Large scale networked system simulation using MLDesigner

Horst Salzwedel, MLDesign Technologies, Inc.

2130 Hanover, Palo Alto CA 94303, http://www.mldesigner.com

- Why MLDesigner uses Ptolemy Technology
- What are large scale networked systems (LSNS)?
- Challenges and solutions in designing LSNS
- Challenges and solutions in simulating LSNS
- Summary

The Challenge of Complexity

- To cope with complexity, model based design techniques have been used in aerospace industry throughout its more than 100 years of development
- Each time new technologies have been introduced, existing models have proved to be insufficient
- Major problems have been
  - not validated specifications
  - incompatible models between disciplines
  - insufficient testing against specifications
  - organizational structure, training and operation

Move towards mission level design: Mult. Models of execution/Ptolemy architecture

CHALLENGES				
Networked Systems/Organizations >100 Systems >1000 ECUs/System Linux, User behavior				Int. modeling of arch/func/user **MLDesigner** - RTOS,HW,SW - design process - test - operation
Networked Componets >100 ECUs			Performance level specifications, reliability analysis BONeS	
Multi-Disciplinary Design		Tool coupling Integr. tools: Ctrl-C MatrixX, Matlab		
Single Discipline Design	Mechanical CAD Library based Sim ACSL	VHDL, Verilog	Functional level specifications SPW/COSSAP	
Year	**1970s**	**1980s**	**1990s**	**2000s**

MLDesigner Software System

Common MLDesigner GUI, Block Diagram Editor and Kernal
XML Model Description, Simulation Control, CVS

Design Domains
Discrete Event
FSM/State Chart
Static Data Flow
Dynamic Data Flow
Analog
NS2
SystemC
New ...

Libraries
Base Library
Add-on Libraries
802.11 MAC
Network Lib
Bus systems
...
User Libraries

Interfaces
Matlab
SatLab
Mathematica
Octave
GDB
Other Sim Tools
Other Applications
Hardware
OpenGL
Tcl/Tk
Altia

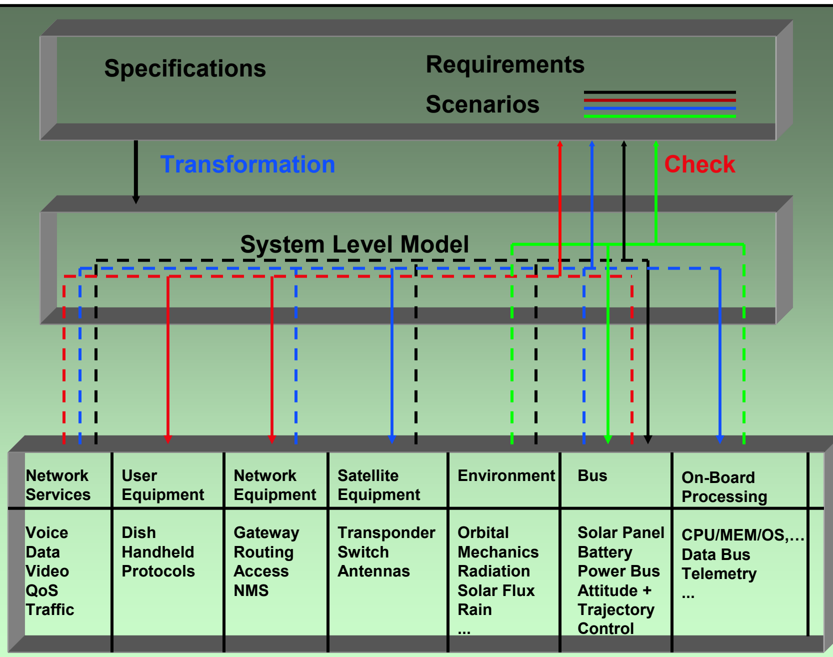
Conversion Util
BONeS => MLD
COSSAP => MLD
SystemC => MLD
UML => MLD
Ptolemy => MLD
MLD => C
MLD => SystemC
MLD => VHDL

