EquiPSim: Hands-On Training in Semiconductor Equipment and Process Behavior

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OUTLINE:

- Motivation - Simulation for Engineering and Education
- Architecture
- Learning System Environment and Tools
- Authoring
- Applications
- Conclusions

Acknowledgements

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Physically-Based Dynamic Simulation for Engineering and Education

- **Powerful engineering applications for simulation, supported by commercial software and popular platforms**

- **Validated dynamic simulators reveal time-dependent behavior critical to semiconductor manufacturing equipment, process, sensor, and control behavior**

- **Applications to engineering design, control, optimization, and mechanistic insight**

- **Applications to broad spectrum of education and training, from novice to practicing engineer**
  - ***Huge need in industrial training***
  - ***Conventional training is highly labor-intensive, limited-term impact***

Motivation

Simulation is a powerful engineering tool, but usability is increasingly limited as complexity and validity increases

User interface design is crucial to usability and effectiveness

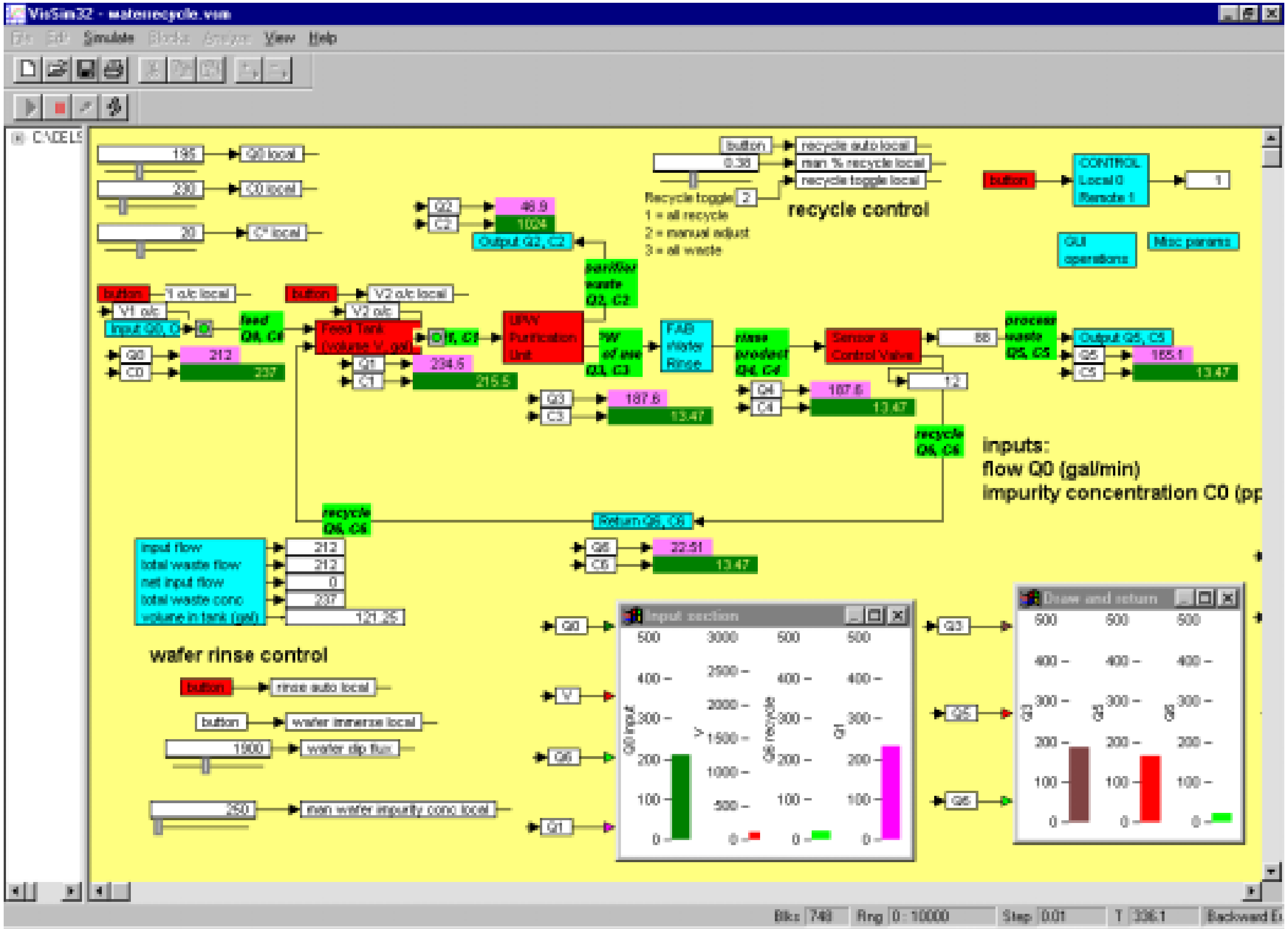
Simulation could provide active learning experiences which enhance education and training

Simulation must be encapsulated in a rich exploratory environment for effective learning at any/all levels

Engineered Learning Systems

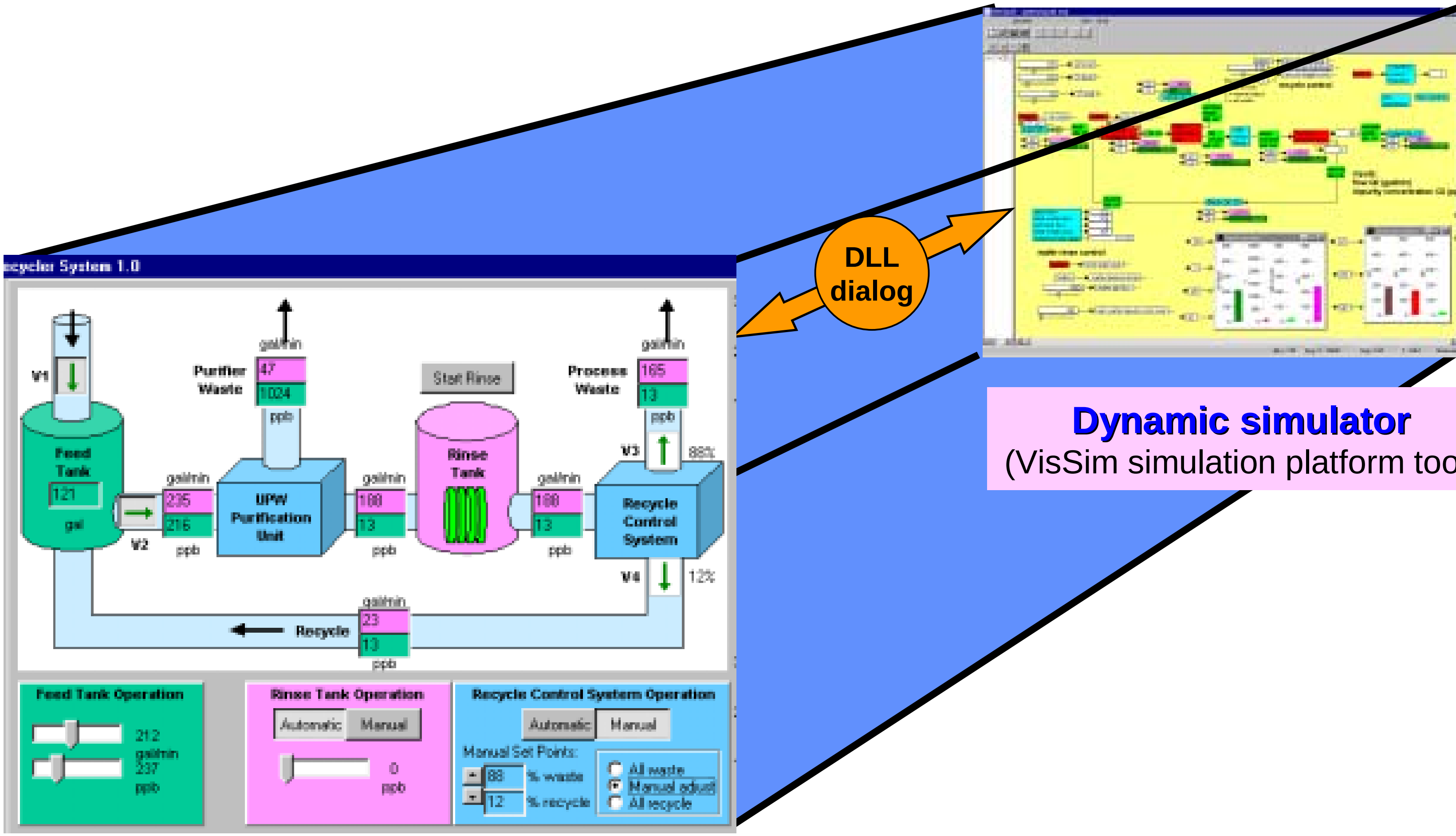
- effective user interface designs
- simulation experiences for active learning
- closely coupled guidance material
- software tools as learning aides
- easy authoring
- educational continuum
  - *novice to expert*
  - *classroom to on-the-job*

