

GAMS

Productivity - Performance - Reliability

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GAMS Software GmbH

Annual Review Meeting CAPD,
CMU Pittsburgh, PA, March 12 – 13, 2007



Agenda

GAMS

Productivity

Performance

Reliability



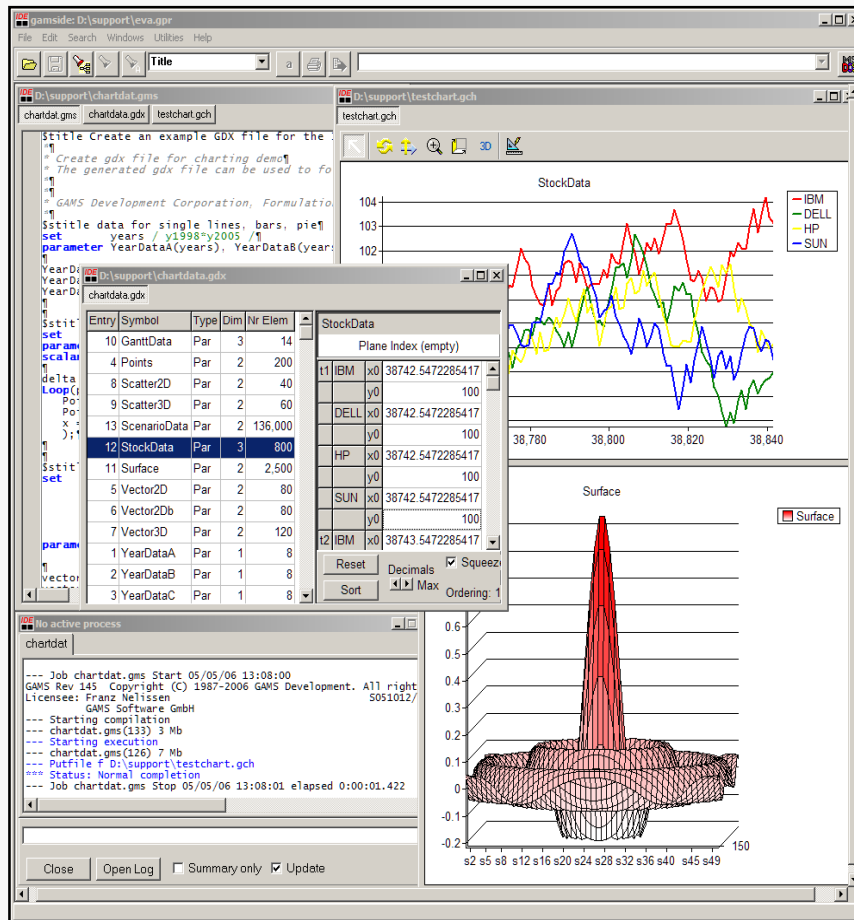
- Roots: Research project World Bank 1976
 - Pioneer in Algebraic Modeling Systems used for economic modeling
 - Went commercial in 1987
 - Offices in Washington, D.C and Cologne
- Professional software tool provider, not a consulting company
 - Operating in a segmented niche market
 - Broad academic & commercial user base and network

Typical Application Areas *



-
- | | |
|---------------------------|-------------------------------|
| • Agricultural Economics | • Applied General Equilibrium |
| • Chemical Engineering | • Economic Development |
| • Econometrics | • Energy |
| • Environmental Economics | • Engineering |
| • Finance | • Forestry |
| • International Trade | • Logistics |
| • Macro Economics | • Military |
| • Management Science/OR | • Mathematics |
| • Micro Economics | • Physics |
-

* Illustrative examples in the GAMS Model Library



General Algebraic Modeling System:
Algebraic Modeling Language,
Integrated Solver, Model Libraries,
Connectivity- & Productivity Tools

Design Principles:

- Balanced mix of declarative and procedural elements
- Open architecture and interfaces to other systems
- Different layers with separation of:
 - model and data
 - model and solution methods
 - model and operating system
 - model and interface

Multiple Solvers & Platforms



Solver/Platform availability - 22.4 February 14, 2007										
	x86 MS Windows	x86_64 MS Windows	x86 Linux	x86_64 Linux	Sun Sparc SOLARIS	HP 9000 HP-UX 11 ¹	DEC Alpha Digital Unix 4.0	IBM RS-6000 AIX 4.3	SGI IRIX ²	Mac PowerPC Darwin
BARON 7.7	✓	32bit	✓	32bit				✓		
BDMLP	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
COIN	✓	32bit	✓	✓						✓
CONOPT 3	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
CPLEX 10.1	✓	✓	✓	✓	✓	10.0	8.1	✓	9.1	
DECIS	✓	✓	✓	✓	✓	✓	✓	✓	✓	
DICOPT	✓	✓	✓	✓	✓	✓	✓	✓	✓	
KNITRO 5.1	✓	32bit	✓	✓						✓
LGO	✓	✓	✓	✓	✓	✓	✓			✓
MILES	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
MINOS	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
MOSEK 4	✓	✓	✓	✓	✓	3.2				✓
MPSGE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
MSNLP	✓	✓	✓	✓	✓	✓			✓	✓
NLPEC	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
OQNLP	✓	32bit	✓	32bit						
OSL V3	✓	32bit	✓	32bit	✓	V2		✓	V2	
OSLSE	✓	32bit	✓	32bit	✓			✓		
PATH	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
SBB	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
SNOPT	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
XA	✓	32bit	✓	✓	✓	✓	✓	✓		
XPRESS 17.10	✓	32bit	✓	32bit	✓	16.10		✓		
¹ GAMS distribution for HP 9000/HP-UX is 22.1.										
² GAMS distribution for SGI IRIX is 22.3.										
Contributed Plug&Play solvers										
AMPLwrap	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
DEA	✓	✓	✓	✓	✓	✓		✓	✓	
Kestrel	✓	32bit	✓	32bit	✓					
For backward compatibility we maintain older versions of operating systems and solvers. Please call.										



Downloads

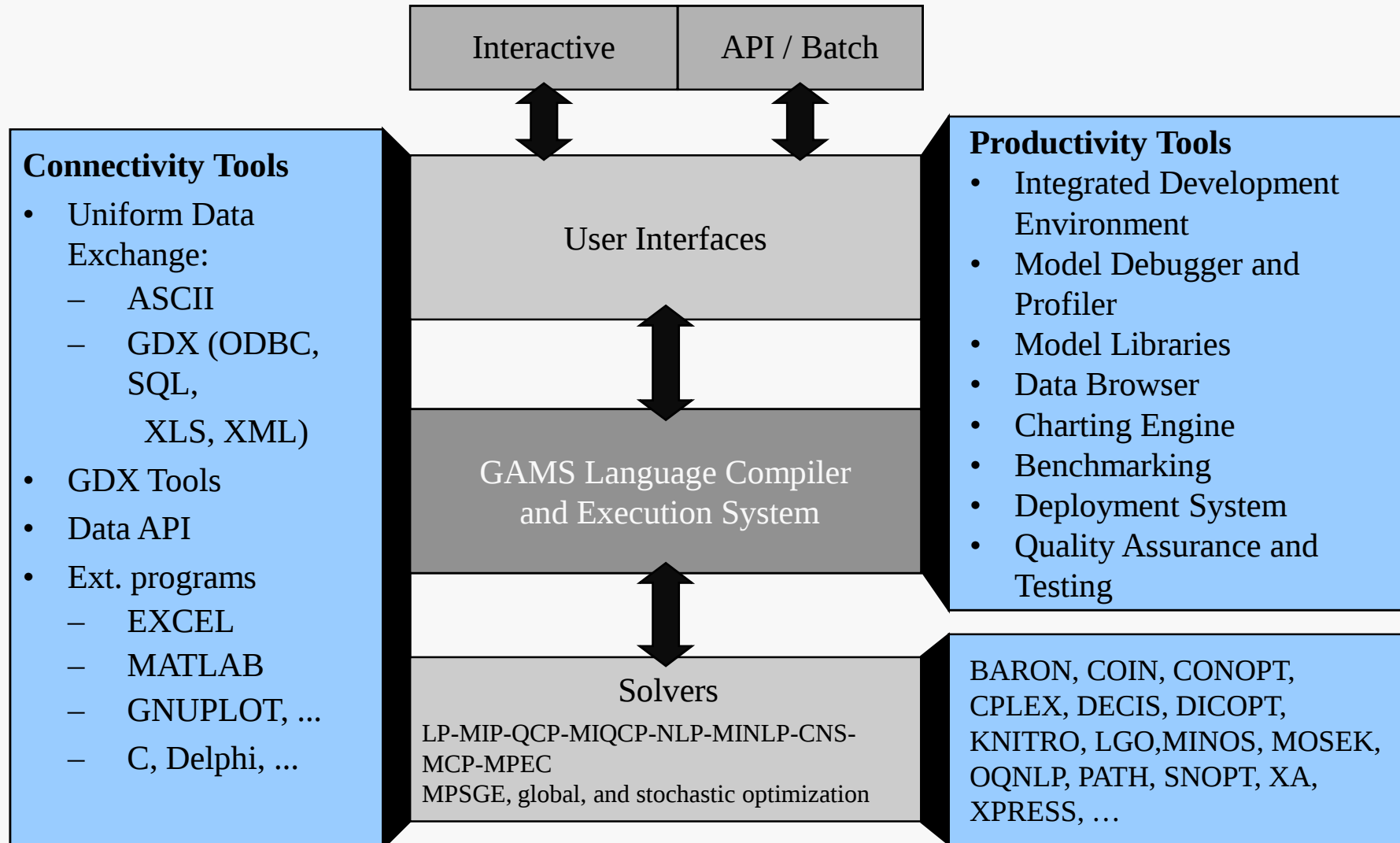
Downloads 2007-02-12 to 2007-03-11

- 9 aix
- 13 axu
- 47 dar
- 6 hp7
- 46 lex
- 100 lnx
- 4 sgi
- 17 sol
- 321 wex
- 1400 win

~ 500 downloads
a week

Total: 1963

System Overview



Who are the GAMS Users?



