Experimental Research

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Chess

Program Review
May 10th, 2004
Berkeley, CA

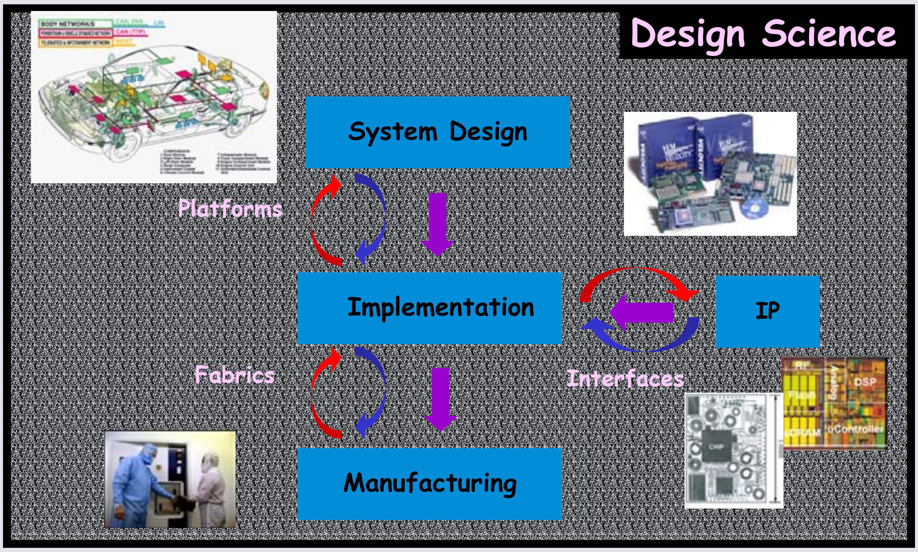
UC Berkeley: Chess
Vanderbilt University: ISIS
University of Memphis: MSI

Foundations of Hybrid and Embedded Software Systems

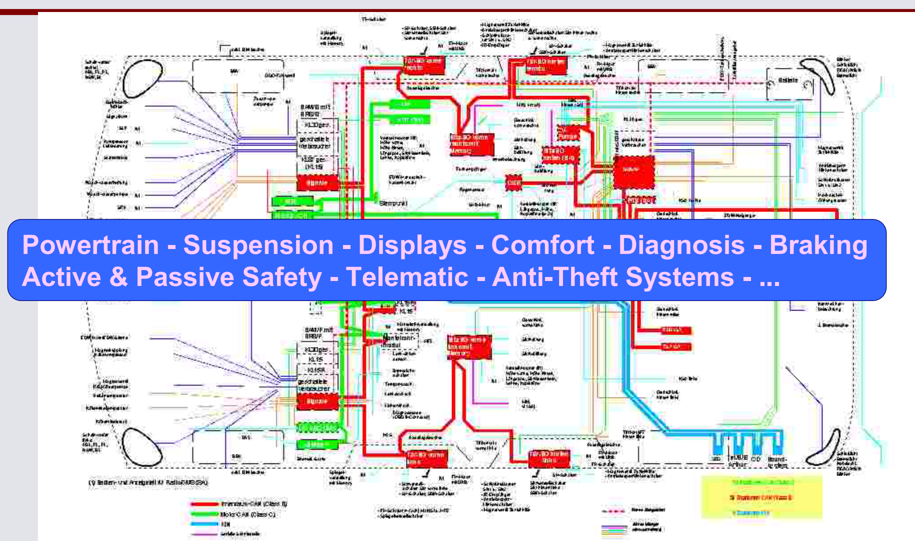
Overview

- Experimental research is an essential component of CHESS
  - Feedback on approach
  - Inspiration for new theory
  - Impact
- Wide range
  - Industrial cases
    - Automotive (safety-critical distributed systems)
    - System-on-Chip (high-complexity platforms)
  - Internal experimental test benches
    - Wireless Sensor Networks (security, low power)
    - UAVs (complex control, sensor integration)
  - New domains:
    - Soft walls
    - Biological Systems

