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

GAMS

- 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

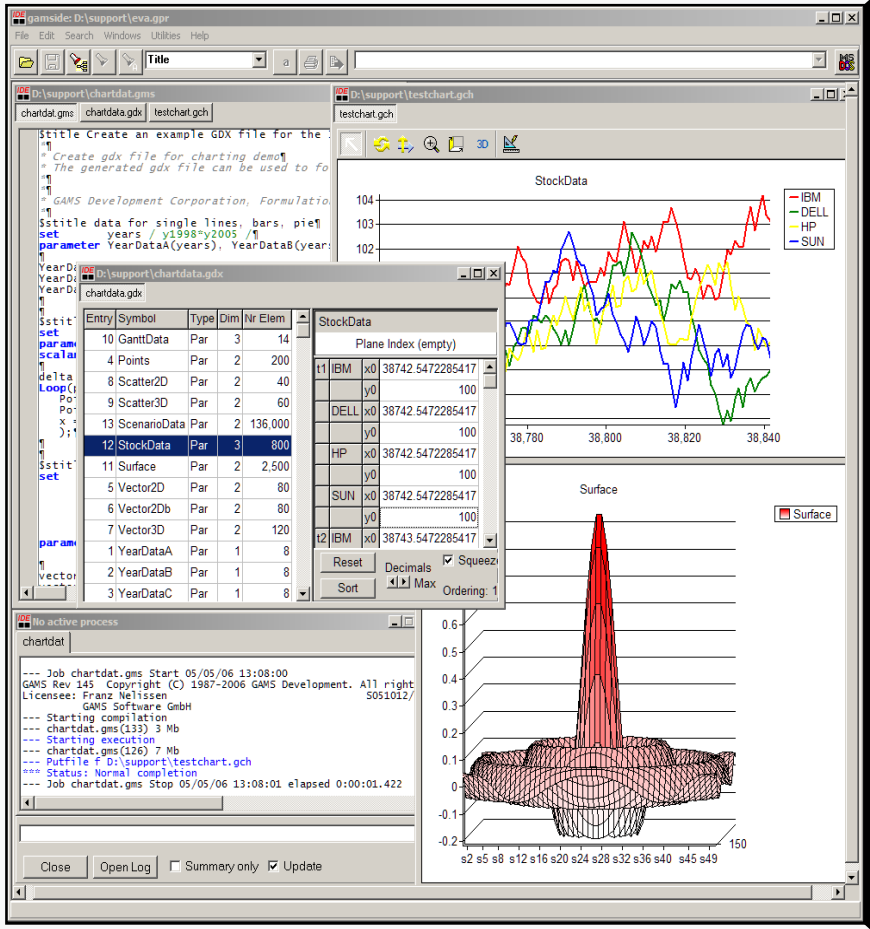
- Professional software tool provider, not a consulting company
- Operating in a segmented niche market
- Broad academic & commercial user base and network

Typical Application Areas *

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

* Illustrative examples in the GAMS Model Library

GAMS at a Glance



General **A**lgebraic **M**odeling **S**ystem:
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