Dynamic Simulator



Commercial VisSim PC simulation platform (Visual Solutions Inc)

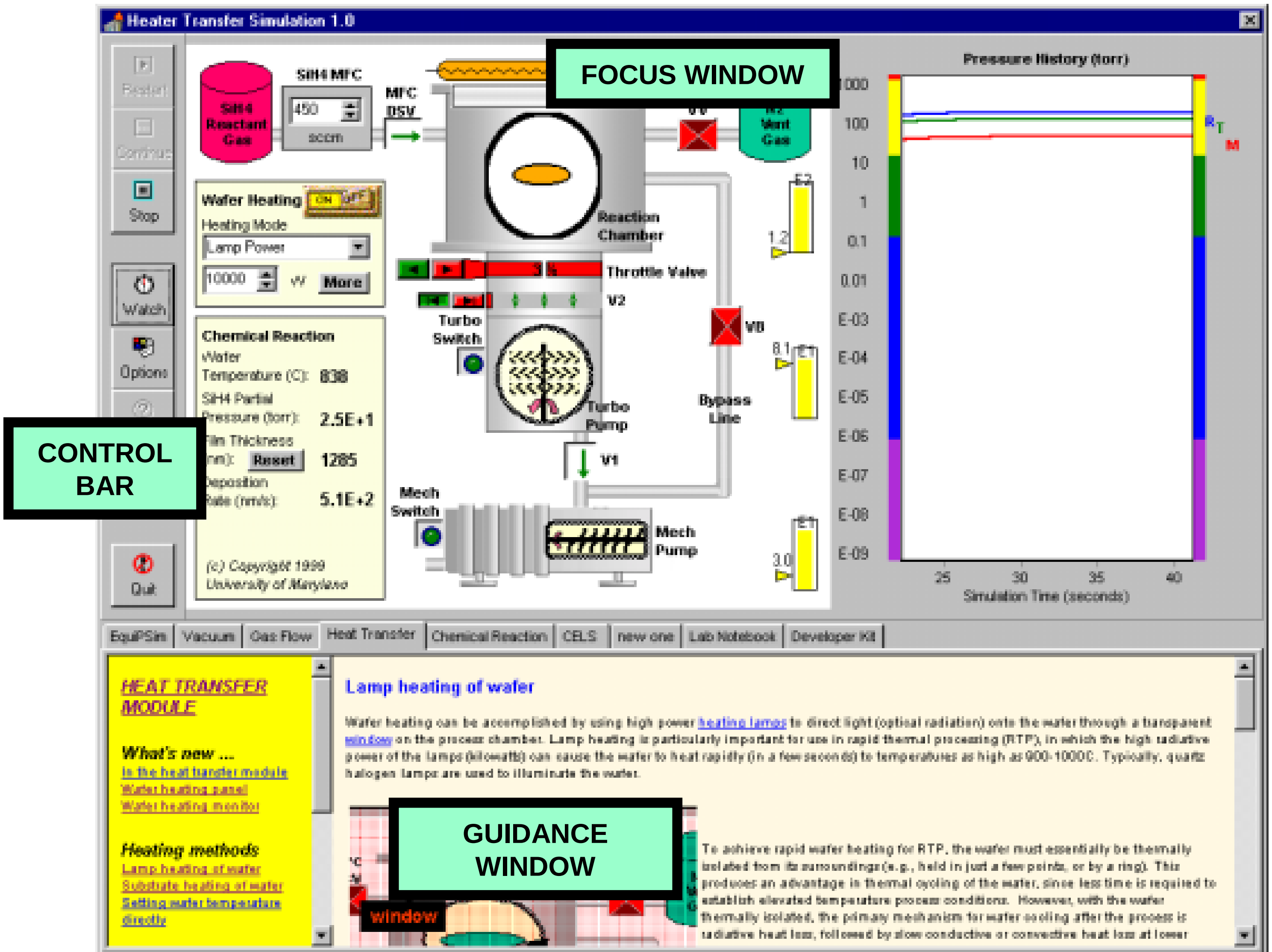
Enhanced User Interface for Learning



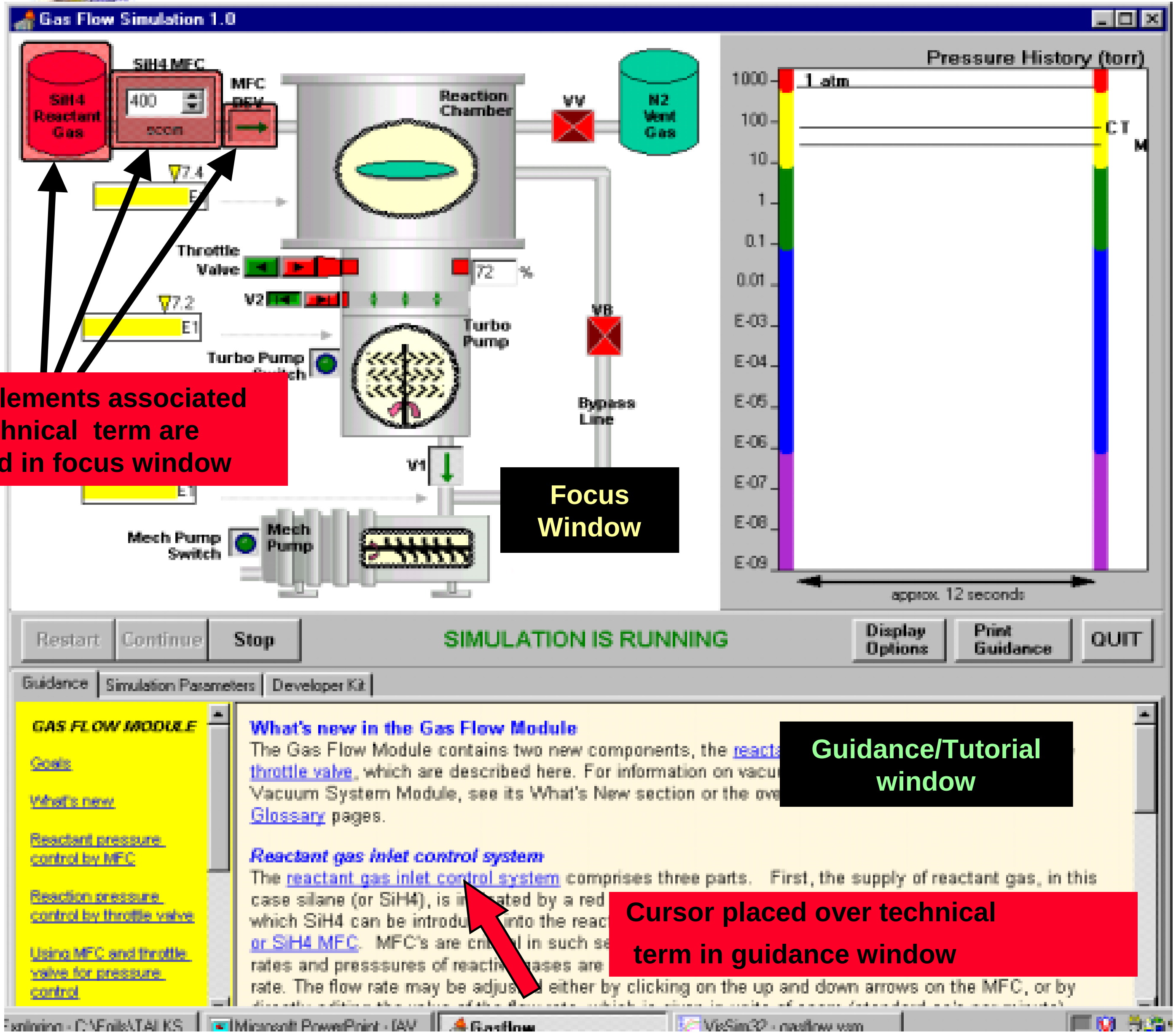
Dynamic simulator
(VisSim simulation platform tool)

Enhanced user interface
(Delphi visual development platform)

