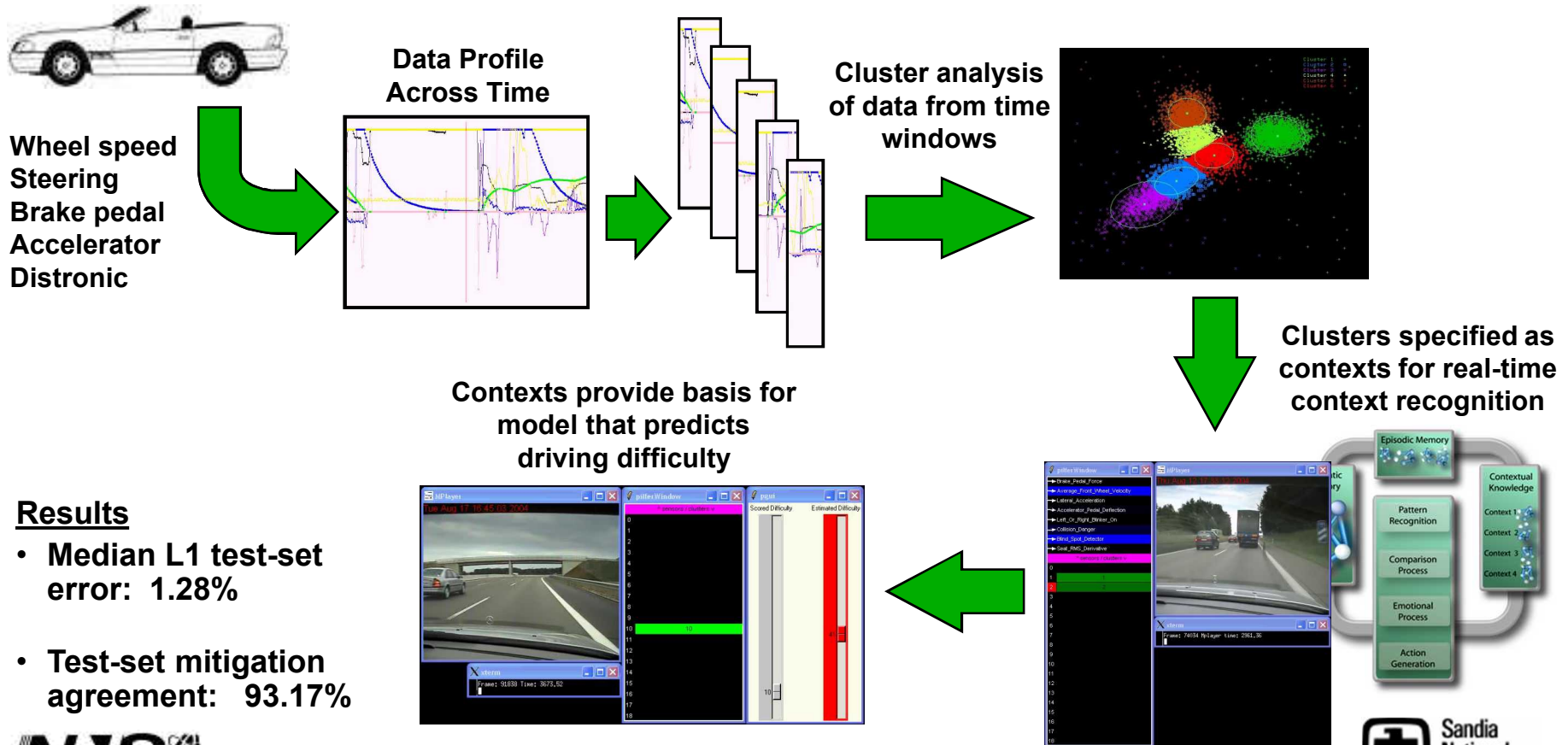
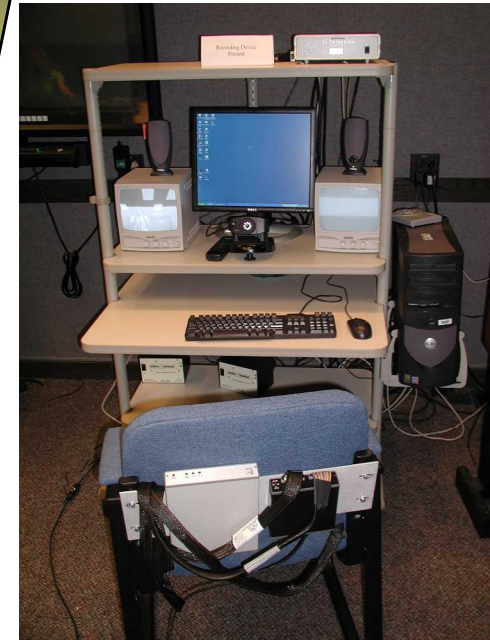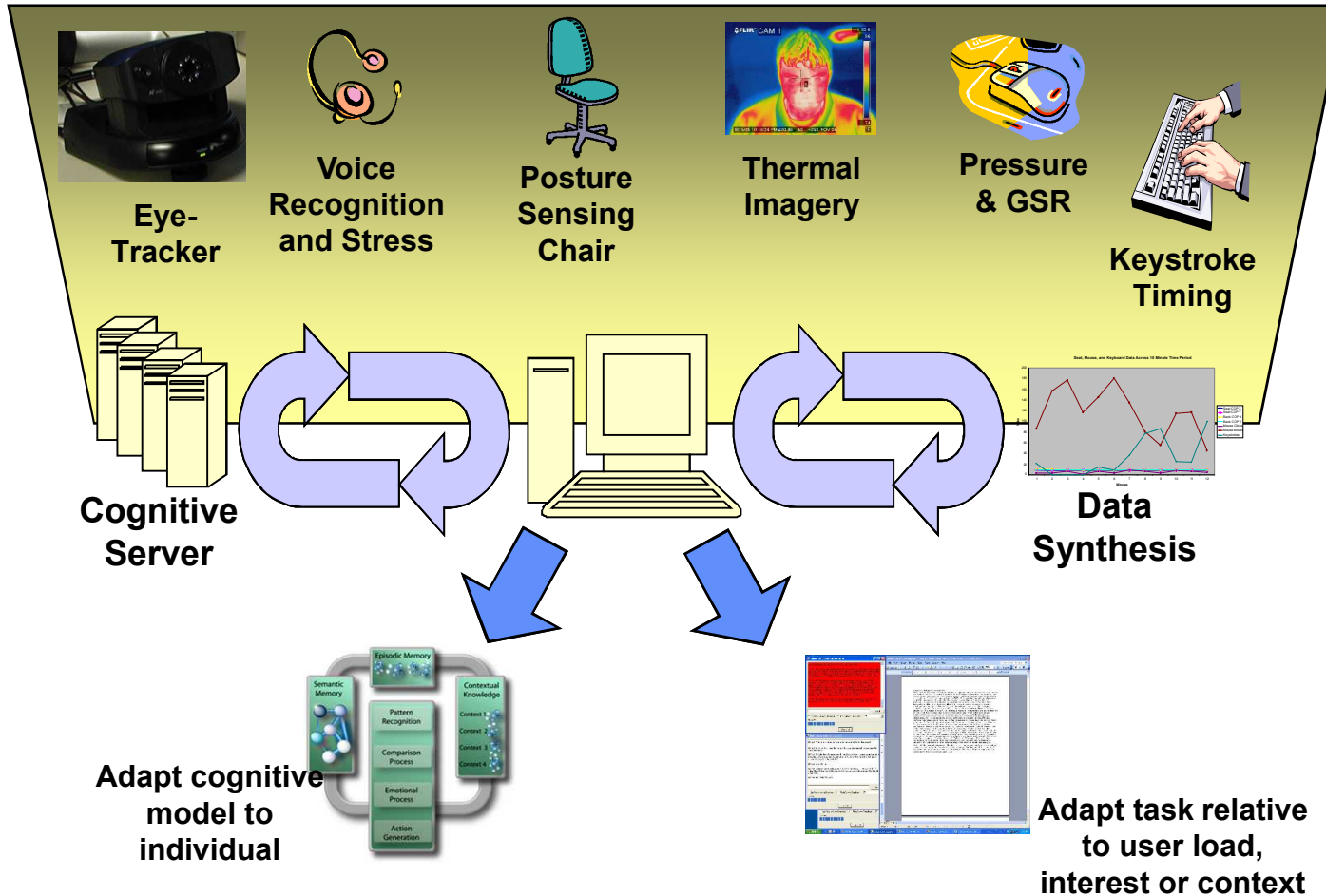# We can create a model customized to an individual through observation of their machine transactions

The Sandia cognitive modeling framework provided the foundation for technology to model automotive driving contexts.

Wheel speed
Steering
Brake pedal
Accelerator
Distronic

Data Profile Across Time

Cluster analysis of data from time windows

Clusters specified as contexts for real-time context recognition

Contexts provide basis for model that predicts driving difficulty

Results

- **Median L1 test-set error: 1.28%**

- **Test-set mitigation agreement: 93.17%**

A suite of non-intrusive sensors provides basis for real-time adaptation

An extensible framework synthesizes data from non-intrusive cognitive state sensors for enhanced models and adaptive systems.

Eye-Tracker

Voice Recognition and Stress

Posture Sensing Chair

Thermal Imagery

Pressure & GSR

Keystroke Timing

Cognitive Server

Data Synthesis

Adapt cognitive model to individual

Adapt task relative to user load, interest or context

Discussion