- (Academic) Researcher
 - One time use (Research Paper)
- Model Expert
 - Model Results used for Consulting
- Black Box User
 - Model integrated in (Optimization) Application

‡ Each Category has its own needs



What are their Risks?

... Relevant new features for productivity increase...

... Performance gains...

... Long term reliability...

User's Risks



Agenda

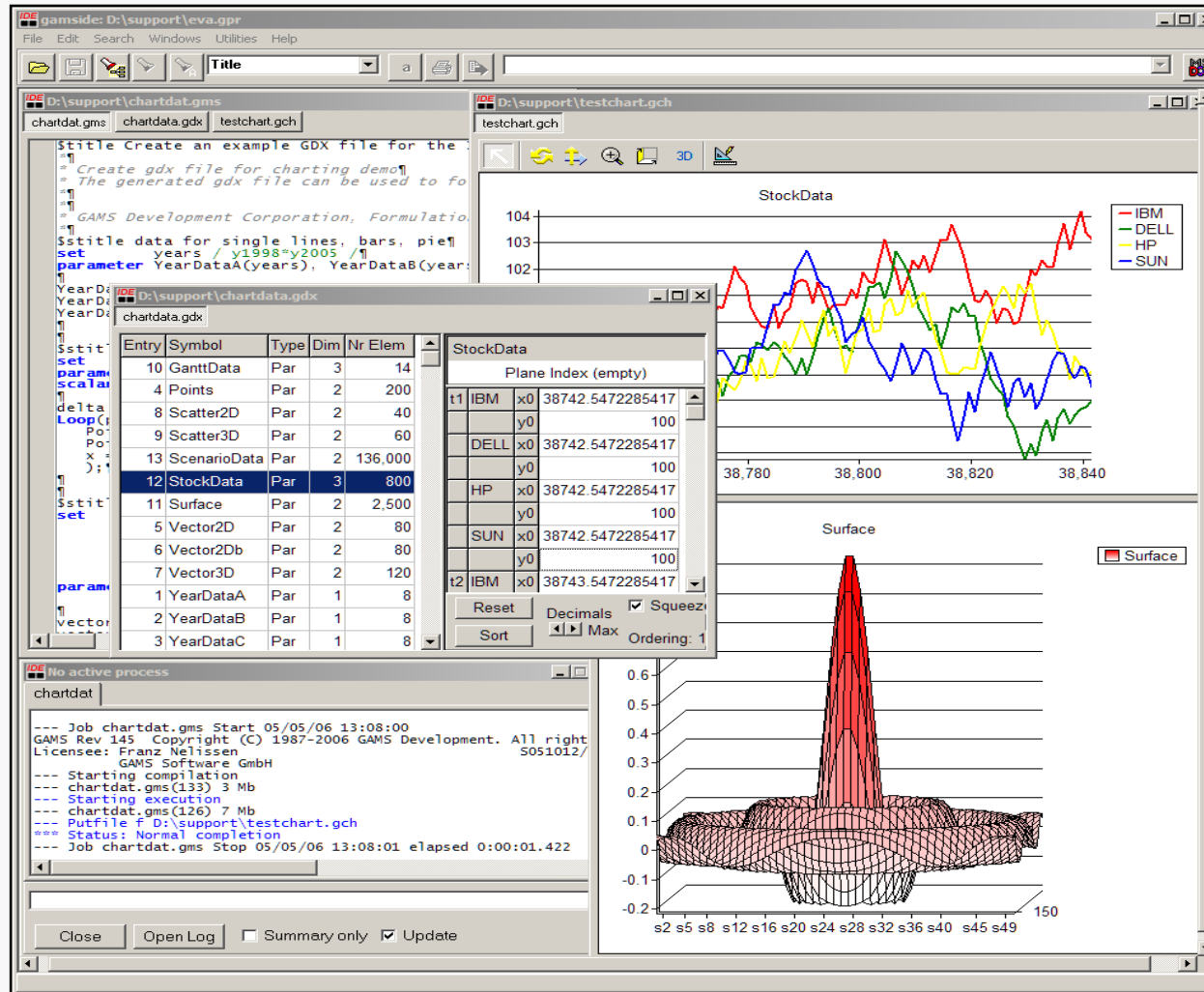
GAMS

Productivity

Performance

Reliability

Integrated Development Environment



“Solver” Convert



The screenshot displays the GAMS IDE interface. The main window shows a GAMS model named 'transport.gms' with the following content:

```

$title A Transportation Problem (TRNSPORT,SEQ=1)
$ontext
This problem finds a least cost shipping schedule that meets
requirements at markets and supplies at factories.

Dantzig, G B, Chapter 3.3. In Linear Programming and Ext.
Princeton University Press, Princeton, New Jersey, 1963.

This formulation is described in detail in:
Rosenthal, R E, Chapter 2: A GAMS Tutorial. In GAMS: A User's Guide.
The Scientific Press, Redwood City, California, 1988.

The line numbers will not match those in the book because of
comments.
$offtext

Sets
  i  canning plants / seattle, san-diego /
  j  markets        / new-york, chicago, topeka /

Parameters
  a(i) capacity of plant i in cases
      / seattle    350
        san-diego  600 /
  b(j) demand at market j in cases
      / new-york   325

```

The output window shows the execution results:

```

trnsport
Reading parameter(s) from "C:\Documents and Settings\Jan\My Documents\cmu\trnsport.gms"
>> All
Finished reading from "C:\Documents and Settings\Jan\My Documents\cmu\trnsport.gms"
--- Writing Ampl : ampl.mod
--- Writing AmplNLC : amplnlc.c
--- Writing Baron : gams.bar
--- Writing CplexLP : cplex.lp
--- Writing CplexMPS : cplex.mps
--- Writing FixedMPS : fixed.mps
--- Writing Gams : gams.gms
--- Writing Lgo : lgo.gms
--- Writing LindoMPI : lindo.mpi
--- Writing Lingo : lingo.lng
--- Writing AlphaECP : alpha.ecp
--- Writing Minopt : minopt.dat
--- Writing NLP2MCP : gamsnlp2mcp.gms
--- Writing ViennaDag : vienna.dag
--- Writing CoinFML : coinfml.xml
--- Writing Dict : dict.txt
--- Writing Jacobian : jacobian.gdx
--- Writing Lgo : lgomain.for

--- Restarting execution
--- trnsport.gms(66) 0 Mb
--- Reading solution for model transport
--- Executing after solve
--- trnsport.gms(68) 3 Mb
*** Status: Normal completion
--- Job trnsport.gms Stop 03/10/07 22:38:05 elapsed 0:00:00

```

At the bottom of the output window, there are buttons for 'Close', 'Open Log', and checkboxes for 'Summary only' and 'Update'.