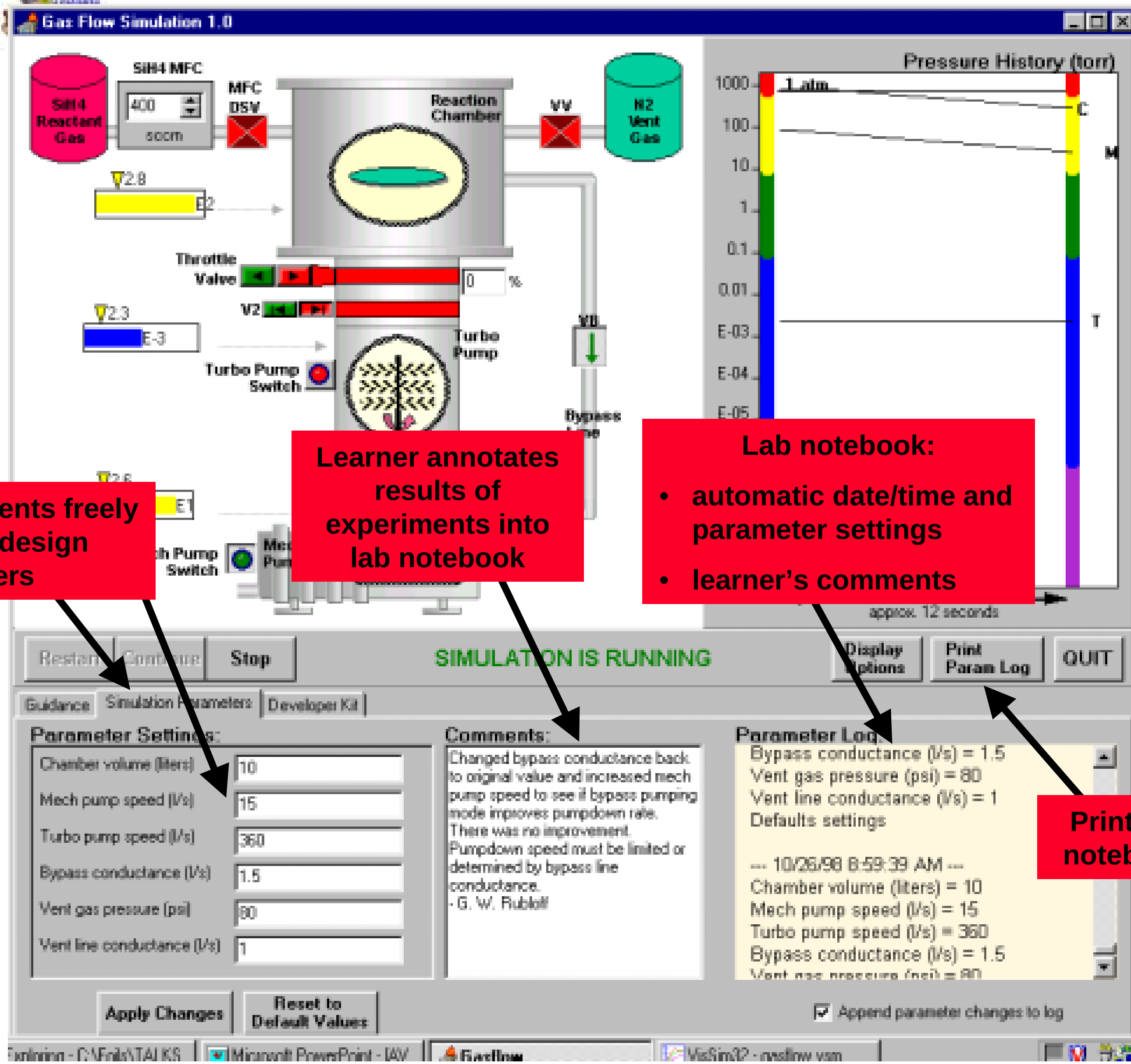
EquiPSim Learning Modules



Guidance Highlighter



Lab Notebook



Learner experiments freely with system design parameters

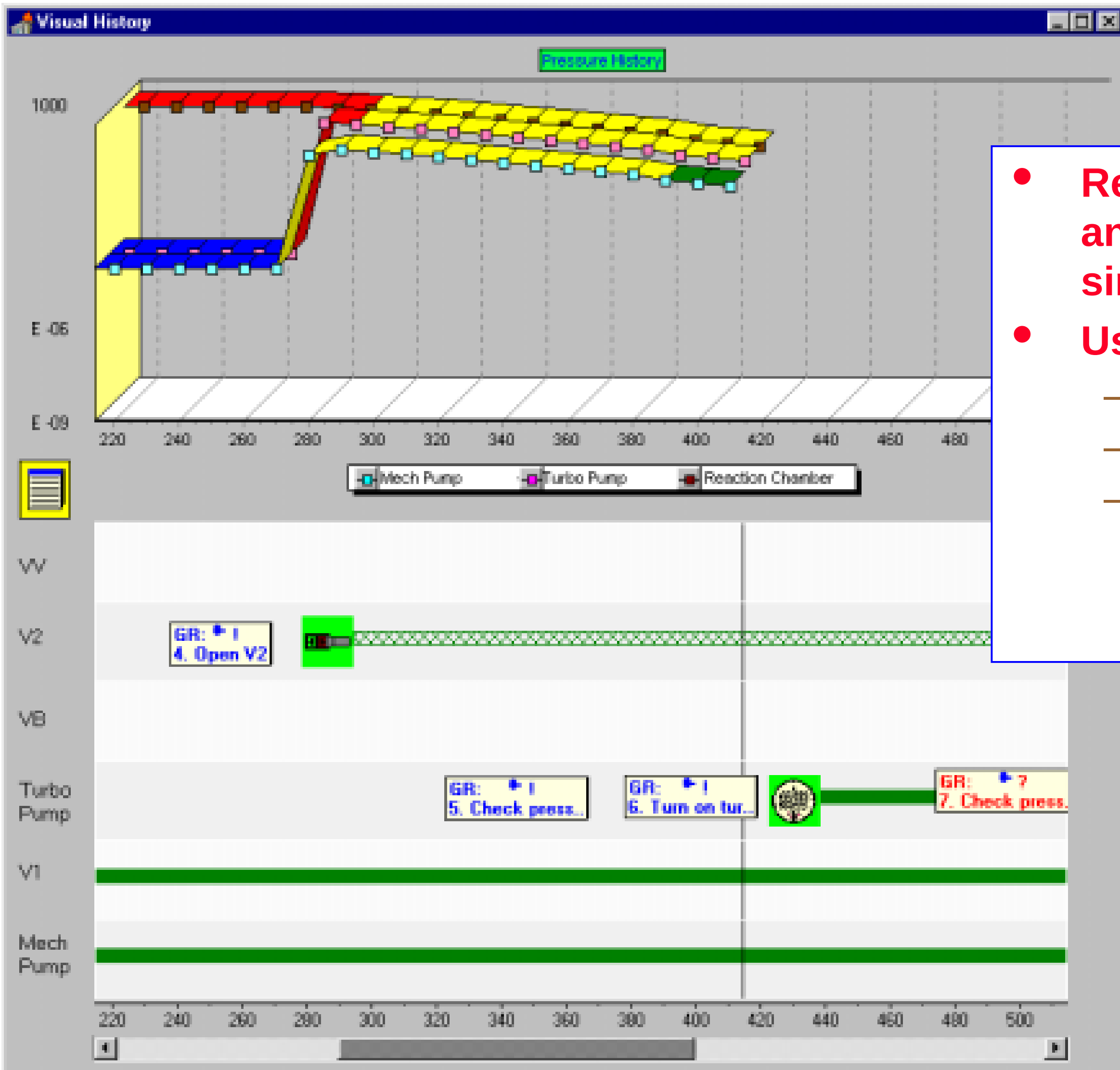
Learner annotates results of experiments into lab notebook

Lab notebook:

- **automatic date/time and parameter settings**
- **learner's comments**

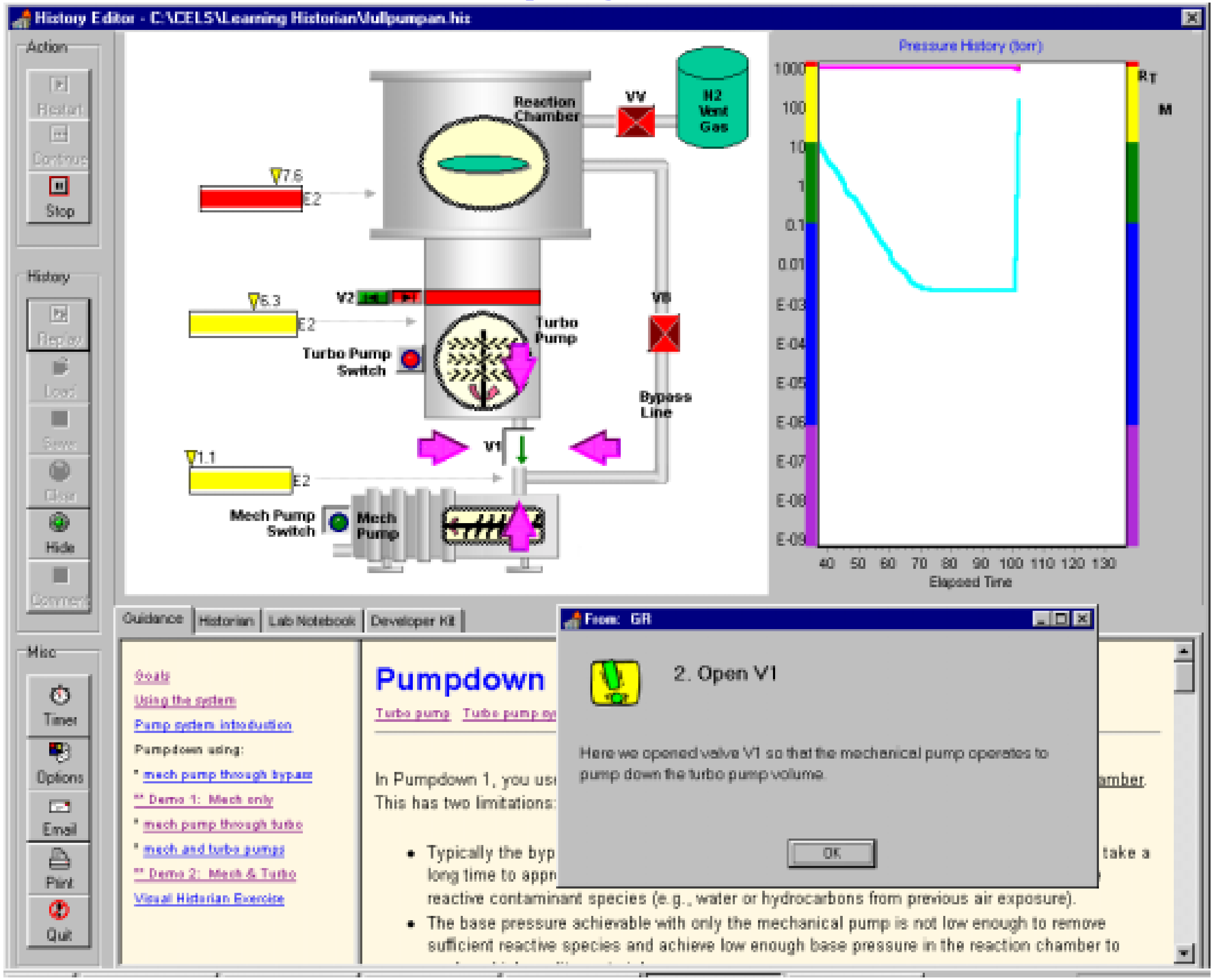
Print lab notebook

Learning Historian
Record of Events

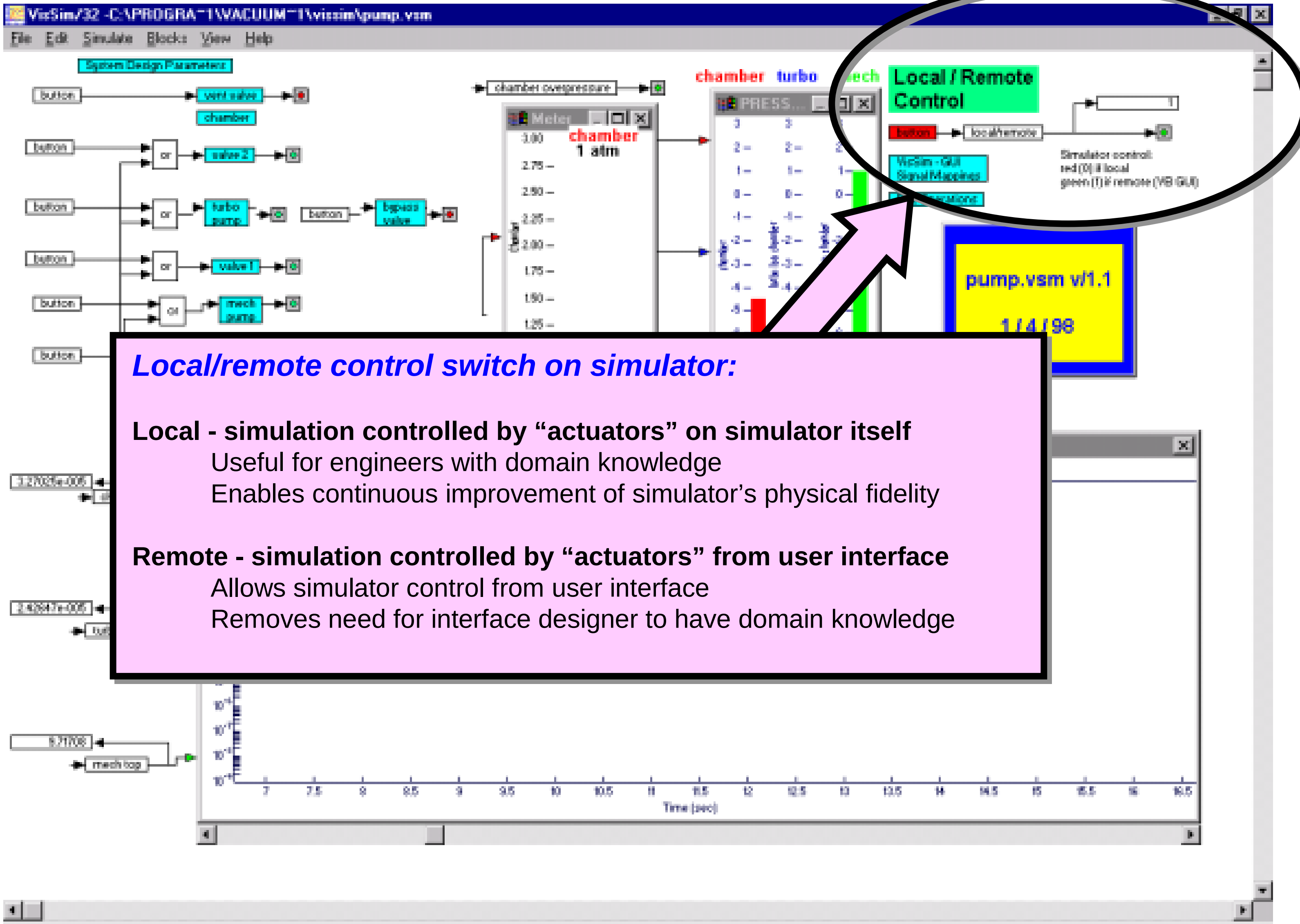


- **Record, revise, replay, and annotate event histories in simulation experiments**
- **Use for**
  - *tutorial generation*
  - *questions to teacher/expert*
  - *peer collaboration*

Learning Historian
Replay of Simulation