MLDesigner Applications

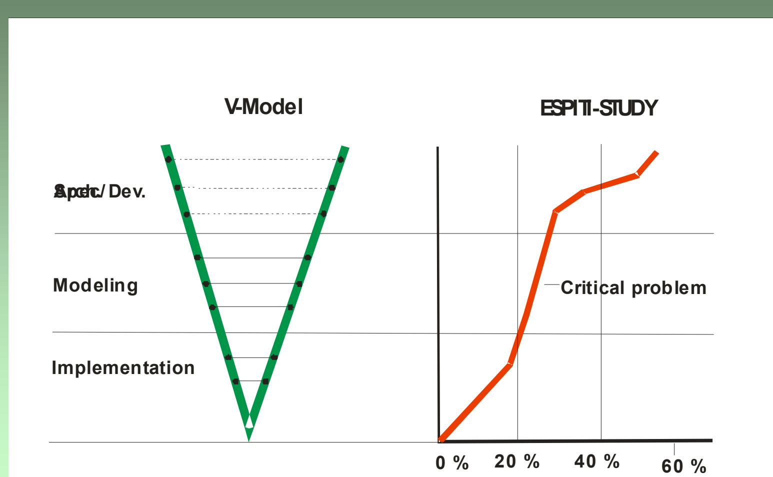
- Networked systems
  - OnChip, Avionics, Aircraft, RPV, AUV, Satellites, Cars, Comm., Networked Computers (GRID), Large Scale IT Systems, Regional Conflicts, TTNT
  - Organizational, Design, Quality and Production Processes
- Electronic system design
  - Embedded systems for controls, comm., …
  - Electronic and mechatronic SoC
  - Architectural performance level
- Reconfigurable electronics
  - Reconfigurable FPGAs
  - Software radios
  - Soft redundancy

What are Large Scale Networked Systems?

- LSNS exhibit a complexity that can no longer be planned at a functional level
  - When subcomponents, designed from written specifications, are assembled to the overall system, the LSNS does not work. Hacking processes can only solve part of the problem
  - Dynamic events couple subcomponents thru the network. Interactions between components and reactions to dynamic events from the mission environment cannot be simulated functional or RTL level
  - Sufficient HIL tests are no longer feasible
  - Major flaws in the design of such systems are not uncommon
  - Problems are often both in the technical design process as well as the organizational process
- Examples include
  - Global satellite communication systems (e.g., Teledesic failed)
  - Integrated comm/nav systems
  - Large scale IT systems
  - Networked onboard ECUs
  - Networked defense systems
  - Organizational or production processes



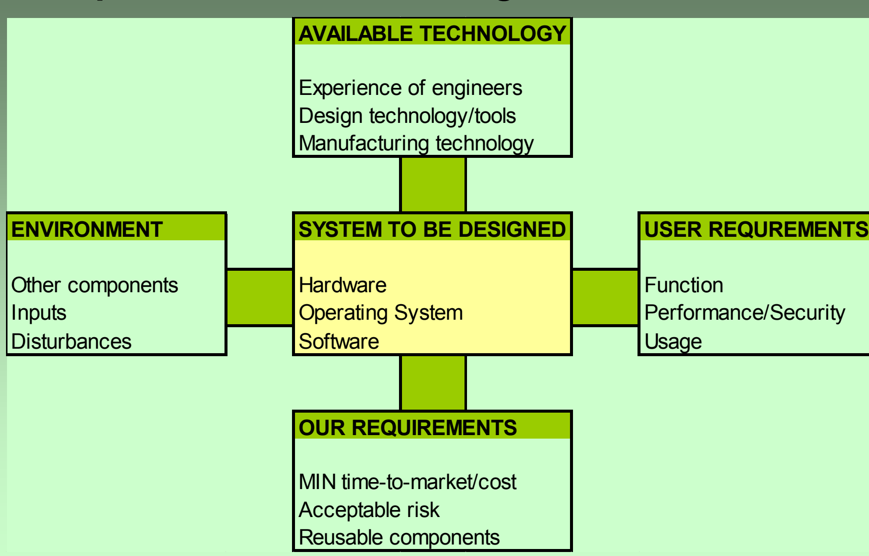
Critical Design Problems



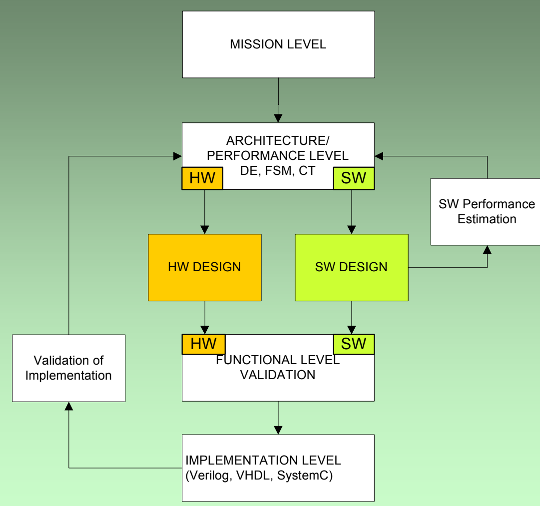
Solution to The Challenge

- Improving the quality of specification
  - Making specifications executable
  - Finding common Description language between engineering disciplines
  - Testing functional level designs against executable specifications
- Integrating the design flow for design, test and evaluation
- Determining requirements for collaborative organizational processes, qualification of engineers and production processes