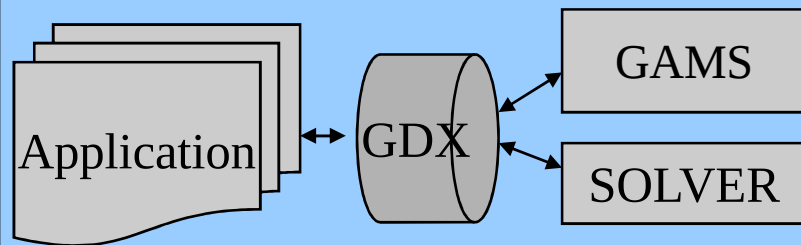
Integrated Development Environment



È DEMO

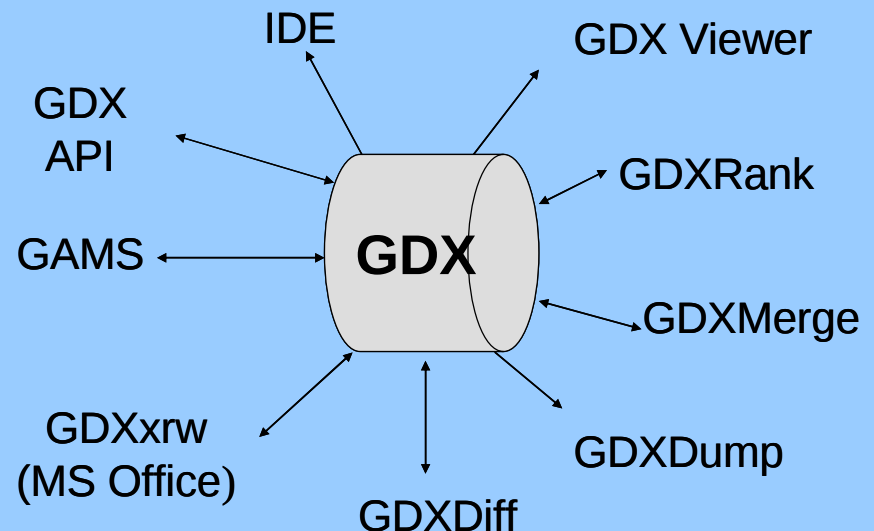
Gams Data eXchange

Binary Data Exchange

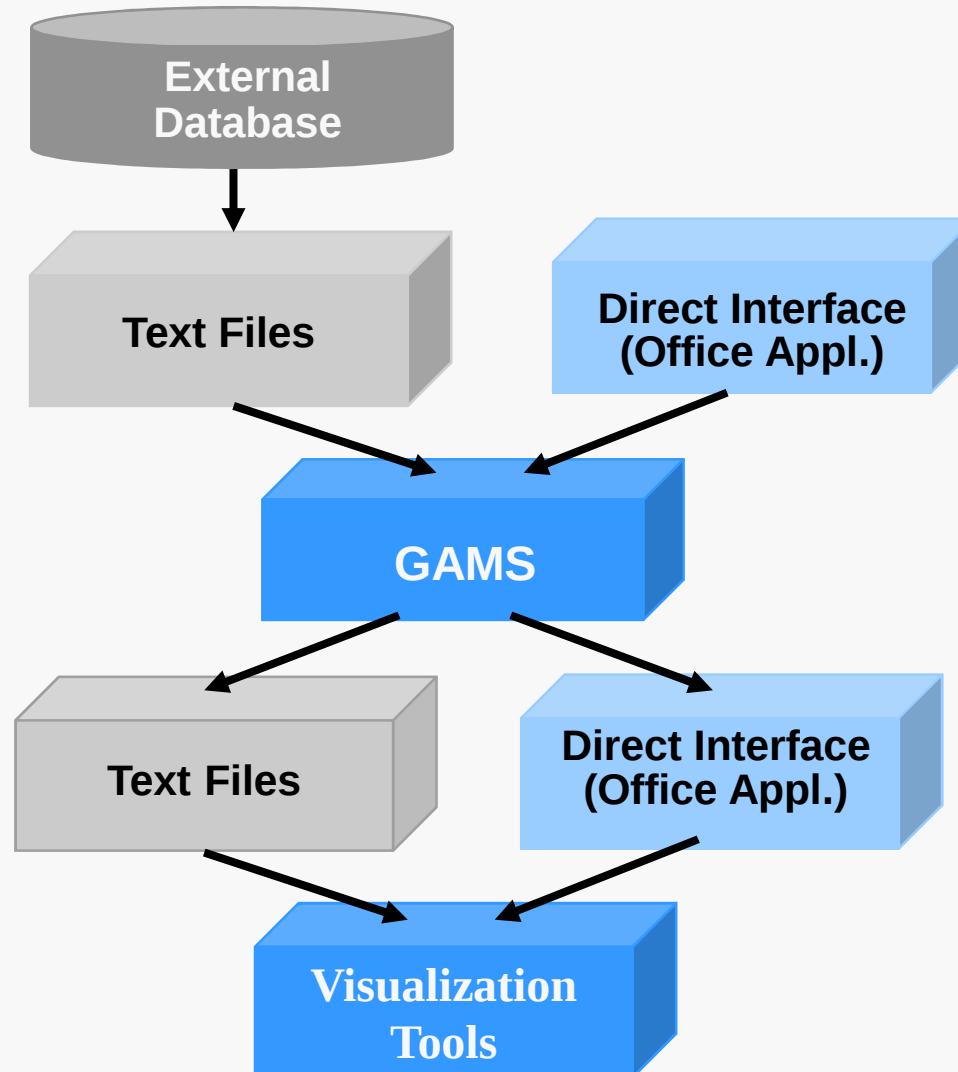


- Complements ASCII data exchange
- Data exchange at any stage
 - Supports ODBC and XML
 - Direct Excel connectivity
 - General API
- Visual Inspection
- Scenario Management Support
- Full Support of Batch Runs

GDX Tools



GAMS in Control

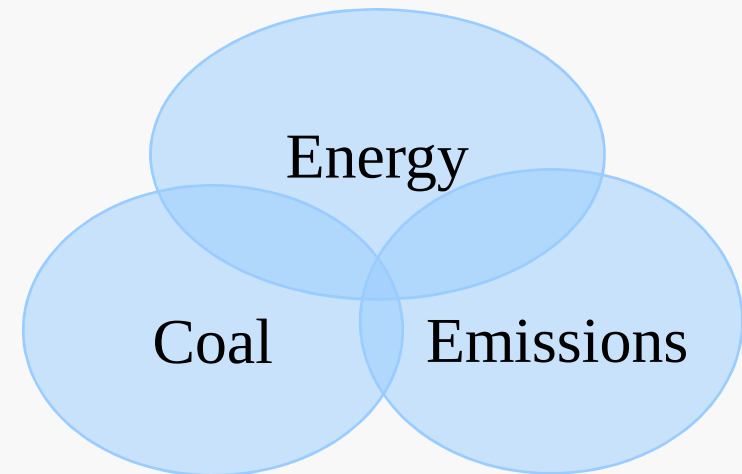


Import

Export

Goal:

- Single annual model
- Unique detail level
- Long term energy outlook



Size:

- MIP, 7.5 million var., 3.5 million con.
- Reduction of almost 80 %, while optimal solution changed by only 0.5 %

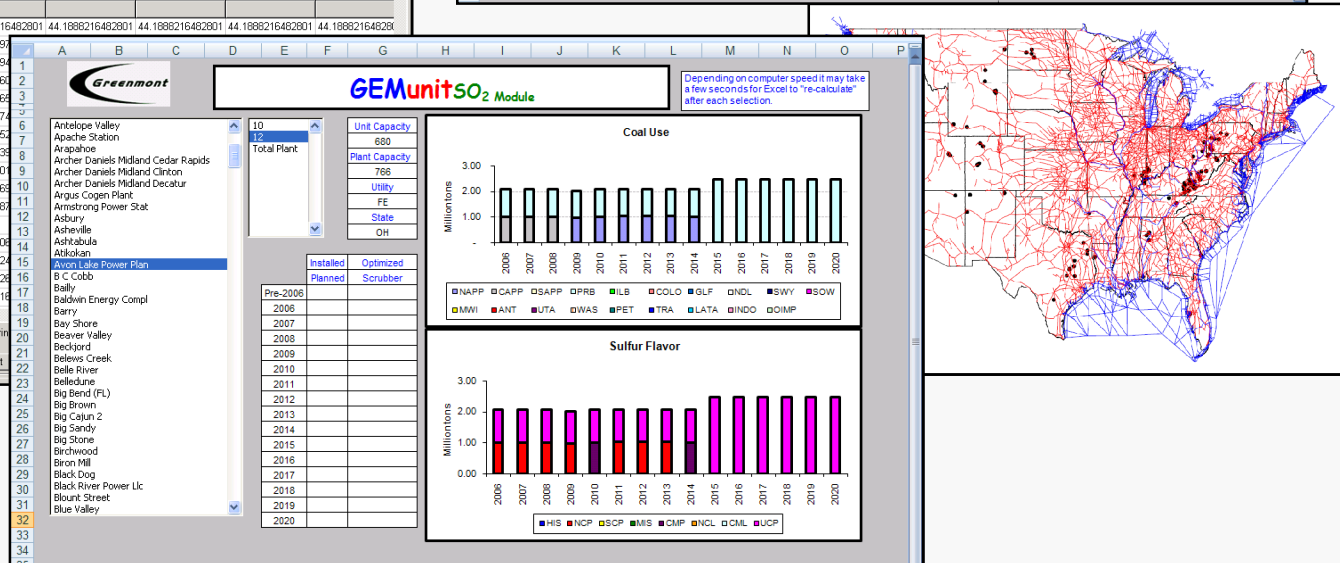
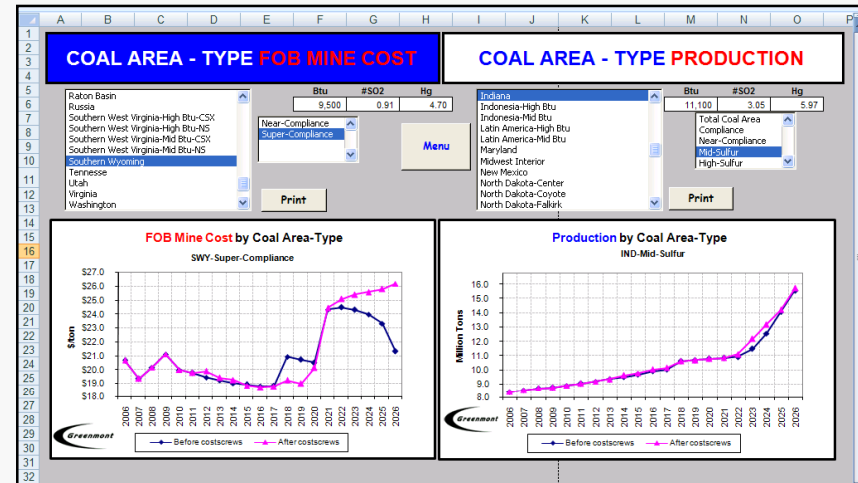
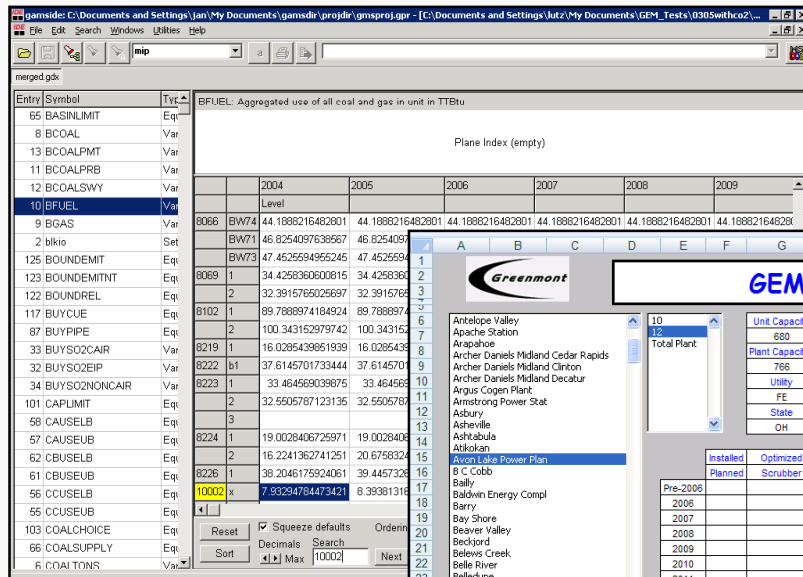
GAMS