Simulator: Local and Remote Control

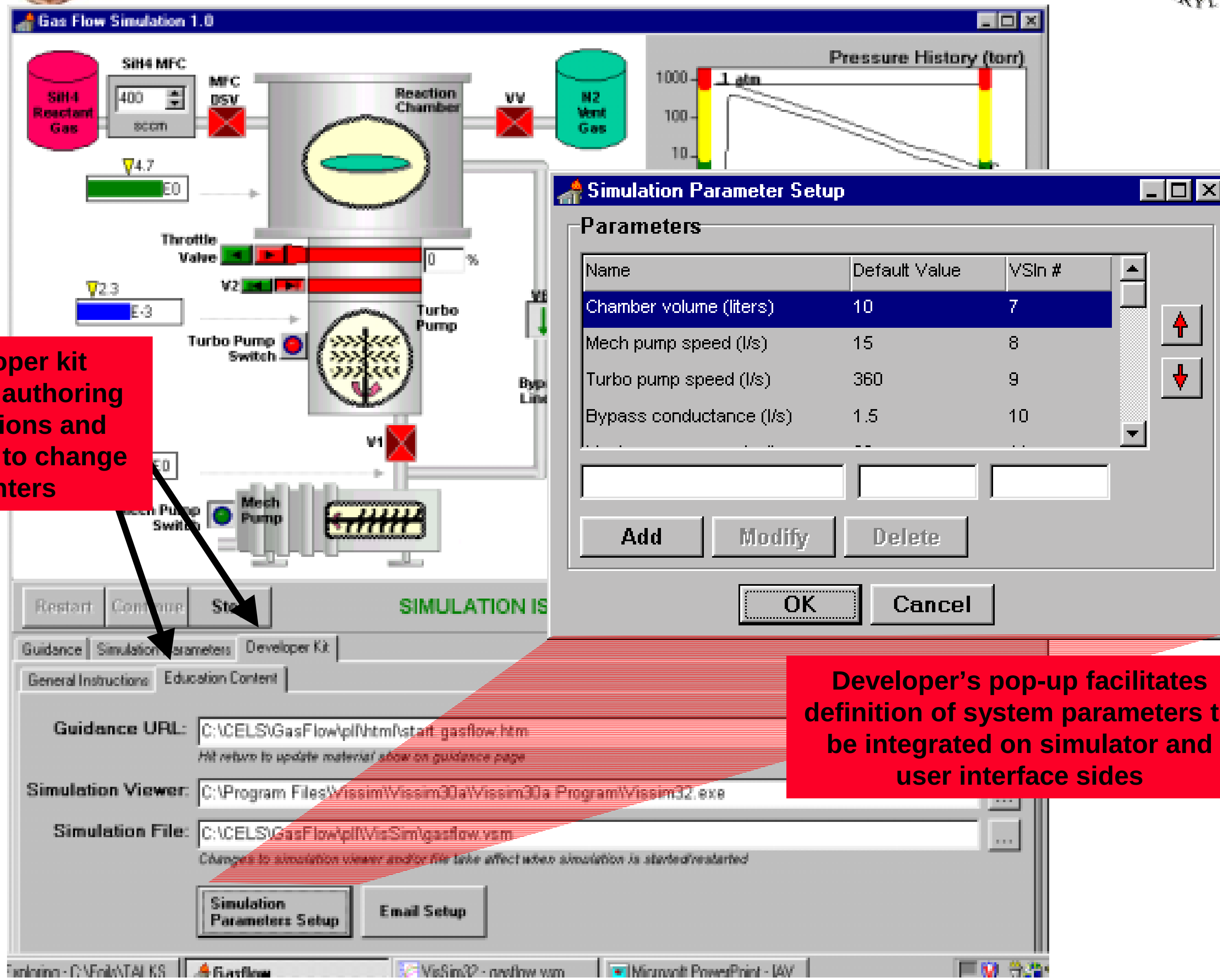


Local/remote control switch on simulator:

Local - simulation controlled by "actuators" on simulator itself
- Useful for engineers with domain knowledge
- Enables continuous improvement of simulator's physical fidelity

Remote - simulation controlled by "actuators" from user interface
- Allows simulator control from user interface
- Removes need for interface designer to have domain knowledge