Disaggregation:
Electronic Systems Design Chain



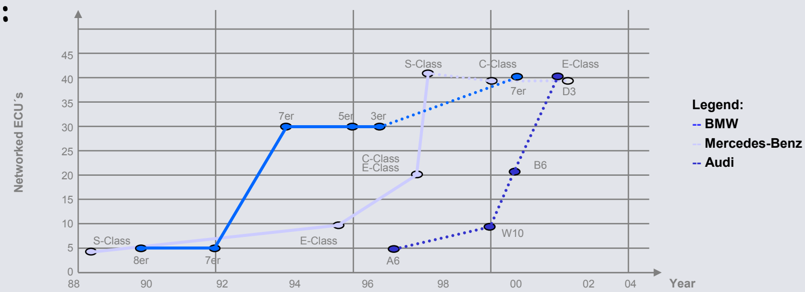
Wiring Harness S-Class 1998



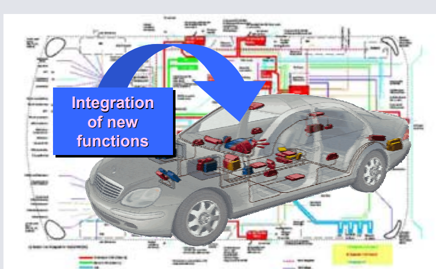
Motivation: Complexity - From 1986 to 1998

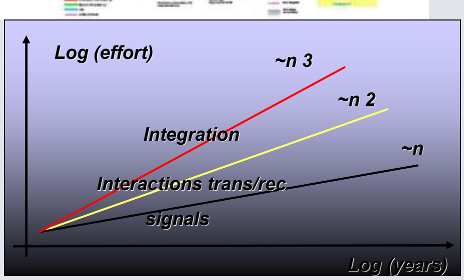
- 1986:
  - Single systems
  - Wiring Harness:
    - weight 37 kg, length 2.4 km, 1200 wires, 2400 wrap connections
  - < 6 ECUs
- 1998:
  - Networked systems
  - Wiring Harness:
    - weight 39 kg, length 2.2 km, 1900 wires, 3800 wrap connections
  - 60 ECUs
  - 113 electric motors

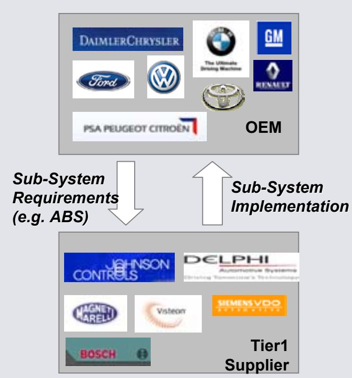
CAN - Networking, e.g. Mercedes-Benz, BMW, Audi:



Design Chain Segmentation: Integration effort

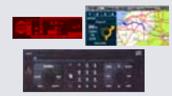






More than 50% of the development effort is in validation

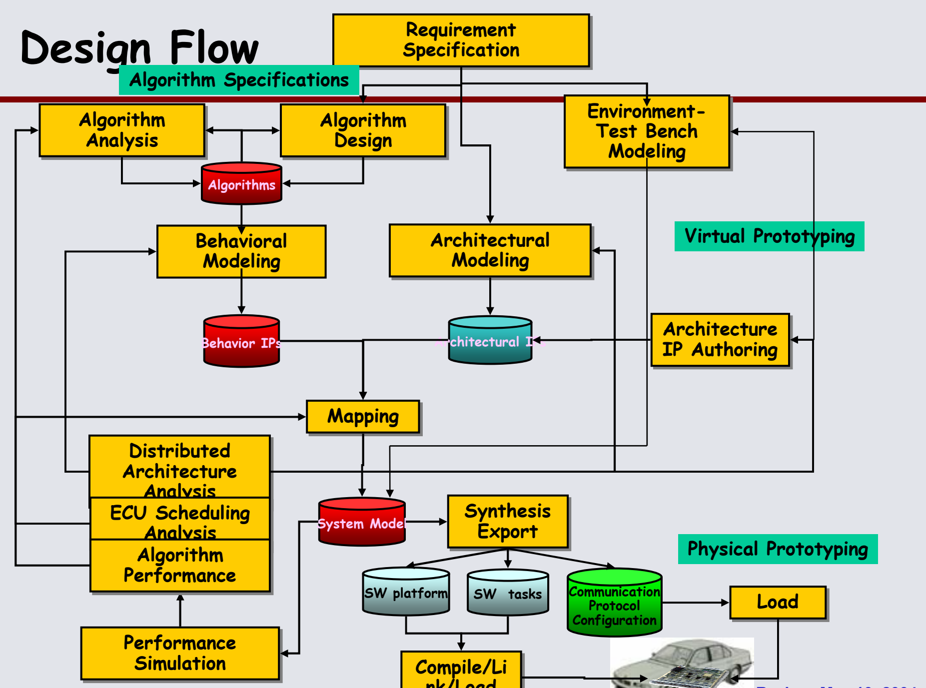
Complexity, Quality, Time-to-Market: TODAY

	PWT UNIT	BODY GATEWAY	INSTRUMENT CLUSTER	TELEMATIC UNIT
				
MEMORY	256 KB	128 KB	184 KB	8 MB
LINES OF CODE	50.000	30.000	45.000	300.000
PRODUCTIVITY	6 LINES/DAY	10 LINES/DAY	6 LINES/DAY	10 LINES/DAY*
RESIDUAL DEFECT RATE @ END OF DEV	3000 PPM	2500 PPM	2000PPM	1000 PPM
CHANGING RATE	3 YEARS	2 YEARS	1 YEAR	< 1 YEAR
DEV. EFFORT	40 MAN-YEAR	12 MAN-YEAR	30 MAN-YEAR	200 MAN-YEAR
VALIDATION TIME	5 MONTHS	1 MONTH	2 MONTHS	2 MONTHS
TIME TO MARKET	24 MONTHS	18 MONTHS	12 MONTHS	< 12 MONTHS

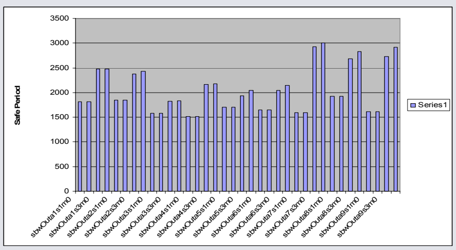
* C++ CODE

FABIO ROMEO, Magneti-Marelli
Design Automation Conference, Las Vegas, June 20th, 2001

Design Flow

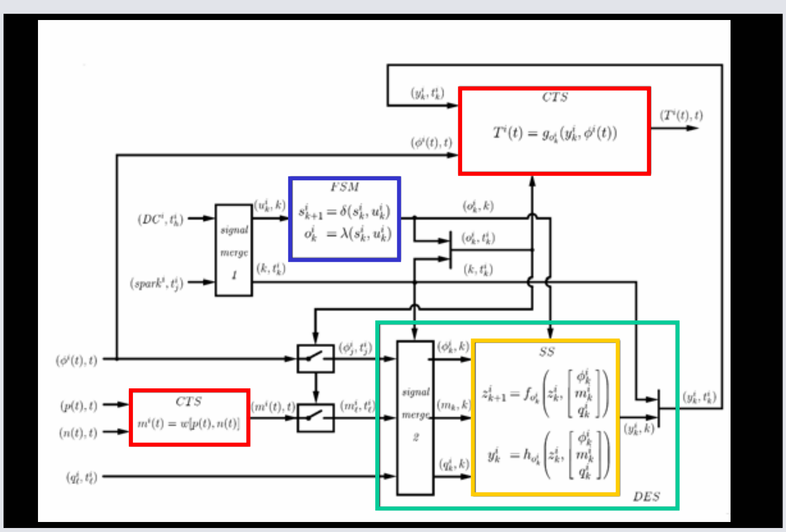


GM Steer-By-Wire System Architecture Exploration



- 36 architectures explored within different dimensions
  - Time-triggered and event-triggered software architectures
  - Sensor/actuator interconnections
  - Network architectures
  - Computing architectures
- Quantitative and qualitative evaluation of architectures in terms of performance, reusability, composability, dependability and modifiability derived.