How Clients want to use our interfaces

Annual Review Meeting 2007

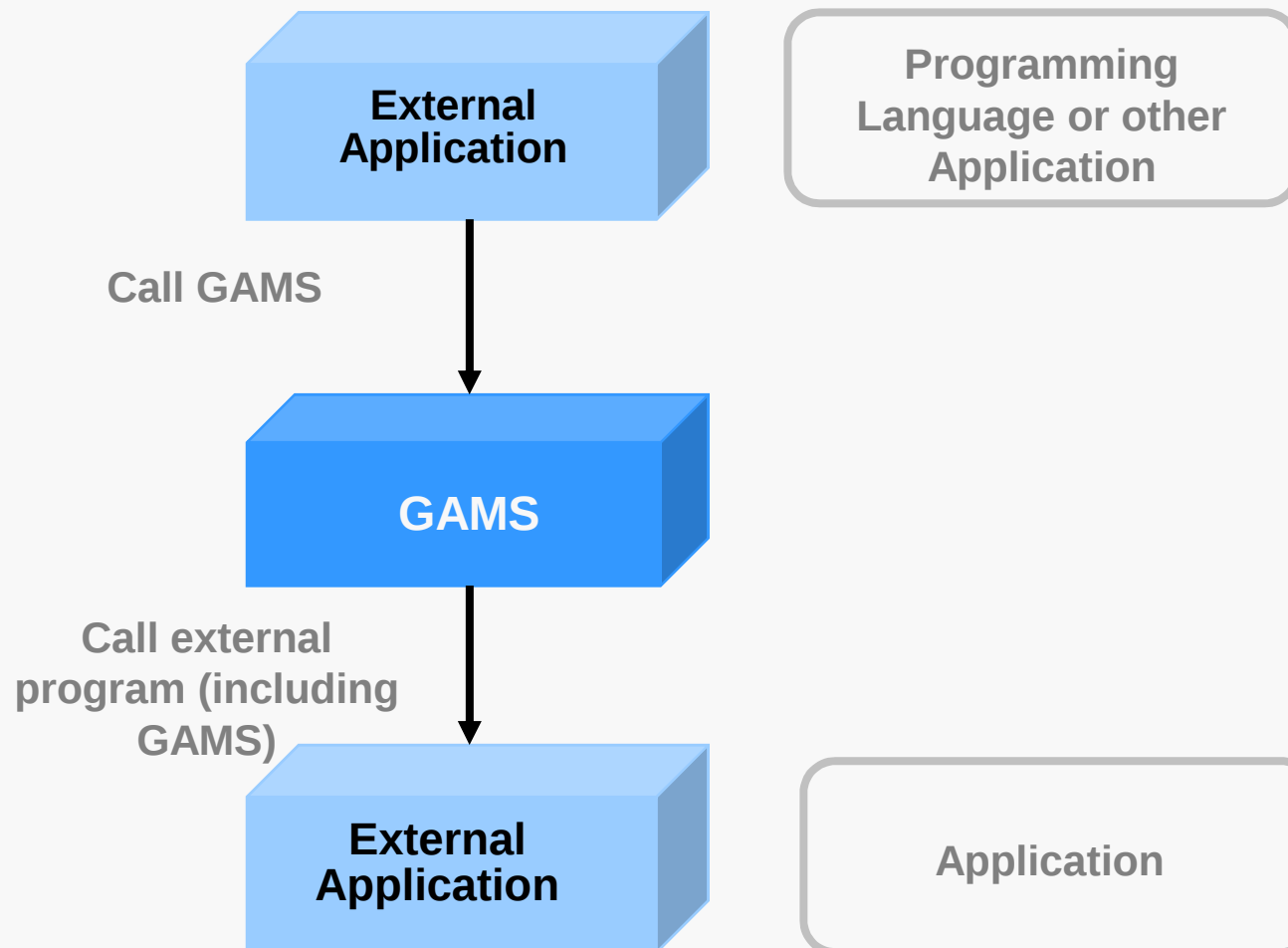


Energy Model



È DEMO

Application in Control



Samurai Sudoku



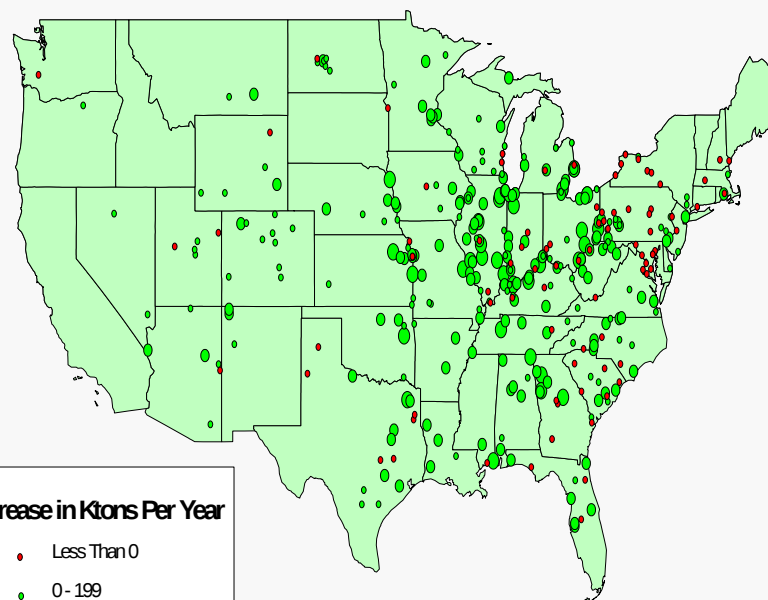
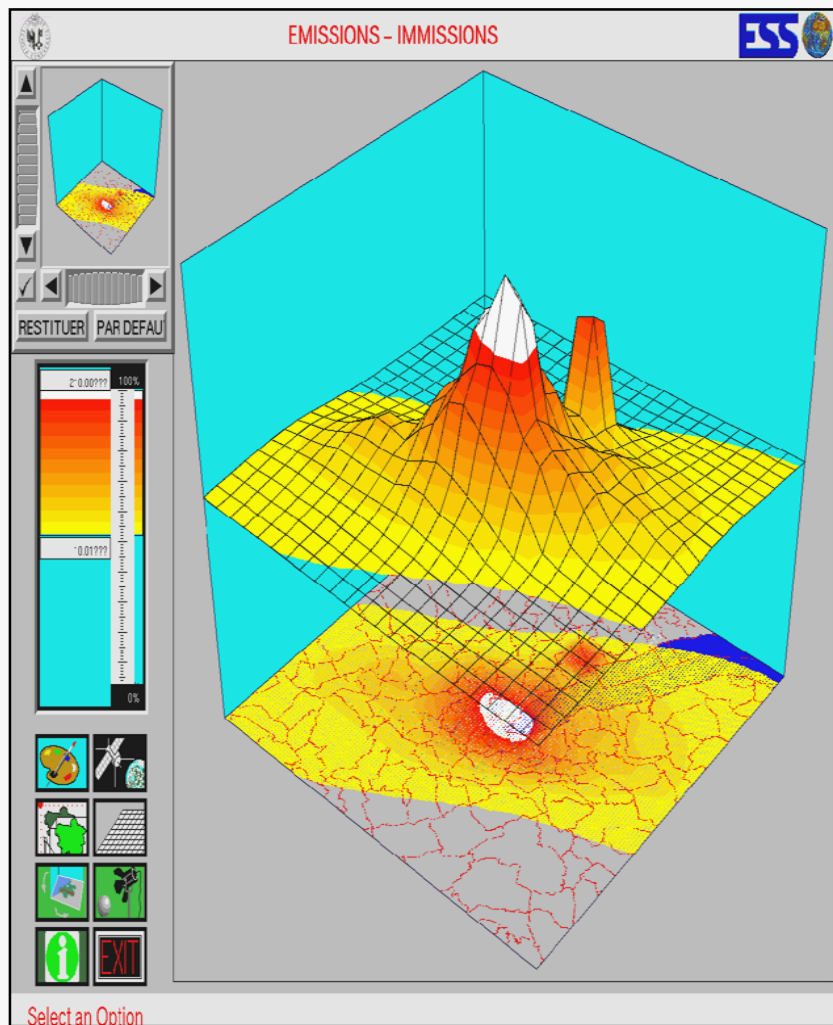
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
1																							
2		8							6						2						3		
3	4	7							5	1					3	7					8	9	
4			5	8			1	9								5	7		3	1			
5			9		5		6									9		5		4			
6				1		6											8		9				
7			3		7		2									4		7		3			
8			4	5		3	1									2	4		7	6			
9	5	3							2	4					1	3						7	4
10		6							3			2				4						2	
11										4		6											
12									3				8										
13										3		8											
14		5						7			1			8							1		
15	2	4						9	1					7	2						9	8	
16			9	8			2	6								9	7		6	2			
17			2		4		9									3		2		4			
18				2		7											6		3				
19			1		3		2										7		1		5		
20			8	5		3	4										2	4		9	1		
21	6	1							5	8							1	7				4	5
22		2							3								4					2	
23																							