Authoring - User Interface

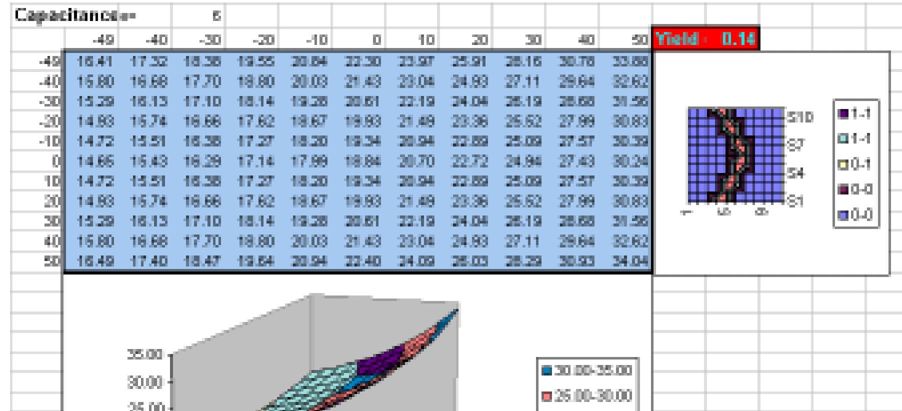


Developer kit provides authoring instructions and flexibility to change pointers

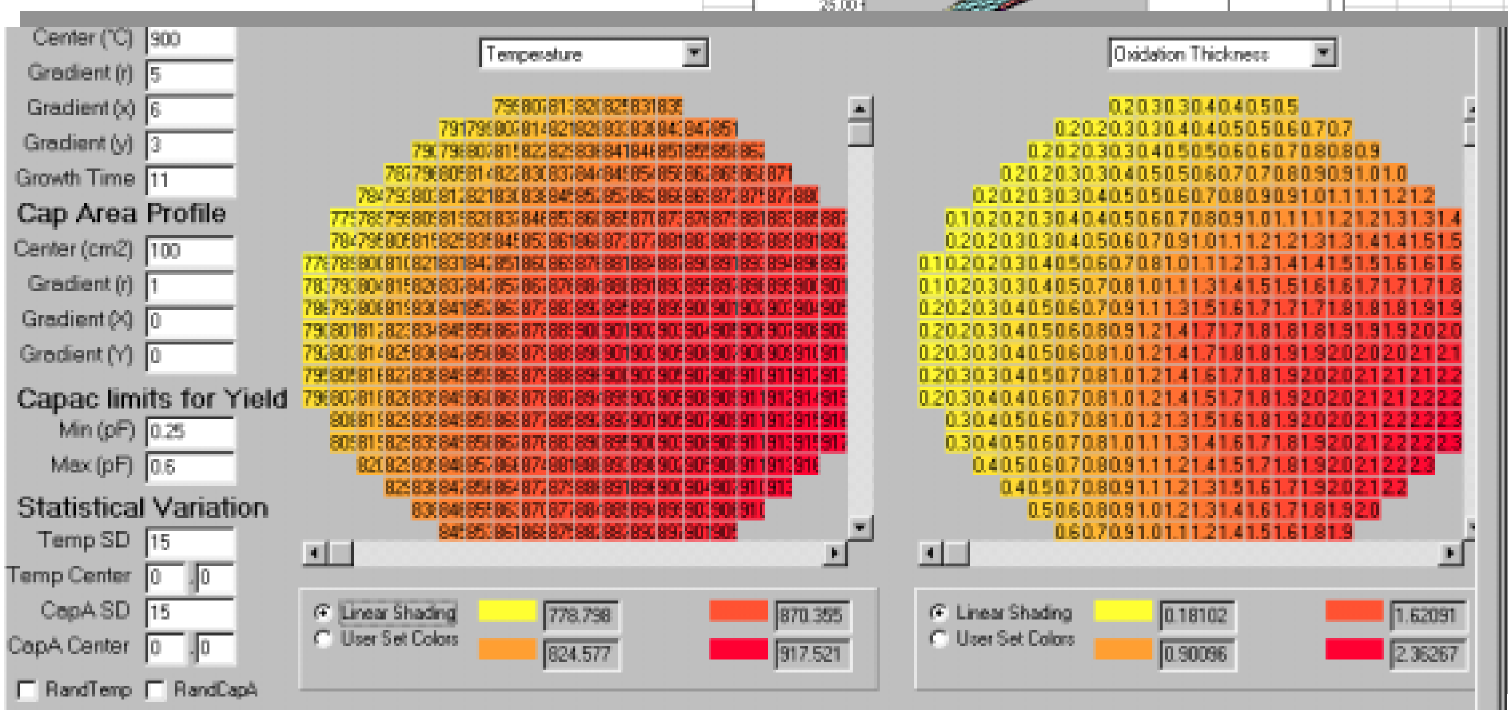
Developer's pop-up facilitates definition of system parameters to be integrated on simulator and user interface sides

Process Integration and Yield Modeling

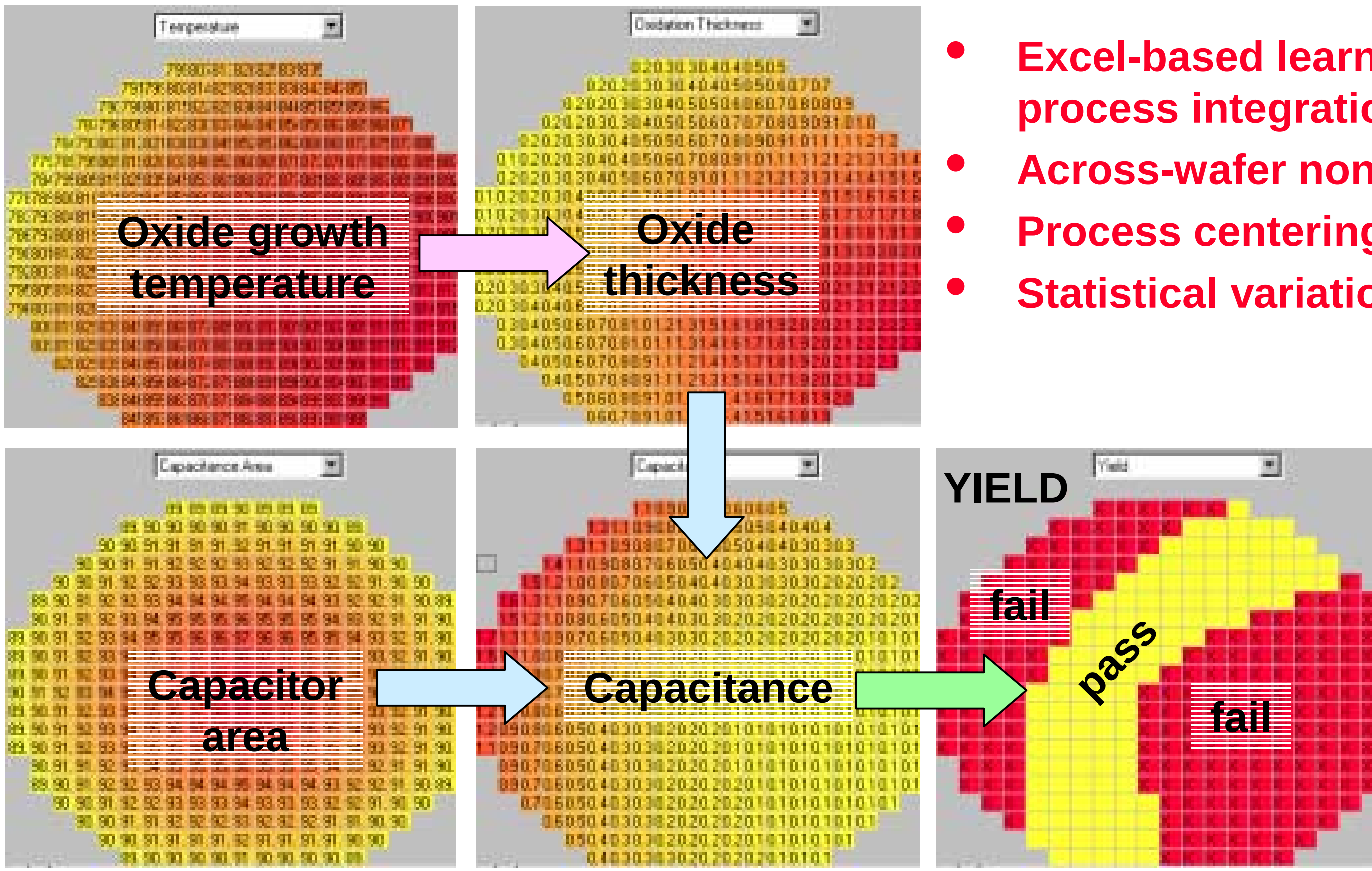
- Expand learning systems to support Excel models
- Process integration example completed (simple device)
- Cost/performance modeling in other industries