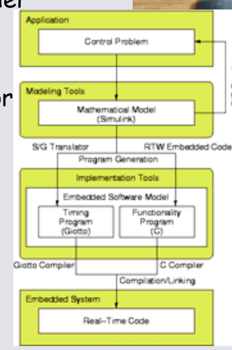
Single Cylinder Hybrid Model



Giotto Applications (TAH):
Drive-by-Wire Throttle

- BMW Throttle Control
- OSEKWorks RTOS
- PID Controller
- Motorola MPC555 40Mhz

Methodology:
from a Matlab/Simulink Model of the Controller:
a) Timing Code (Giotto): generated via S/G Translator (University of Salzburg)
b) Functionality Code (C): via Real-Time workshop.



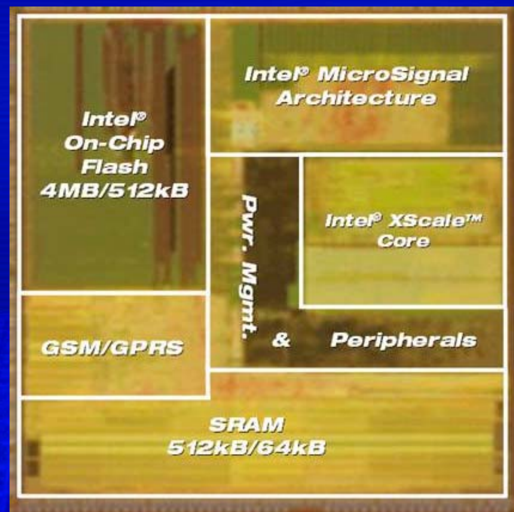
Outline

- Industrial cases
  - Automotive (safety-critical distributed systems)
  - System-on-Chip (high-complexity platforms) (ASV, K. Keutzer)
- Internal experimental test benches
  - Wireless Sensor Networks (security, low power)
  - UAVs (complex control, sensor integration)
- New domains:
  - Soft walls
  - Biological Systems

Typical Application: Intel PXA800F

Industry's First Complete GSM/GPRS Class solution

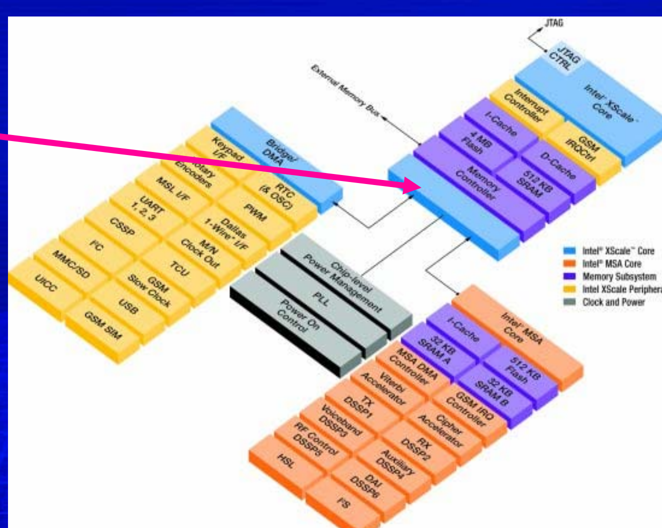
- Intel® XScale ™ Core
- Intel® Micro Signal Architecture
- Intel® On-Chip Flash Memory
- GSM/GPRS Communications Stack, RTOS and applications code for a single-chip mobile solution