Application in Control



È DEMO

Interfacing with GIS Applications



Increase in Ktons Per Year

- Less Than 0
- 0 - 199
- 200-1000
- 1000-3000

Interfacing with MATLAB

Figure 1: US dollar short rate scenarios

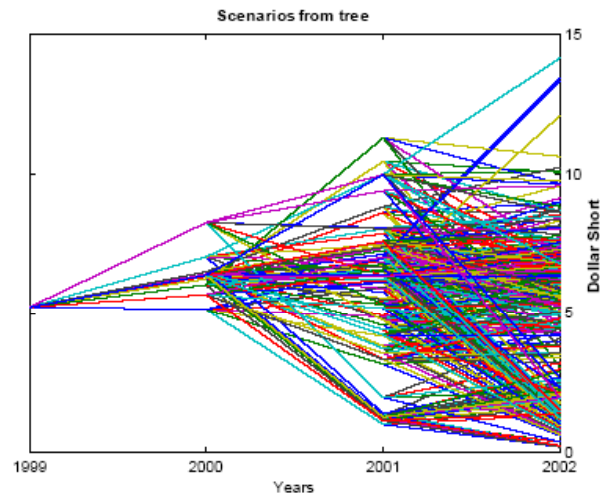
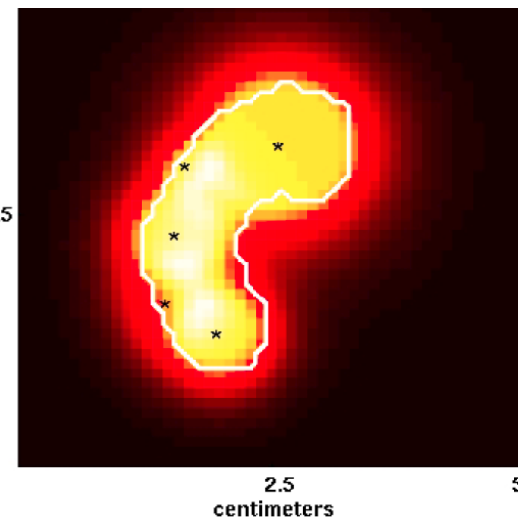
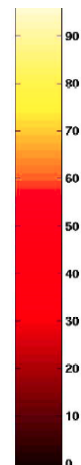
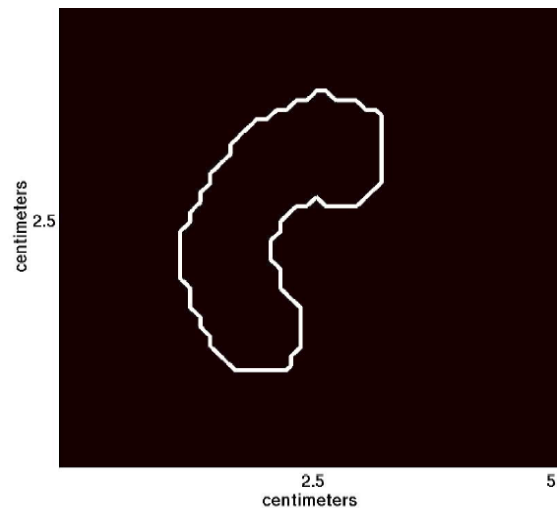
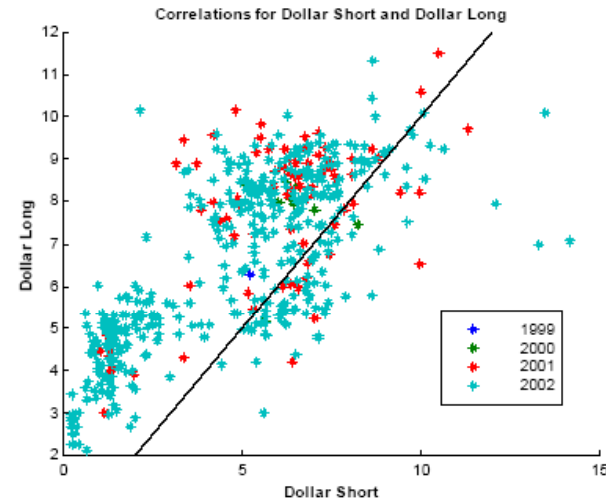


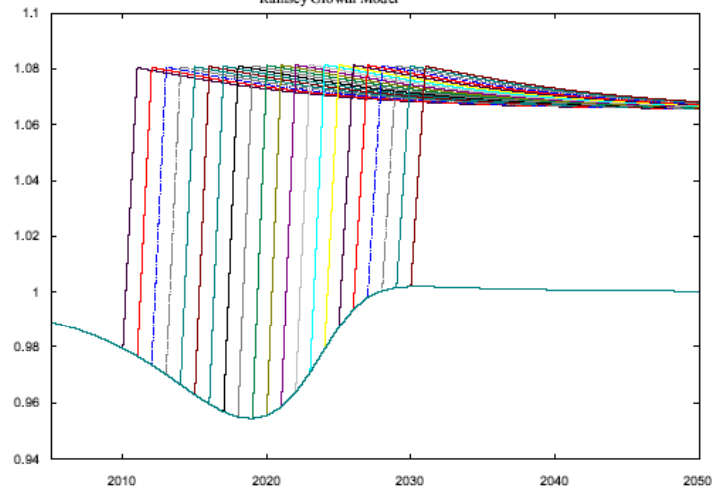
Figure 2: Short vs. long rates



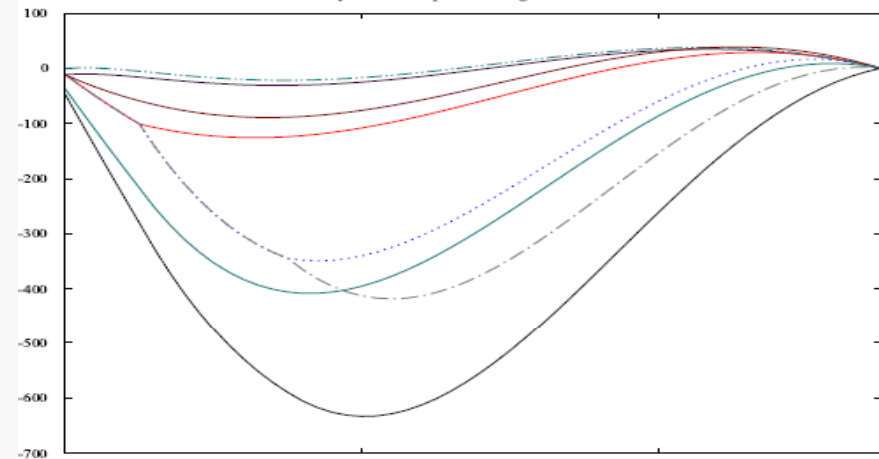
Interfacing with GNUPLLOT

Investment

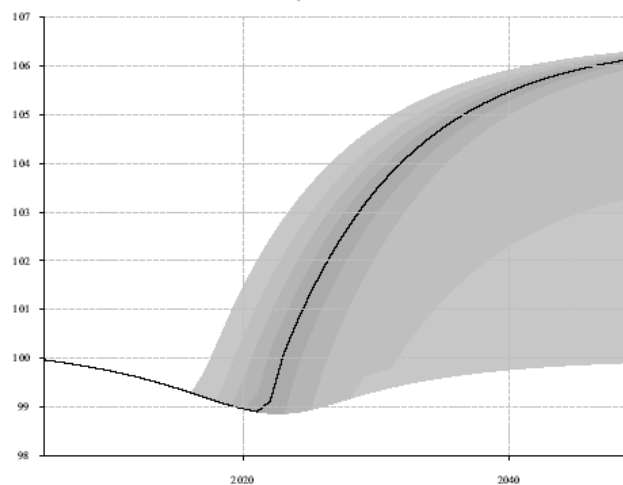
Ramsey Growth Model

**Asset Balances with Borrowing**

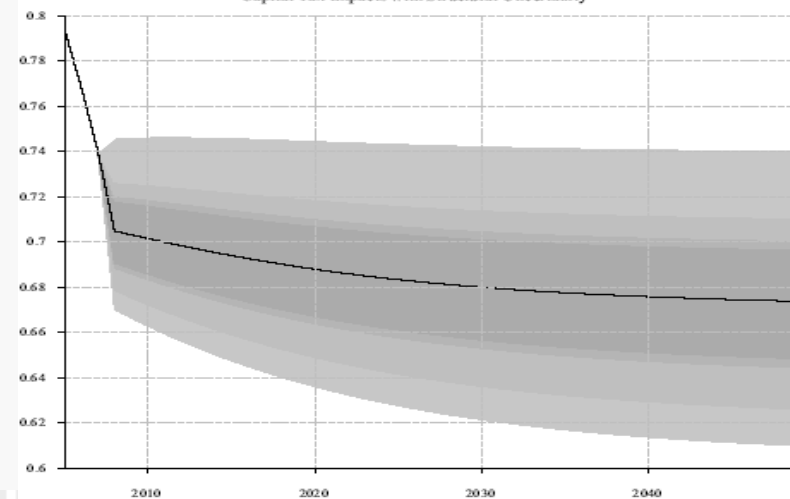
Lifecycle Consumption-Savings Model

**Fan Plot of Output Distribution**

Ramsey Growth Model

**Investment**

Capital Tax Impacts with Structural Uncertainty



Interfacing with Web Applications



Cadet Schedules with Constraint Violations, AYT 2001-1

Header Information

Select Constraint Type: 3 FREE HOUR CONSTRAINT Free Hour Violations: 43 →

Filter by: Design Group Violations: 4 →

Unbalanced Schedule Violations: 7 →

Cadets With Schedule Violations FREE HOUR CONSTRAINT

Course	Total Enrollment	Name	SSN	Grad Yr	Reviewed
EM362A		BASS, WILLIE C.		2002	☐
PH365		BROWN, JAMEY A.		2002	☐
EM362A		BUNTING, BRIAN M.		2002	☐
EM301A		CHONOWSKI, DAVID P.		2002	☐
EN302		COOPER, GRAIG W.		2002	☐
EM301A		CULLUMBER, CRAIG M.		2002	☐
EM362A		DONNELL, TYLER R.		2002	☐
EM362A		EDGAR, BENJAMIN T.		2002	☐

Cadets: 43

Name: **BASS, WILLIE C.** FOS1: Civil Engineering Major FOS2:

Eng Seq: CIVIL ENGINEERING TQPA: 2.414 CQPA: 2.699 (3) 1 Day (3) 2 Day

Activity Code(s): CSWV

Hour	Course	Violation	Override
A	PE310		
B	MA364		
C	PL300		
D	PL300		
E	EM362A	FREE HOUR CONSTRAINT	
F	EM362A	FREE HOUR CONSTRAINT	