Capacitance=		6									
	-49	-40	-30	-20	-10	0	10	20	30	40	50
-49	16.41	17.32	18.38	19.55	20.84	22.30	23.97	25.91	28.16	30.78	33.88
-40	15.80	16.68	17.70	18.80	20.03	21.43	23.04	24.93	27.11	29.64	32.62
-30	15.29	16.13	17.10	18.14	19.28	20.61	22.19	24.04	26.19	28.68	31.56
-20	14.93	15.74	16.66	17.62	18.67	19.93	21.49	23.36	25.52	27.99	30.83
-10	14.72	15.51	16.38	17.27	18.20	19.34	20.94	22.89	25.09	27.57	30.39
0	14.66	15.43	16.29	17.14	17.99	18.84	20.70	22.72	24.94	27.43	30.24
10	14.72	15.51	16.38	17.27	18.20	19.34	20.94	22.89	25.09	27.57	30.39
20	14.93	15.74	16.66	17.62	18.67	19.93	21.49	23.36	25.52	27.99	30.83
30	15.29	16.13	17.10	18.14	19.28	20.61	22.19	24.04	26.19	28.68	31.56
40	15.80	16.68	17.70	18.80	20.03	21.43	23.04	24.93	27.11	29.64	32.62
50	16.49	17.40	18.47	19.64	20.94	22.40	24.09	26.03	28.29	30.93	34.04



Process Integration and Yield Modeling



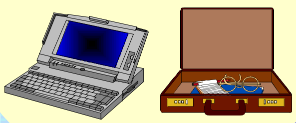
- Excel-based learning system for process integration and yield
- Across-wafer nonuniformity
- Process centering
- Statistical variation

Center for Engineered Learning Systems

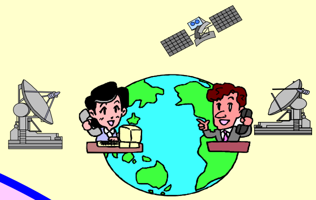
CELS

www.isr.umd.edu/CELS/

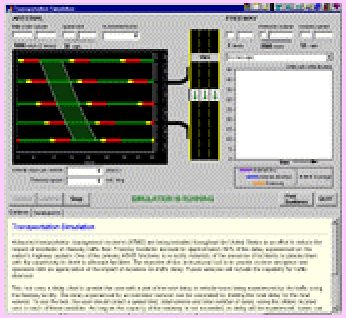
Portable, standalone



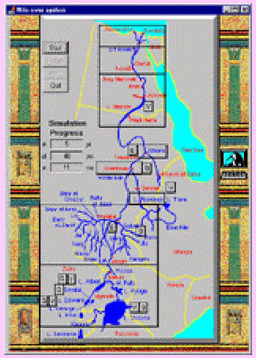
Internet-connected



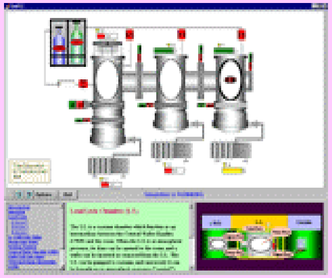
APPLICATIONS



Systems management



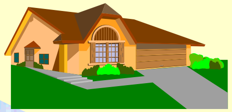
Politics, history, economics, and society

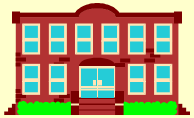


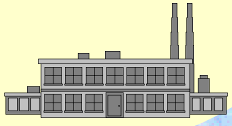
Science and technology

Individual and group active learning experiences

Real-time and asynchronous collaboration and counsel







At work, in school, and at home

CELS is administered as a Center within the Institute for Systems Research, an entity of the A. James Clark School of Engineering at the University of Maryland.

Conclusions

- High quality **user interface design** expands value of simulation to engineering and education

- Effective **engineered learning systems** combine
  - *Simulation with good user interfaces*
  - *Tightly coupled guidance materials*
  - *Software learning aides*
  - *Tools to facilitate experimentation and collaboration*
  - *Easy authoring for both domain knowledge and software environment*

- **EquiPSim** learning modules
  - *Prototypes available (www.isr.umd.edu/CELS/)*
  - *Vacuum, gas flow, heat transfer, chemical reactions*
  - *Statistics, optimization, process control*