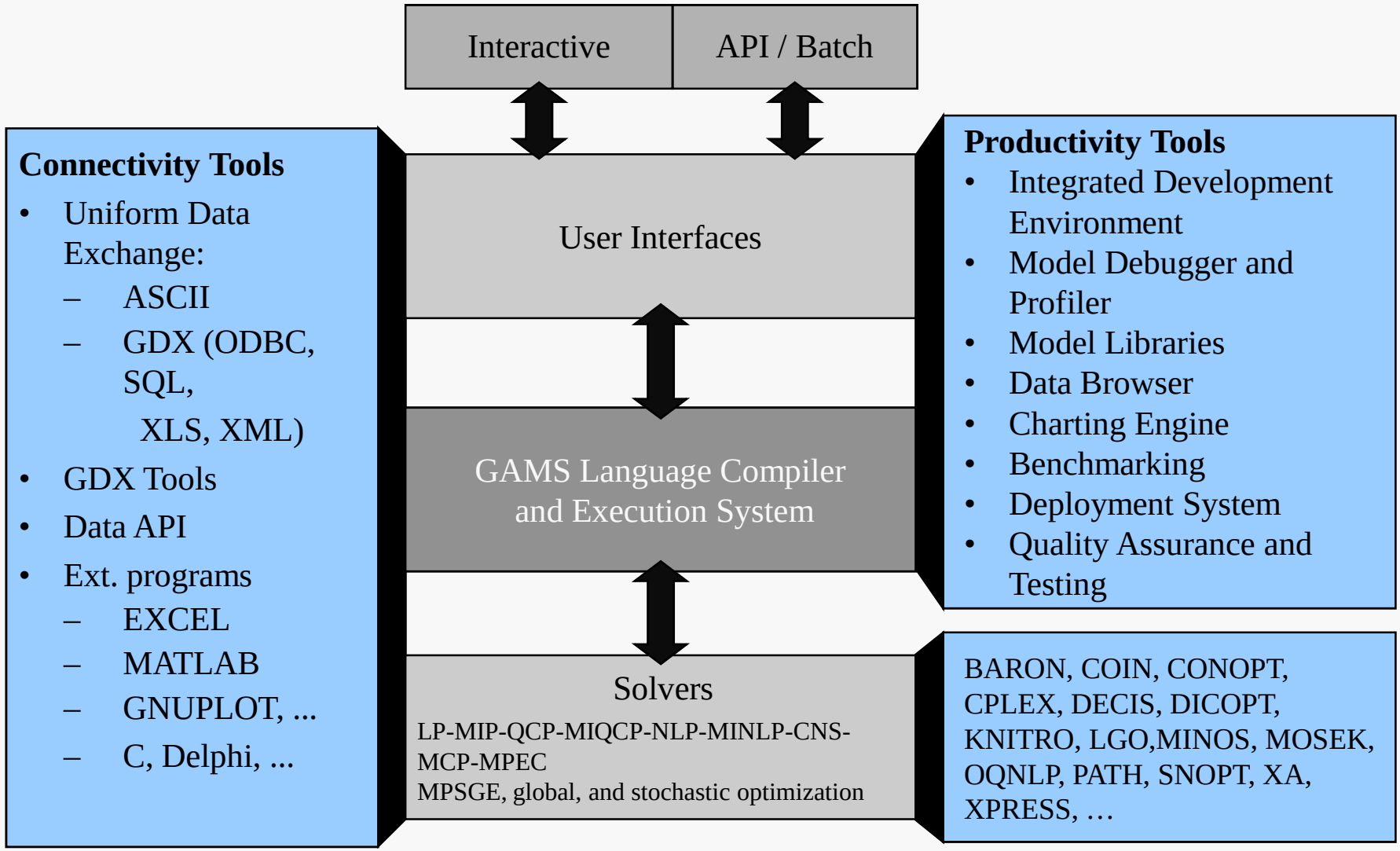
Downloads 2007-02-12 to 2007-03-11

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

Total: 1963

~ 500 downloads
a week

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

à Each Category has its own needs

What are their Risks?