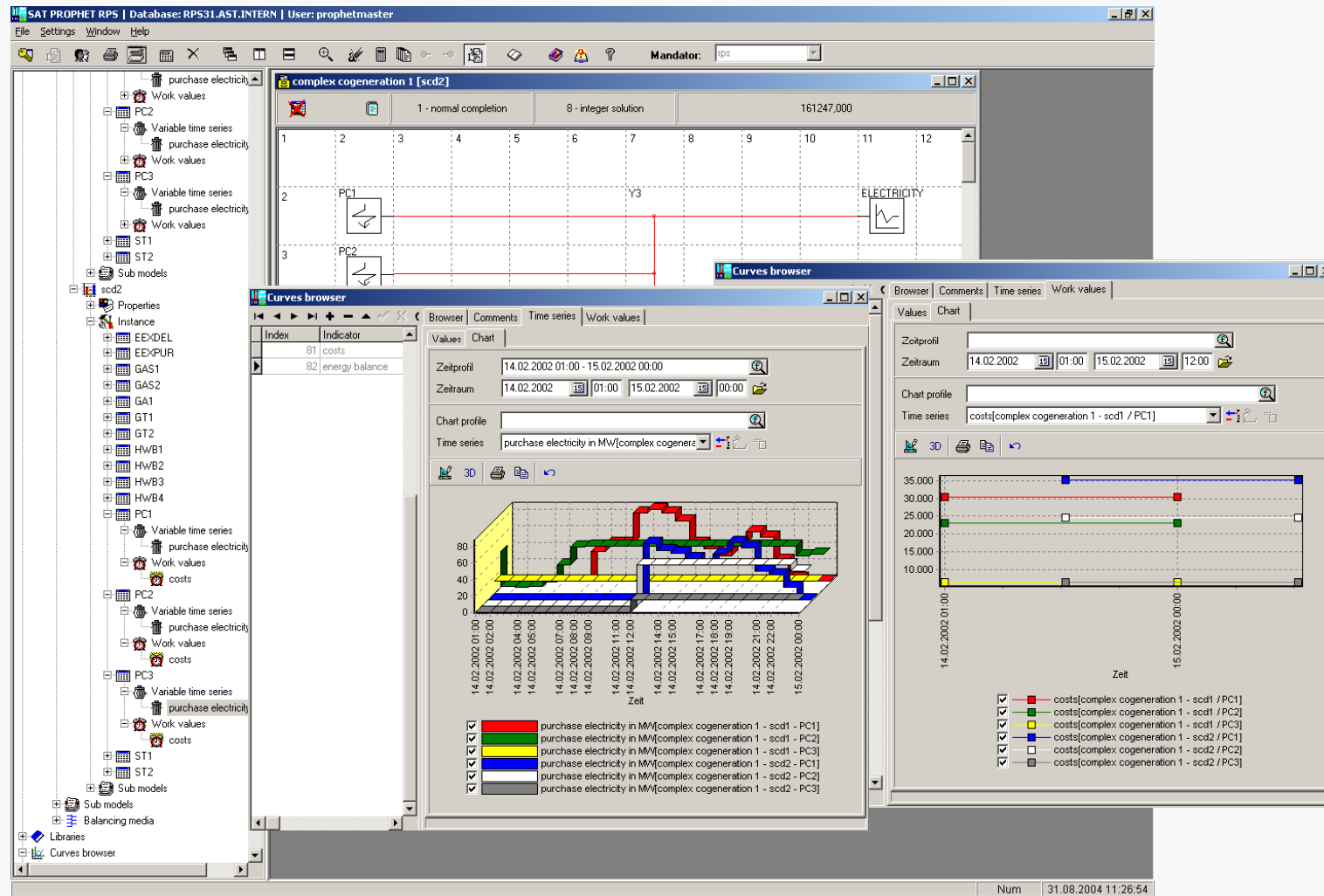
Z Hour

Hour	Course	Violation	Override
G	SS307		
H	HI301		
I	EM364A		
J	EM364A		
K	, R		
L			

Schedule

OK Close

Individual Front Ends



Deployment



The screenshot shows the GAMS IDE with the following components:

- IDE Window:** Displays the deployment model code in `deploy.gms`. The code includes a title, context, instructions, and a set of products.
- File Explorer:** Shows the `gmsdeploy.zip` file in the `C:\Documents and Settings\utlz\Desktop\CMU\CMU.gpr` directory.
- GAMS Model Library:** A window showing a search for `dep` with the following results:

SeqNr	Name +	Application Area	Type	Contributor	Description
092	DEM07	Agricultural Economics	NLP	Kutcher, G P	Nonlinear Simple Agricultural Sector Model
308	DEPLOY	GAMS Language Features	GAMS	GAMS Develop	GAMS Deployment Model
176	DICE	Mathematics	MIP	Gardner, M	Non-transitive Dice Design
272	DICEX	Mathematics	MIP	Bosh, R A	Non-transitive Dice Design - Enhanced

The selected model is **GAMS Deployment Model (DEPLOY,SEQ=308)**. The description states: "This model creates a GAMS deployment system".

Deployment



È DEMO



Agenda

GAMS

Productivity

Performance

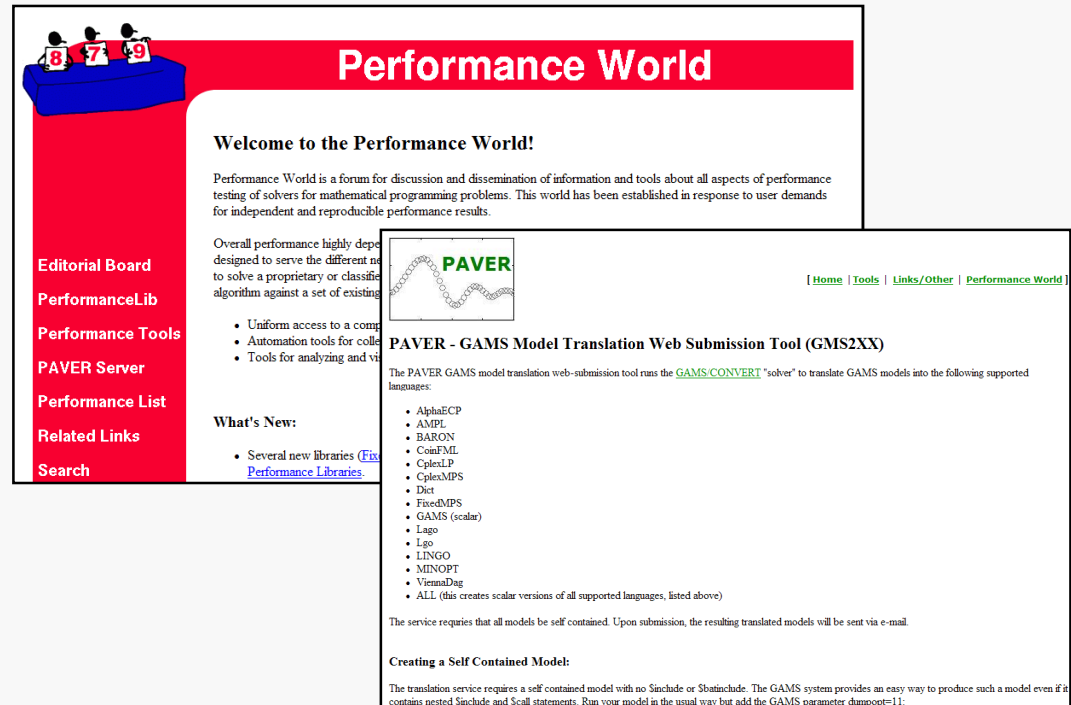
Reliability

Performance Analysis

- Solver **robustness** and **correctness**
- Solver **efficiency**
- **Quality of solution** (nonconvex and discrete models)

‡ Cross comparison of solver resource times

- Cone World
- Global World
- MINLP World
- MPEC World
- MPSGE World
- Performance World $\neq$ PAVER
- Translation World $\neq$ Convert



Performance World

Welcome to the Performance World!

Performance World is a forum for discussion and dissemination of information and tools about all aspects of performance testing of solvers for mathematical programming problems. This world has been established in response to user demands for independent and reproducible performance results.

Overall performance highly depends on the solver used. The Performance World is designed to serve the different needs of users to solve a proprietary or classified algorithm against a set of existing solvers.

- Uniform access to a common set of solvers
- Automation tools for collecting performance results
- Tools for analyzing and visualizing performance results

What's New:

- Several new libraries ([Fix Performance Libraries](#))

PAVER - GAMS Model Translation Web Submission Tool (GMS2XX)

The PAVER GAMS model translation web-submission tool runs the [GAMS/CONVERT](#) "solver" to translate GAMS models into the following supported languages:

- AlphaECP
- AMPL
- BARON
- ConFNL
- CplexLP
- CplexMPS
- Dct
- FicoDMPs
- GAMS (scalar)
- Lgo
- Lgo
- LINGO
- MINOPT
- VienaDag
- ALL (this creates scalar versions of all supported languages, listed above)

The service requires that all models be self contained. Upon submission, the resulting translated models will be sent via e-mail.

Creating a Self Contained Model:

The translation service requires a self contained model with no \$include or \$binclude. The GAMS system provides an easy way to produce such a model even if it contains nested \$include and \$call statements. Run your model in the usual way but add the GAMS parameter `changepopt=11`.

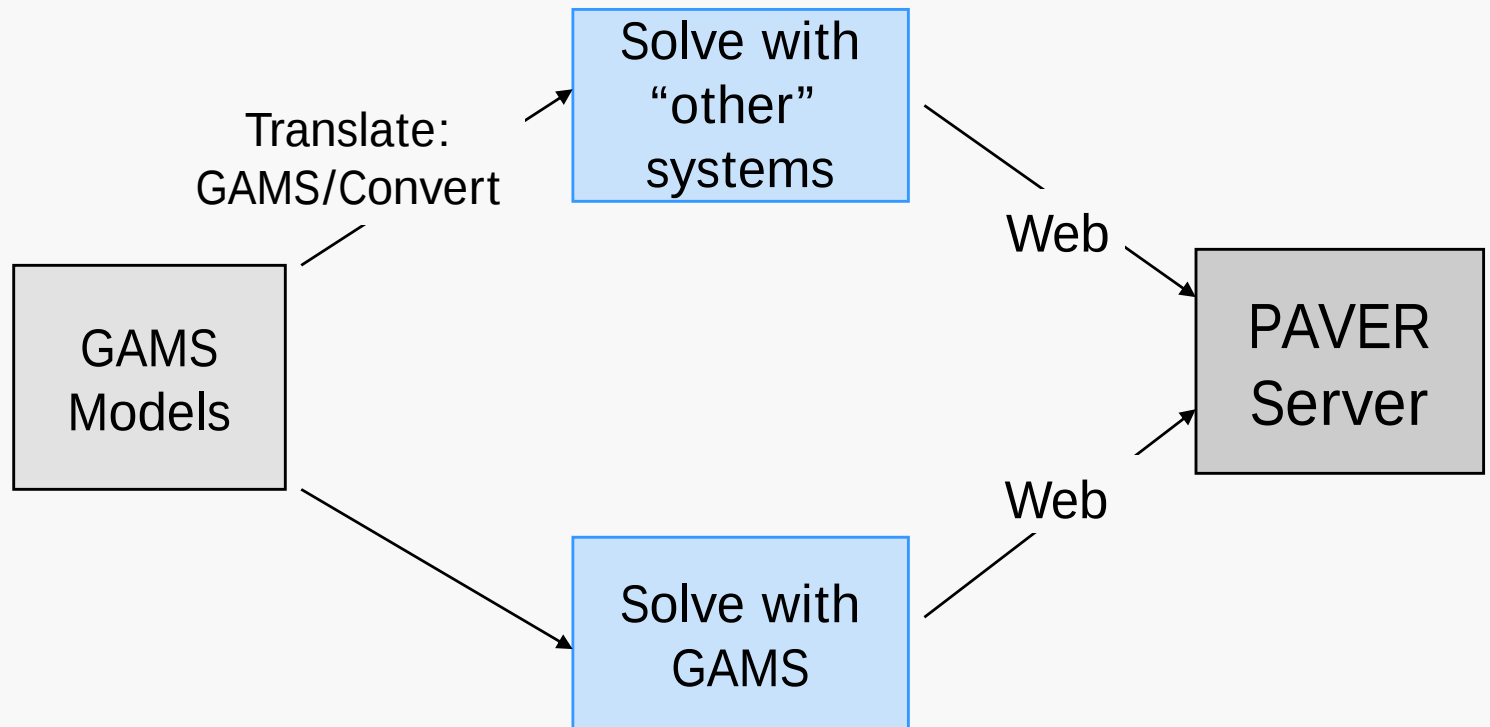


- **Performance Analysis and Visualization for Effortless Reproducibility**

www.gamsworld.org/performance/paver

- Online server to facilitate performance testing and analysis/visualization
- Results sent via e-mail in HTML format
 - **System independent**