intel

Typical Problem: Next Generation PXA800F

Design Improved IP Block Interconnection Module for Increased Performance

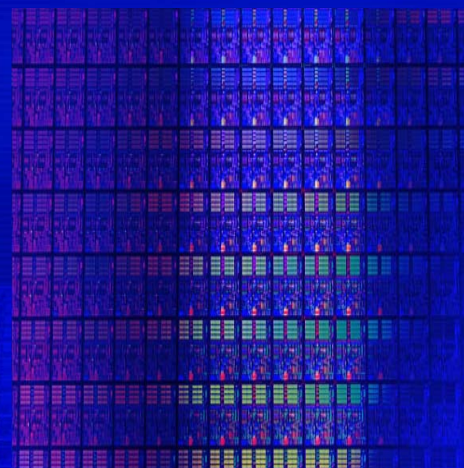


Employ Metropolis QUANTITIES for POWER ESTIMATION of the new design

intel

Typical Application: The Intel MXP5800

- Complete Solution for high performance Digital Imaging Applications
  - Multifunction Printers
  - High End scanners



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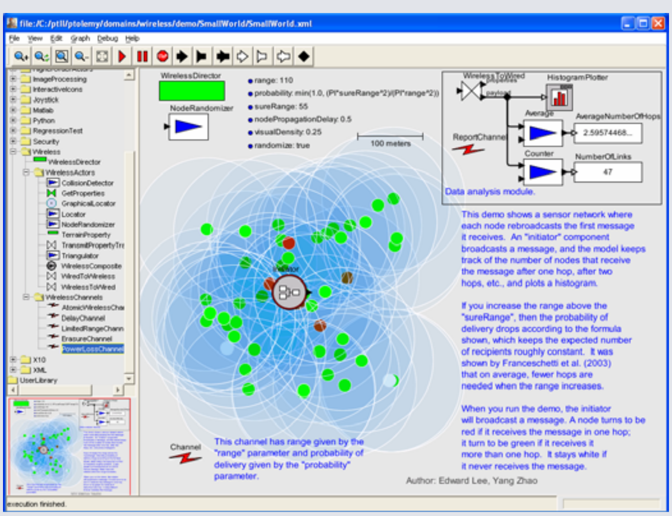
Networks of Embedded Systems (SS)

- Pursuit Evasion Game Demo with 100 sensor motes performed in July 2003
- 10^4 mote scaling issues being discussed for oil pipeline surveillance and protection. For conceptual issues see Franceschetti and Bollobas talks to follow
- Drop experiment planned with 40 motes at China Lake in February 2003
- Infrastructure Protection using secure networks of embedded systems is a new direction.

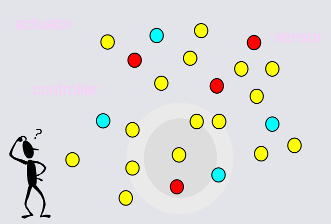
VisualSense: Modeling and Simulation of Wireless Sensor Nets Based on Ptolemy II



VisualSense extends the Ptolemy II discrete-event domain with communication between actors representing sensor nodes being mediated by a *channel*, which is another actor.

The example at the left shows a grid of nodes that relay messages from an *initiator* (center) via a custom channel that models a low (but non-zero) probability of long range links being viable.

Picoradio Sensor Networks (BWRC, J. Rabaey and ASV)



- Control Environmental parameters (temperature, humidity…)
- Minimize Power consumption
- Cheap (<0.5$) and small (< 1 cm^3)
- Large numbers of nodes between 0.05 and 1 nodes/m^2
- Limited operation range of network maximum 50-100m
- Low data rates per node 1-10 bits/sec average
- Low mobility (at least 90% of the nodes stationary)

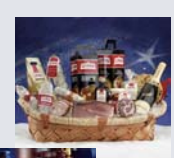
- Key challenges
  - Satisfy tight performance and cost constraints (especially power consumption)
  - Identify Layers of Abstraction (Protocol Stack)
  - Develop distributed algorithms (e.g. locationing, routing) for ubiquitous computing applications
  - Design Embedded System Platform to implement Protocol Stack efficiently