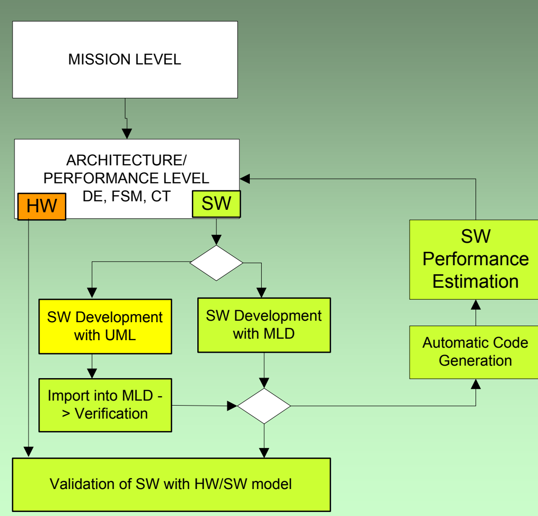
Requirements for the design of LSNS



Mission Level Design Flow



ML Design Flow with UML-based SW Development



LSNS Examples

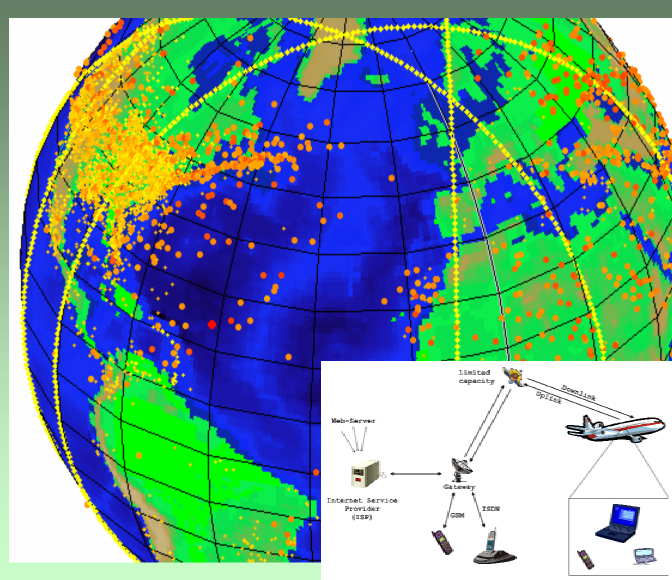
- Air traffic management system for North Atlantic
- Aeronautical communication system with hundreds of airplanes
- US GRID
- Country-wide automated toll collection/vehicle information system
- Resource allocation for regional conflict
- Large scale IT system
- Tactical Target Network Technology
- Global satellite system
- Large scale onboard system

Analysis of Requirements for ADS Communications

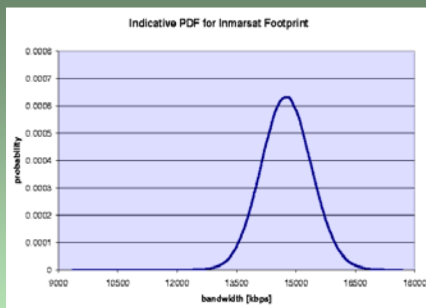
▷**345 Aircrafts in one direction**

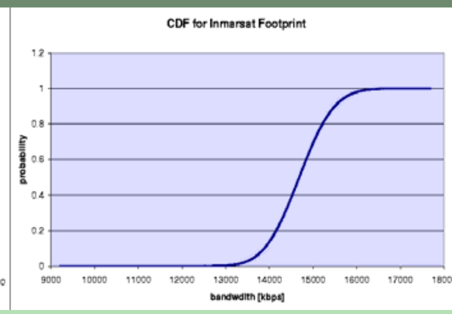
▷**2 Inmarsat satellites for North Atlantic**

▷**Worst Case Analysis for Inmarsat GAN**



Worst Case Scenario for Inmarsat GAN





- Worst Case 345 Aircrafts within the Footprint
  - Total Number of Aircraft flying from Europe to North America per day
- Mean Bandwidth Usage: 15 Mbps
- Maximum Bandwidth Usage: 17.7 Mbps