… Relevant new features for productivity increase…

… Performance gains…

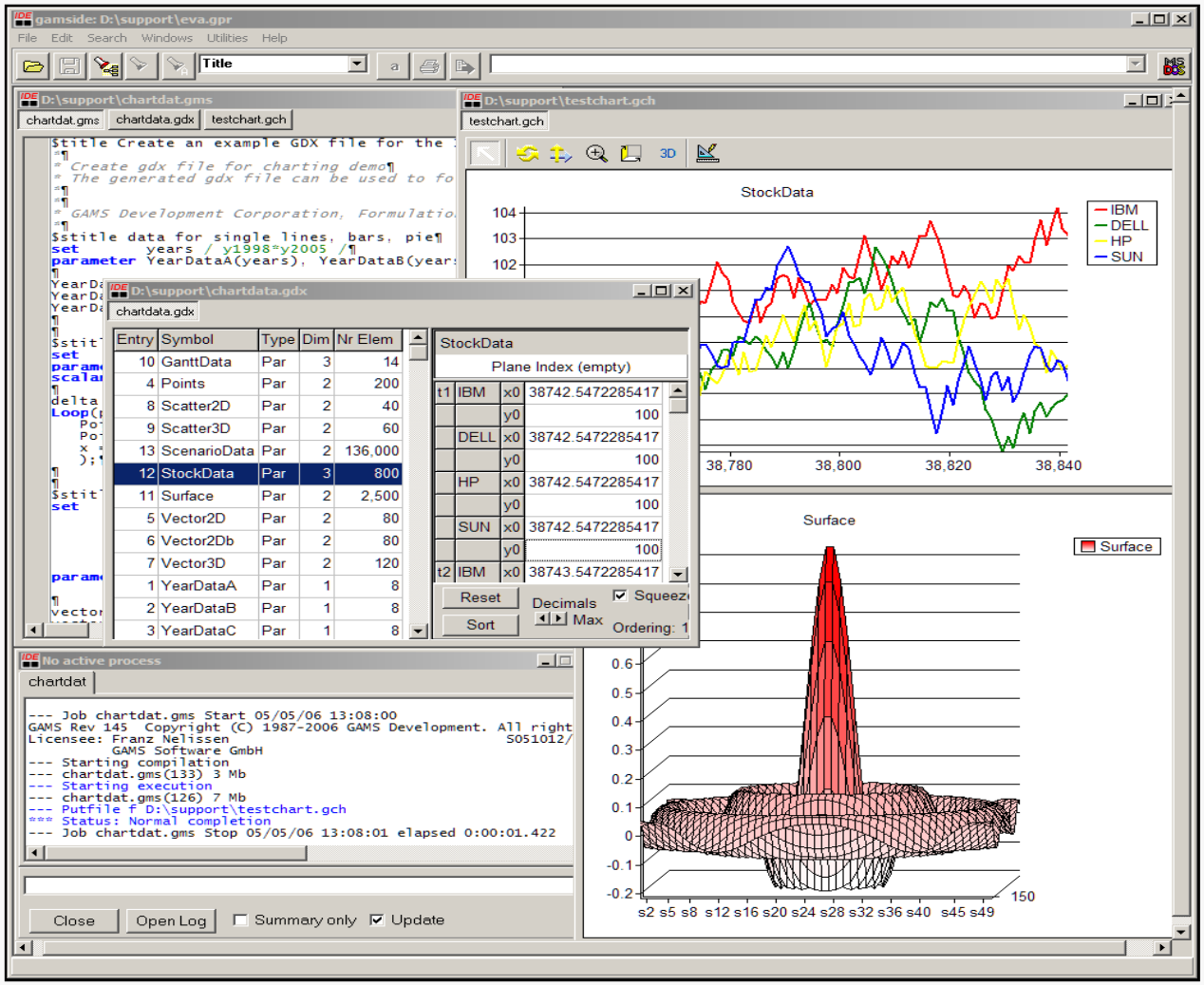
… Long term reliability…

User's Risks

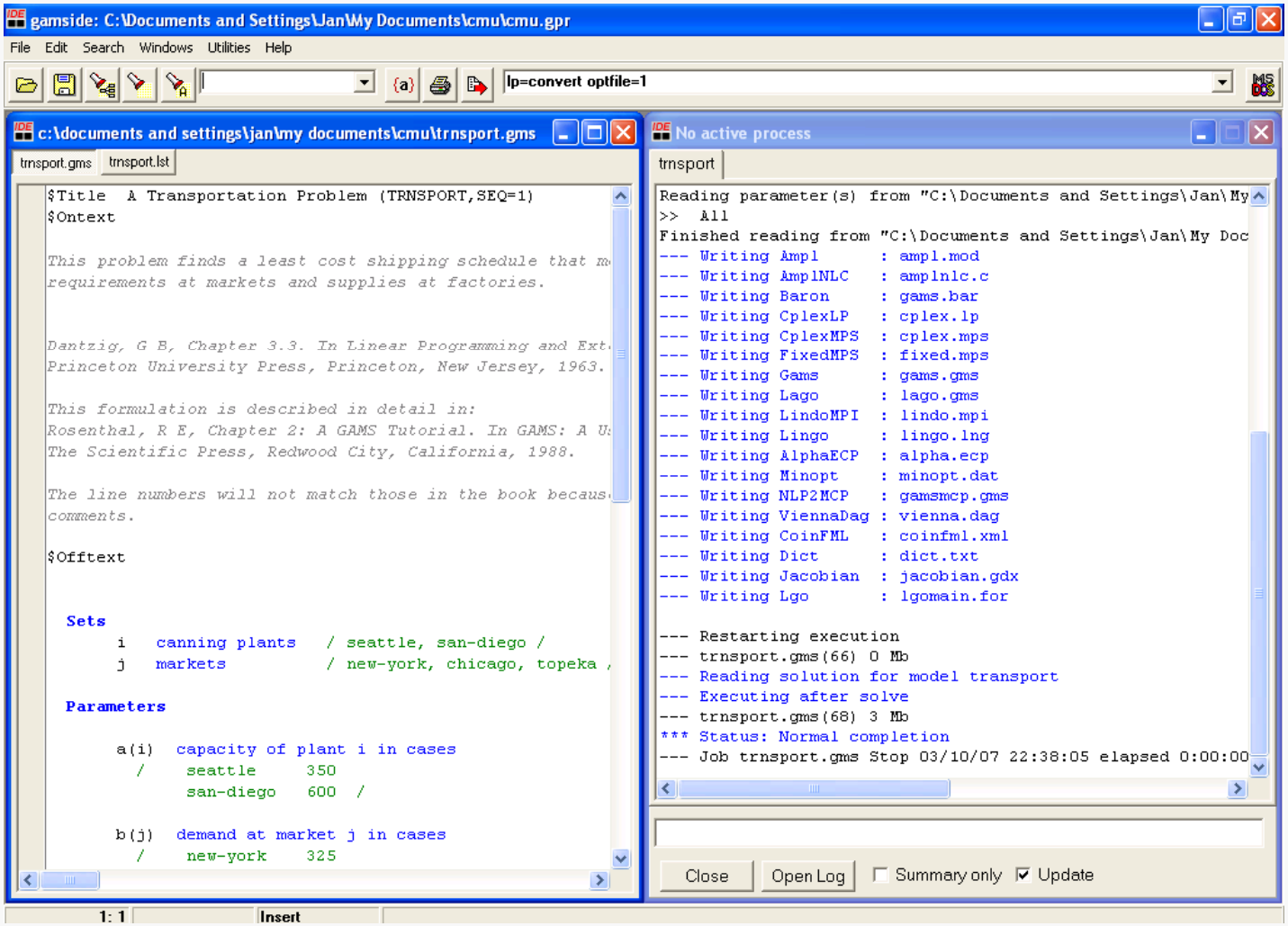
Agenda

- GAMS
- **Productivity**
- Performance
- Reliability