Open Testing Architecture

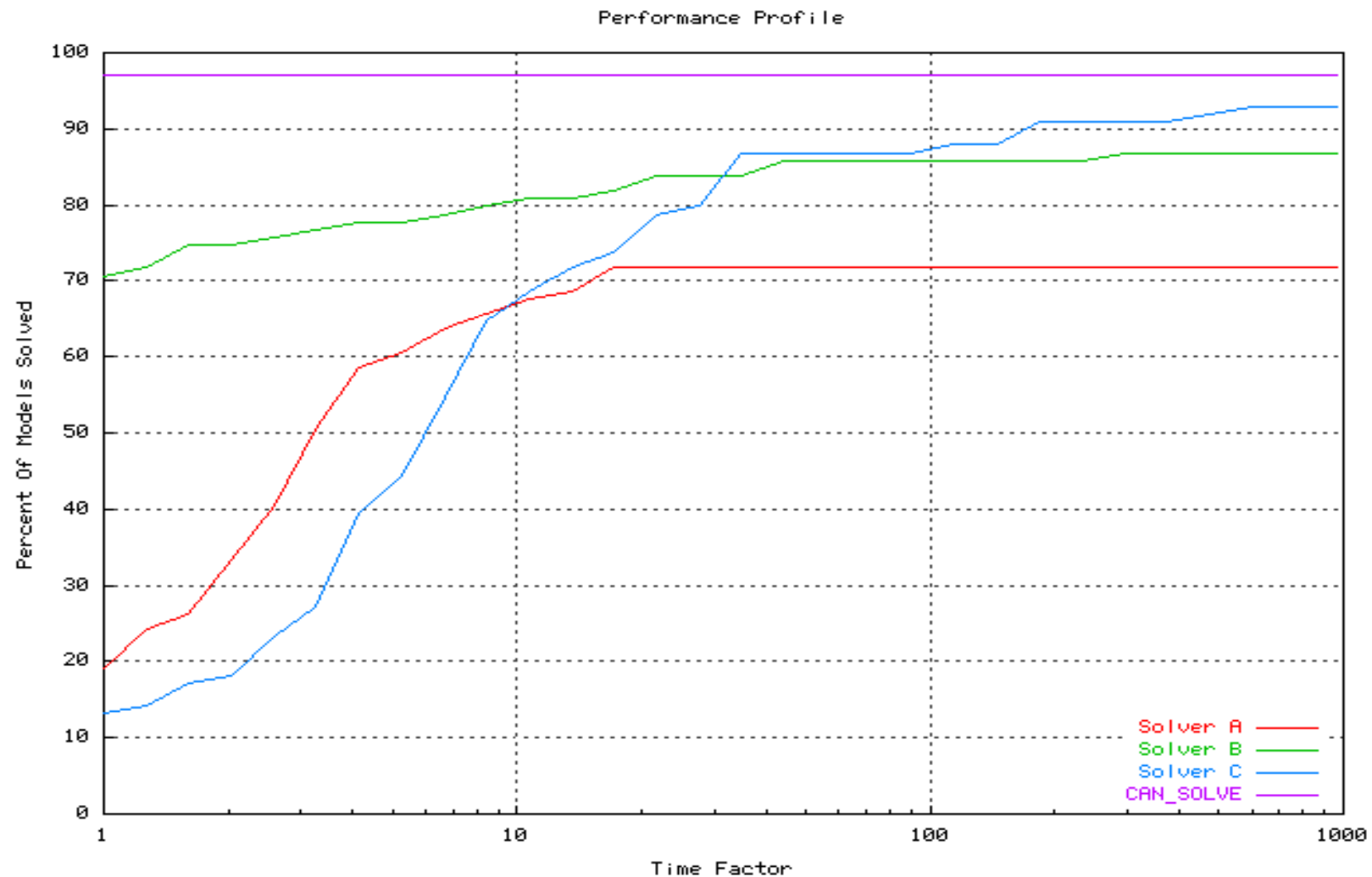


I. Models

II. Data
Collection

III. Analysis &
Visualization

Analysis / Visualization





È DEMO

Agenda

GAMS

Productivity

Performance
↳ **Grid Computing**

Reliability



Grid Computing

Imagine...

.. you have to solve 1.000's of independent scenarios...

.. and you can do this very rapidly for little additional money...

.. without having to do lots of cumbersome programming work...

Grid Computing

What is Grid Computing?

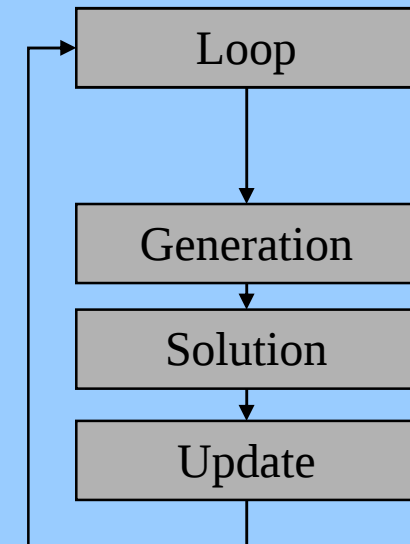


A pool of connected computers managed and available as a common computing resource

- Effective sharing of CPU power
- Massive parallel task execution
- Scheduler handles management tasks
- E.g. Condor, Sun Grid Engine, Globus
- Can be rented or owned in common
- Licensing & security issues

Simple Serial Solve Loop

```
Loop(p(pp),  
  ret.fx = rmin +(rmax-rmin)  
    /(card(pp)+1)*ord(pp) ;  
  Solve minvar min var using miqcp;  
  xres(i,p)      = x.l(i);  
  report(p,i, 'inc') = xi.l(i);  
  report(p,i, 'dec') = xd.l(i)  
);
```

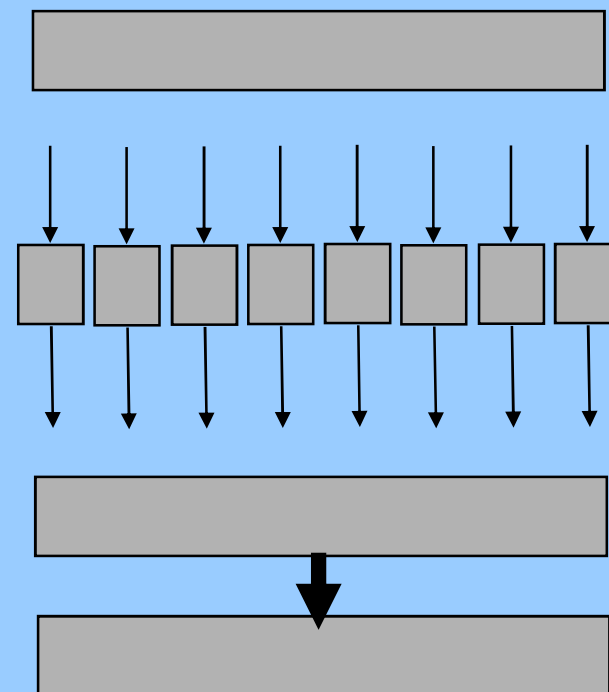


How do we get to parallel and distributed computing?

GRID Specific Enhancements



1. Submission of jobs
2. “Grid Middleware”
 - Distribution of jobs
 - Job execution
3. Collection of solutions
4. Processing of results



Grid Facilities

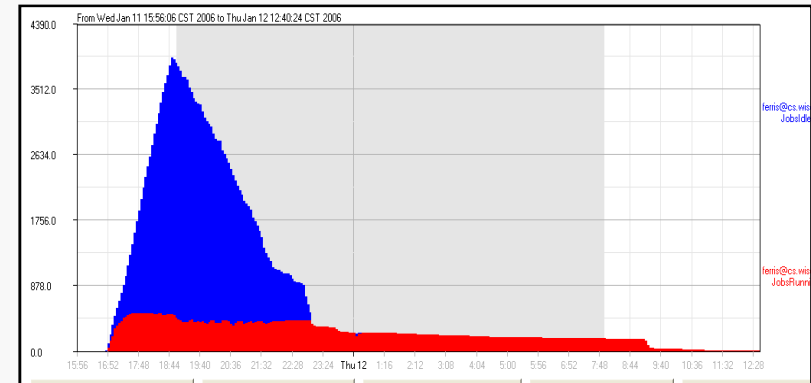


È DEMO

GAMS & Grid Computing



- **Scalable:**
 - support of massive grids, **but also**
 - multi-cpu / multiple cores desktop machines
 - “1 CPU - Grid”
- Platform **independent**
- Only **minor changes** to model required
- **Separation** of model and solution method
 - ‡ Model stays **maintainable**