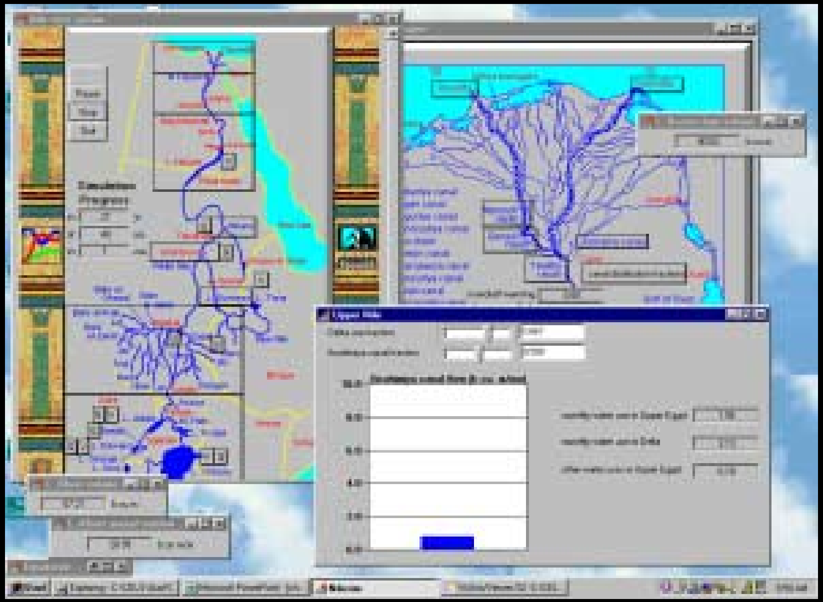
BACKUP

Other Simulator-Based Learning Systems

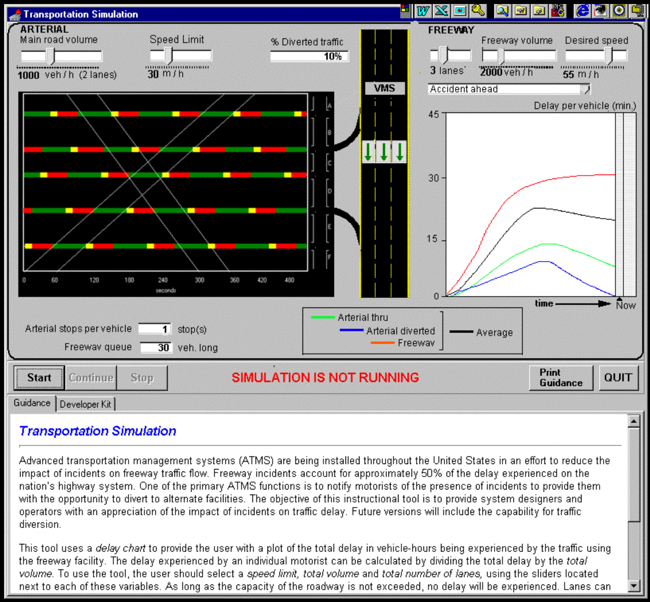
CELS

www.isr.umd.edu/CELS/

NileSim



TrafficSim

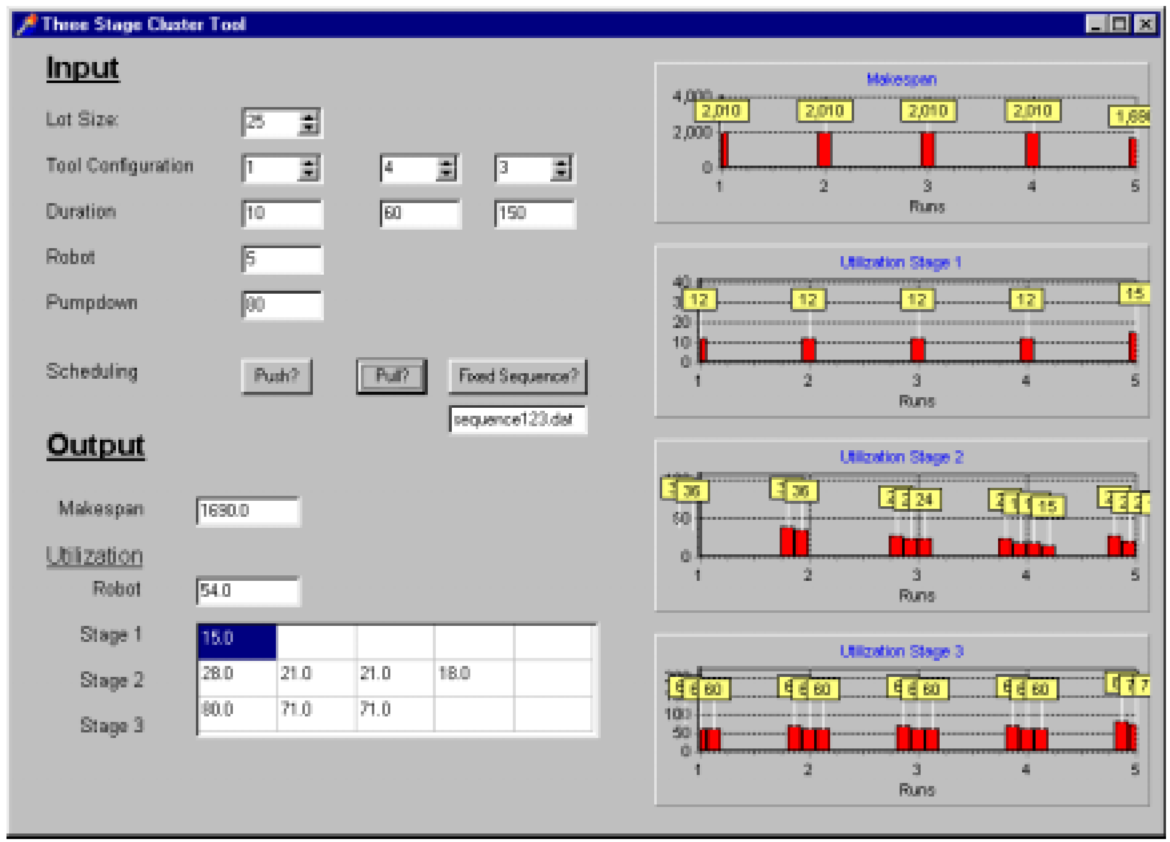


EquiPSim: Hands-On Training in Semiconductor Equipment and Process Behavior

We have developed EquiPSim (Equipment and Process Simulation), a software-based learning system for semiconductor manufacturing aimed at providing active hands-on experience in vacuum and gas flow technology, heat transfer mechanisms, chemical reaction processes, process control approaches, and optimization strategies. A validated simulator engine constructed under commercial PC-based dynamic simulation software (VisSim™) expresses physically-based time-dependent response to variations in the equipment controls represented, allowing the user to operate the system freely and observe realistic responses. Visualization of the system is accomplished through an enhanced graphical user interface, built on a Delphi v/4 visual development platform. This platform then becomes an engineered learning system by incorporating not only an improved visual representation of the system, but with a host of user-controllable learning aides, including: a guidance section of hypertext, accessed locally or over the Internet; active links between the guidance materials and the visual system representation; tools for modifying system design parameters; a lab notebook for recording design parameter sets along with annotation of results of user experiments; facilities for distance collaboration; and a learning historian for recording, reviewing, revising, and replaying action sequences. The content is aimed at both novices and more experienced engineers (depending on concept being treated). The software architecture is structured to facilitate separable authoring, in which the domain expert need concentrate only on the physical fidelity of the simulator and the guidance concepts to be taught, while the user interface is built from templates and predefined application objects.

Discrete Event Simulation and Factory Operations

- Expand learning systems to support legacy code (Fortran, C/C++, …)
- Cluster tool simulator (logistics, scheduling) - implemented in Java, now incorporated into engineered learning system



- Factory operations simulator (Factory Explorer), consisting of Excel front end which drives simulation engine, now incorporated into engineered learning system

Simulator-Based Manufacturing Education and Training for Microelectronics Processing

- **NSF grant EEC - 9526147, 9/15/95 - 8/31/00, PI G. W. Rubloff, $600K**

- **Goal**
  - *Develop and assess methodologies in which physically-realistic simulation tools can be incorporated into broader software-based learning environments which are available anytime, anywhere, and which can provide value not only for experienced engineers, but also for manufacturing operators or technicians with little relevant technical background*

- **Manufacturing Training Modules - for operators, technicians, and students with little technical background**
  - *Vacuum-Based Process Equipment*
  - *Heat Transfer*
  - *Chemical Processes*

- **Engineering Design Modules - for practicing engineers and graduate students**
  - *Statistics and Design Optimization*
  - *Process Control*

Simulation-Based Learning Systems for Environmentally-Benign Semiconductor Manufacturing

- **NSF grant EEC, 10/1/99-9/30/02, $400K**
- **PI G. W. Rubloff (U. Maryland ISR), Co-PI F. Shadman (U. Arizona CEBSM)**
- **Goals**
  - *Education modules at 3 levels: undergraduate, graduate, practitioners*
  - *Incorporation of legacy simulators*
  - *Simulation explorer*
  - *Educational assessment*

Wish List for ESH Learning Systems

- **User-driven system design**
  - *Choose individual system components*
  - *Expand and reconfigure network*
- **Exploit existing models and simulations**
  - *Utilize existing codes directly (Fortran, …)*
  - *Generate compact models in simple, systematic fashion*
- **Facilitate design and optimization of control system**
  - *Incorporate various control systems elements*
  - *Experiment with optimization and fault management algorithms*

- **Build the basis for systems design and optimization**
  - *Educate new practicioners*
  - *Support systems engineering for current practicioners*