DARPA Program

Tactical Targeting Network Technology (TTNT)

Adam Baddeley
Afeo.langley.af.mil/news/acticles/2004

http://www.rockwell.com/news/page5678.html

- “plug and play” tactical network extension to DoD Global Information Grid (GIG)
  - < 2 milliseconds
  - > 2 mbps
  - > 100 nm
  - 3 sec ingress time for new nodes
  - > 2000 users
- Rockwell Collins: TTNT

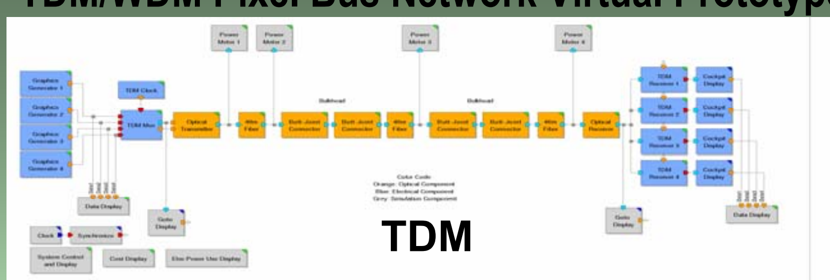
DARPA Program
Tactical Targeting Network Technology (TTNT)

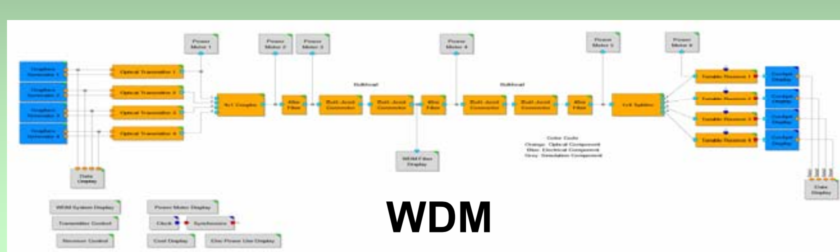
- Over 3 years the simulation model has evolved from two-node prototype, to a 1000-node system (air, ground, water)
- Simulation of communication between 1000 nodes would have taken several month and exceeded the address space of 32 bit operating systems
- Update of simulator
  - Removing object oriented data transport reduced memory requirements by more than a factor 10
  - New schedulers reduced simulation time, e.g., from 2 month to 30 min
  - Dynamic instantiation
  - Distributed simulation

=>Detailed performance level analysis identified protocol and interface challenges that would otherwise been identified after hardware integration

=>High performance requires improvements at all levels of abstraction

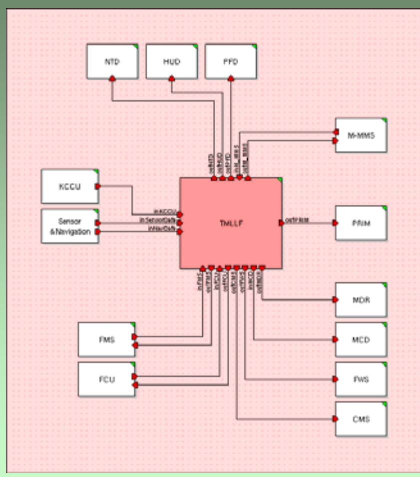
TDM/WDM Pixel Bus Network Virtual Prototype





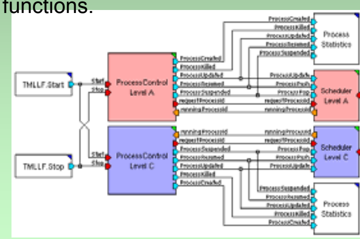
HCS-UFL/Rockwell Collins

Model of architecture and function



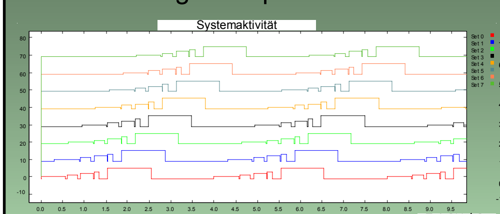
TMLLF = Terrain Masking Low Level Flight

- Implementation on distributed processor boards
- Communication with other systems over network
- Modeled with MLDesigner for a Two-Board-System of Level A and Level C functions.