Agenda

GAMS

Productivity

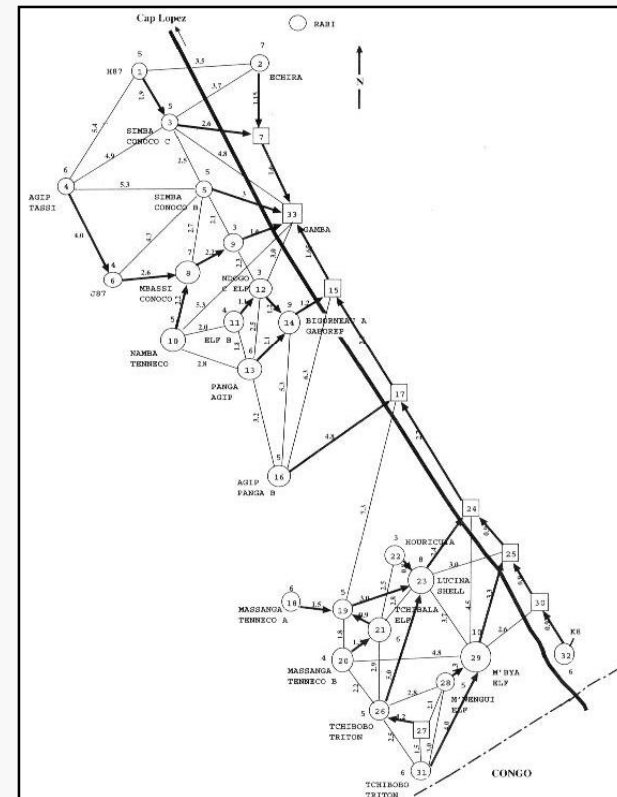
Performance

↳ **Branch & Cut & Heuristic Facility**

Reliability

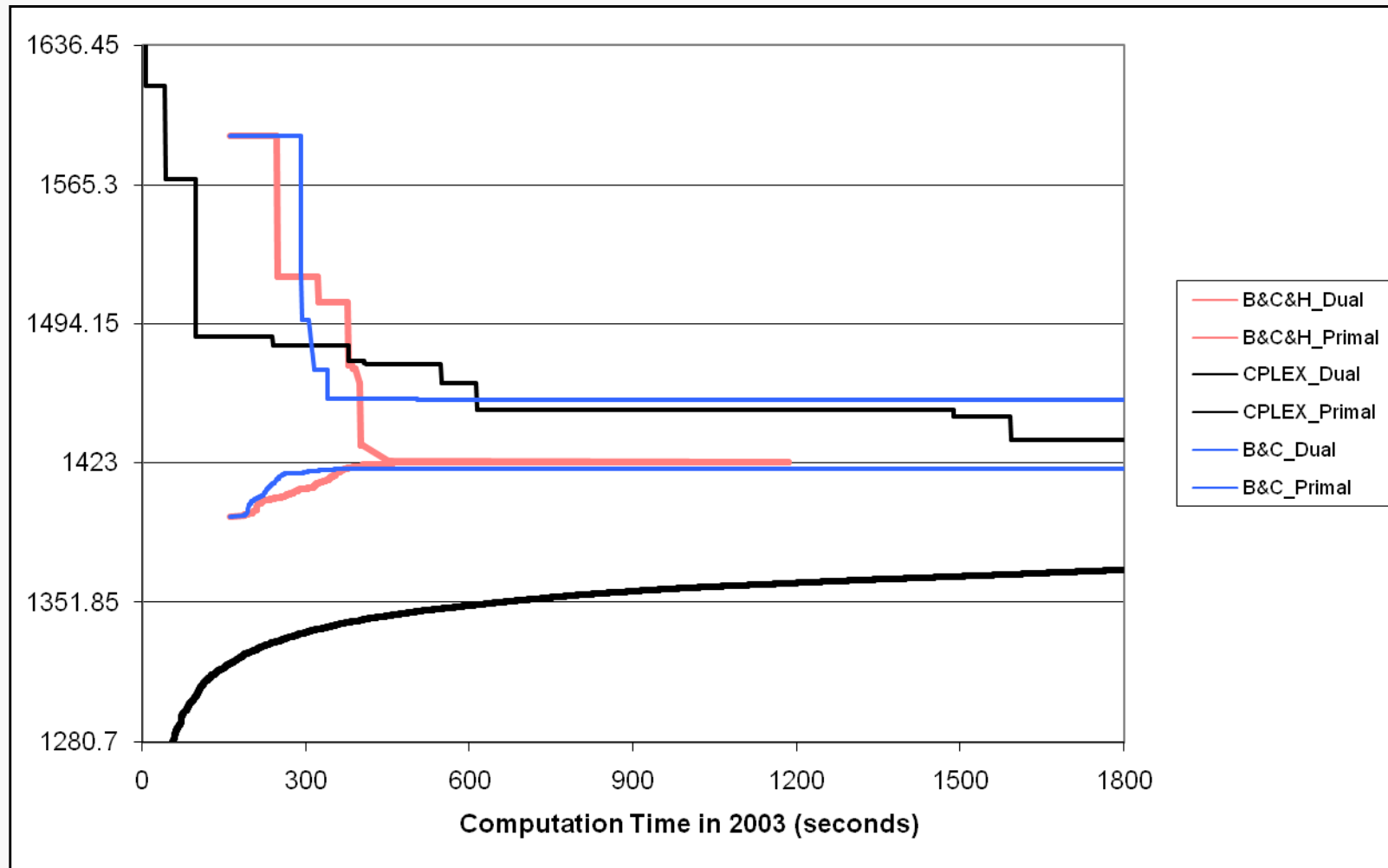
Oil Pipeline Design Problem

J. Brimberg, P. Hansen,
K.-W. Lih, N. Mladenovic,
M. Breton 2003.
An Oil Pipeline Design Problem.
Operations Research,
Vol 51, No. 2 228-239



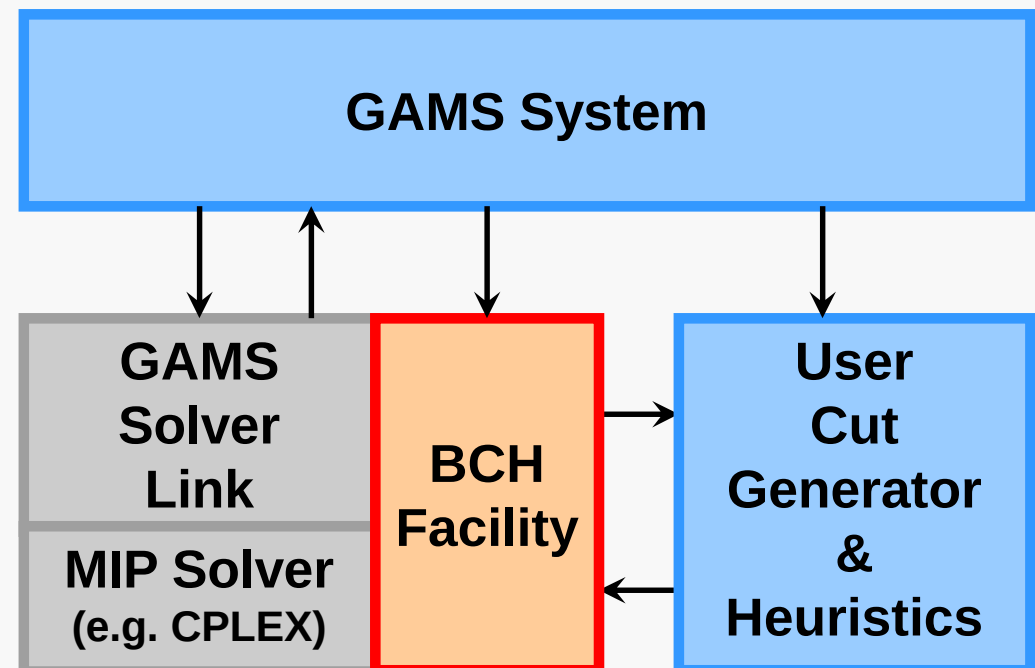
<http://www.gams.com/modlib/libhtml/bchoil.htm>

Convergence – Pipeline Design



- Cut Generator and Heuristic
 - Represented in terms of original GAMS problem formulation
 - Independent of the specific MIP solver
 - Use any other model type and solver available in GAMS

- Design Principle:



BCH Facility



È DEMO



Agenda

GAMS

Productivity

Performance

Reliability

Long Term Commitment



- Backward compatibility
- Performance comparison tools: Bench / Paver
- Model converter and “encryption” tool: Convert
- Solution verification tool: Examiner
- Software Quality Assurance (SQA)
 - Software configuration management
 - Quality control and tests of the product
 - Client model testing

‡ SQA becomes more and more important for MP industry



Software configuration management

- Audit strings

KNITRO Nov 27, 2006 WIN.KN.NA 22.3 009.035.041.VIS KNITRO 5.0
KNITRO ALFA 5Mar07 WIN.KN.NA 22.5 010.036.041.VIS KNITRO 5.1.0

- Build automation tools: Automatic build of the whole system every week - *build early and build often*
- Simple source management system (automatic version and audit string checks)

SQA at GAMS Testing



Quality control and tests of the product

- Goal: Continuous quality improvement using automated and reproducible tests
- Test libraries (available online):
 - GAMS Model Library (solver tests)
 - GAMS Quality Test Models Library (modeling system test)
- Continuous addition of new test models
- Bugtracking System

SQA at GAMS

Client Model Testing



- Clients with complex application
- Need assurance that application will work with new GAMS releases
- Only limited resources to do major testing themselves
- Confidentiality issues

SQA at GAMS

Client Model Testing



- Includes:
 - Ability to solve (= no bugs)
 - Returns the “same” solution back
 - Similar or better performance
- Improves communication between development team and clients
- ‡ Benefits both for solver developers, for clients and for GAMS

Summary



- GAMS increases **productivity**
- Continuous gain in **performance**
- Proven **reliability** (+30)
- Opens doors to a large network of GAMS developers and clients with modeling needs

Thank you!



Performance of bchoil example:

- Cplex/BCH: 17 seconds
- Regular Xpress: 124 seconds
- Regular Cplex: 311 seconds
- Regular Coincbc: > 10,000 seconds

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