Wireless Sensor Networks: Applications

The present

The future

But also …



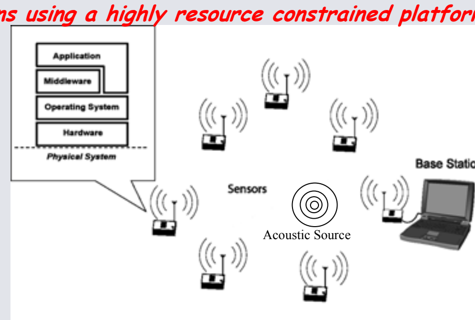
Wireless Sensor Networks

- Use of commercially available platforms
  - Test validity of algorithms
  - Verify Networking properties
  - Implement Network Platform abstraction
- Nodes are getting cheaper and cheaper!
  - More companies are interested in joint projects (Johnson Controls, Pirelli, ST, Levoni Prosciutto, COMAU,…)
  - Volumes expected to be even higher
  - Building temperature and humidity control are the main drivers

Acoustic Localization Experiments (K.Frampton, Vanderbilt)

Goal: To test the composition, synthesis and verification techniques on real-world networked embedded system applications using a highly resource constrained platform

- Applications
  - Active acoustic sensor self localization
    - 10 m range, 20 cm average accuracy
  - Acoustic event localization
    - TDOA, AOA or TOA based methods
    - 1 m 3D accuracy, 2 sec latency
  - Acoustic signal recorder
    - Raw signal or zero crossing encoded
    - 5 Kb short term buffer, 512Kb long term buffer
- Middleware services developed
  - Time synchronization
    - 20 µsec per hop accuracy, 1 msg per node per min
  - Message routing framework
    - Directed flooding, interchangeable flooding policy
    - Broadcast, convergecast, fat spanning treecast
  - Time-slot negotiation (graph coloring)
    - TDMA for acoustic measurements
  - Remote command
    - Reconfiguration, health monitoring
- Field experiments
  - ~50-100 nodes, ~4000 m^2, 8-hop diameter, cluttered environment
- Collaborators
  - Akos Ledeczi and Miklos Maroti, ISIS



Sensor platform:
- UCB MICA2:
  - 8MHz microcontroller, 4KB RAM, 433MHz radio, TinyOS
- ISIS Acoustic Sensorboard:
  - 3 acoustic channels, programmable up to 1MHz ADC, Xilinx Spartan FPGA, I2C interface

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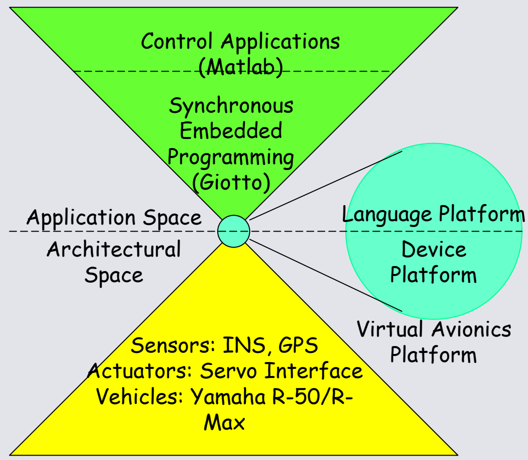
The Legacy of Success in UAV Research at BErkeley AeRobotics

- Pursuit-evasion games 2000- to date
- Architecture for multi-level rotorcraft UAVs 1996- to date
- Landing autonomously using vision on pitching decks 2001- to date
- Multi-target tracking 2001- to date
- Formation flying and formation change 2002, 2003
- Conflict resolution with model predictive control/ stochastic hybrid systems, 2003
- Airspace Management and personal aviation, 2004?