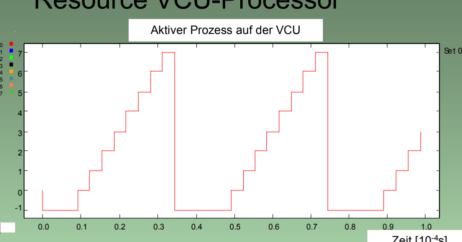


Resource usage of parallel processors

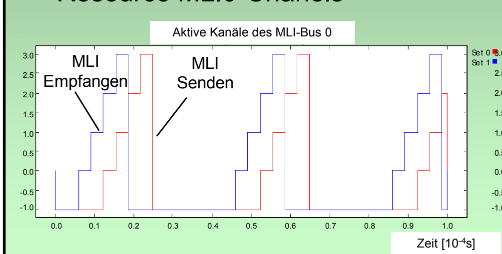
Processing of loops



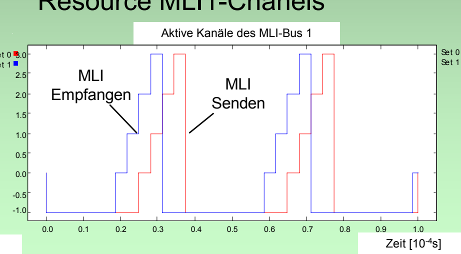
Resource VCU-Processor



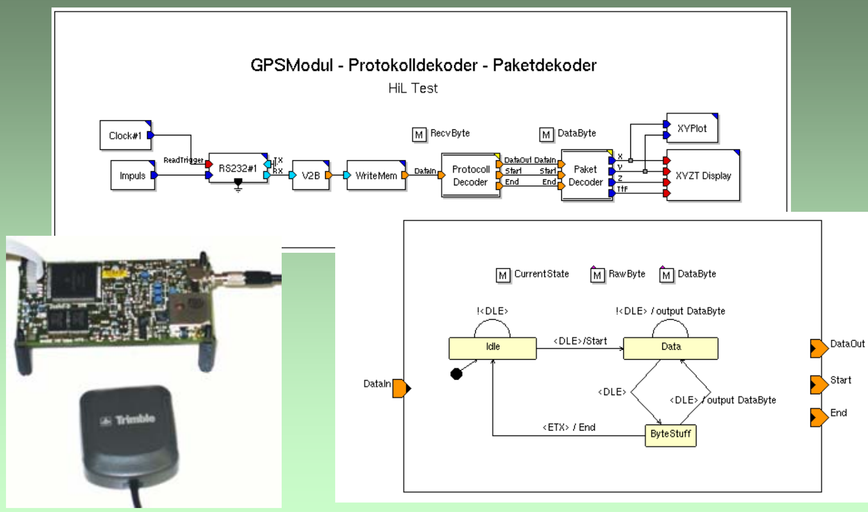
Resource MLI0-Chanels



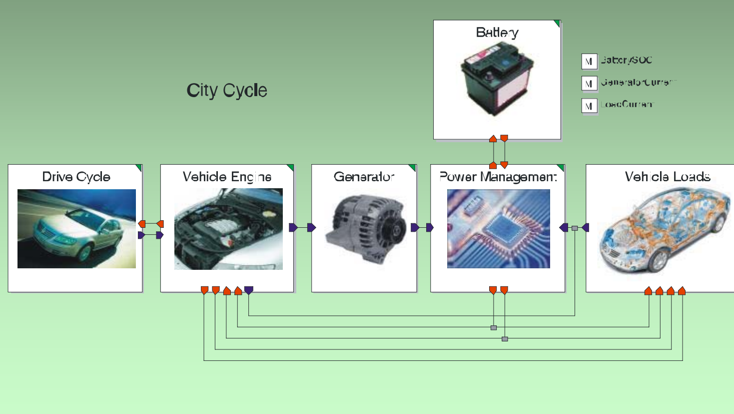
Resource MLI1-Chanels



HW in the loop tests



Applying LSNS abstraction/simulation techniques to an Automotive Power Management System model reduced simulation times from > 1 month to several seconds



Summary

- For simulating high performance LSNS the simulation technology had to be significantly improved in memory usage, speed and robustness of schedulers and parallel execution. Models had to be moved to higher levels of abstraction
- Main experience with integrating design flow for LSNS from application/mission to implementation
  - Reduced risk in design of complex systems because of validated specifications
  - Reduced number of iterations in design
  - Project completion in time
  - Speedup of design/development of up to 10x and more

Questions?

http://www.mldesigner.com