Platform Based Design for UAVs

- Device Platform
  - Isolates details of sensor/actuators from embedded control programs
  - Communicates with each sensor/actuator according to its own data format, context, and timing requirements
  - Presents an API to embedded control programs for accessing sensors/actuators
- Language Platform
  - Provides an environment in which synchronous control programs can be scheduled and run
  - Assumes the use of generic data formats for sensors/actuators made possible by the Device Platform



Giotto Applications:
Unmanned Helicopter Control Systems

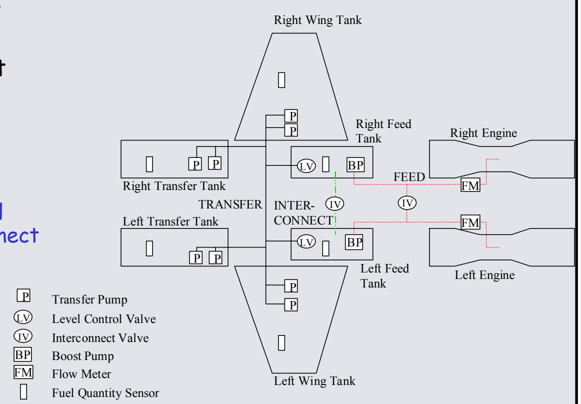
RMAX UC Berkeley Helicopter (BEAR):
- RTOS: VxWorks
- Control: Model Predictive
- Navigation: GPS & INS & Vision based
- Hardware-in-the-Loop Simulation

Swiss Federal Institute of Technology Zürich Helicopter (OLGA):
- RTOS: Customized HelyOS
- Control: LQR based
- Navigation: GPS & INS (EKF)
- Processor: StrongARM 200Mhz

Experimental Test Bed (G. Biswas, Vanderbilt): Fuel Transfer System

- Always have adequate flow to engines
- Avoid imbalances that affect center of gravity of system
- Two primary subsystems, left and right symmetric
  - Engine feed system
  - Transfer system
- Engine Feed System
  - Feed tanks with level control valves, Boost pump, interconnect valve, pipes
- Transfer System
  - Fuselage and Wing Tanks, Redundant pump system, Transfer manifold, pipes

Typical Fuel System Configuration



Number of sensors: pressure transducers, flow meters, temperature gauges

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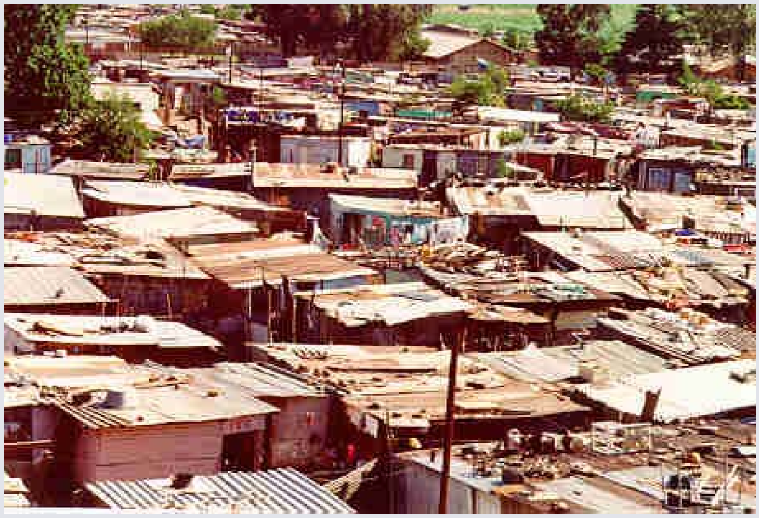
Challenges of Systems (SS) (post genomic biology)

- Hybrid Systems Models for Intracellular functioning: stochastic hybrid systems (see talk by Abate)
- Hybrid Systems tools for ensembles of cells: group behavior of complex networked systems
- Biologically complex networks are an exemplar of how networked embedded systems could evolve, self-organize and reprogram themselves (network programming?) See talk by Franceschetti

Concluding Remarks

- Applications are critical to drive research and to test quality of results
- Safety-critical Real Time and secure system emphasis
- Industrial and Experimental Test Benches
- Rigorous methodology for hybrid distributed systems

Embedded Software: Today



Embedded Software: Future?