Integrated Development Environment



"Solver" Convert

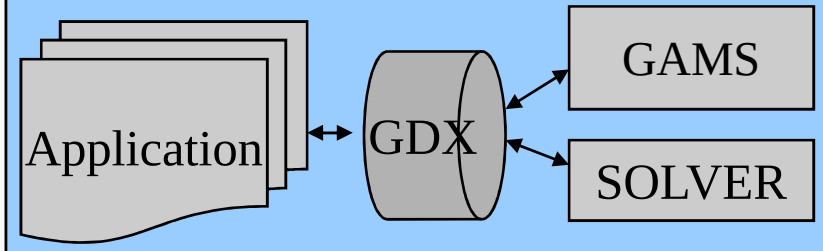


Integrated Development Environment

è DEMO

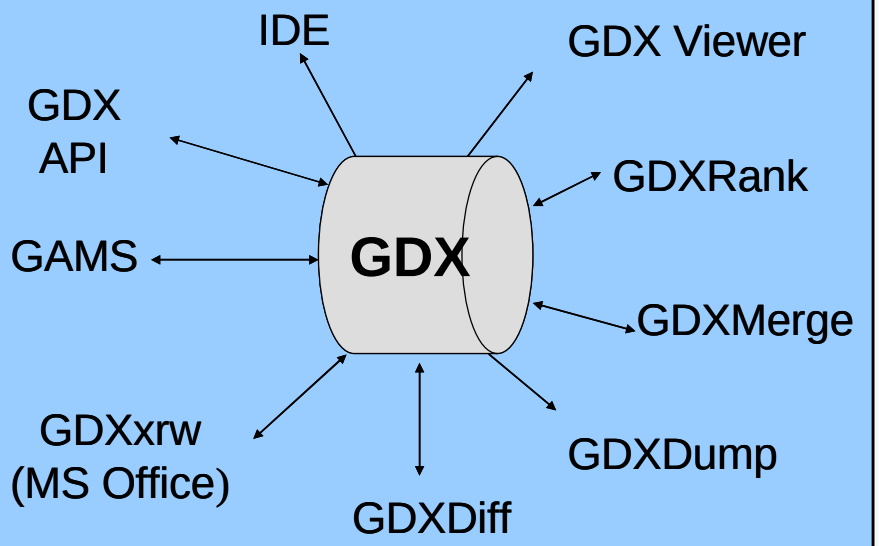
Gams Data eXchange

Binary Data Exchange

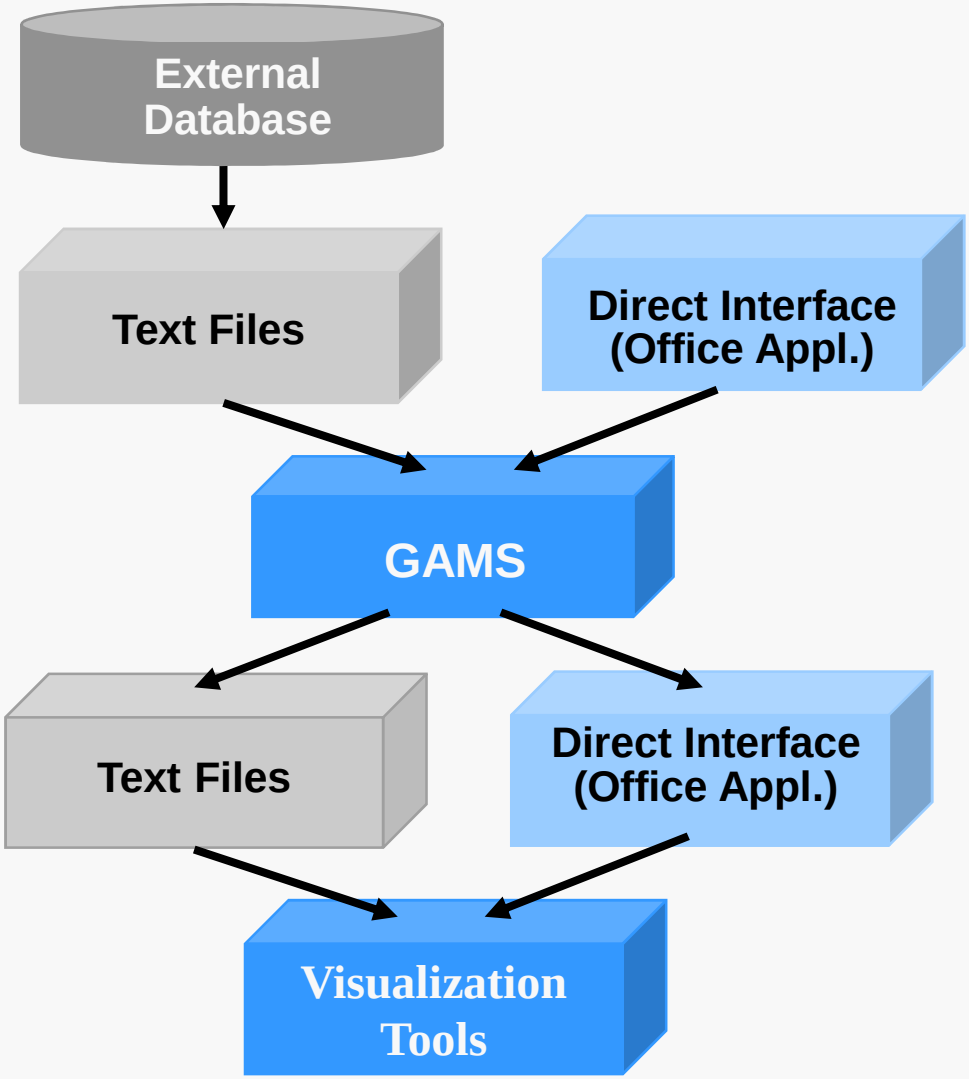


- Complements ASCII data exchange
- Data exchange at any stage
  - Supports ODBC and XML
  - Direct Excel connectivity
  - General API
- Visual Inspection
- Scenario Management Support
- Full Support of Batch Runs

GDX Tools



GAMS in Control



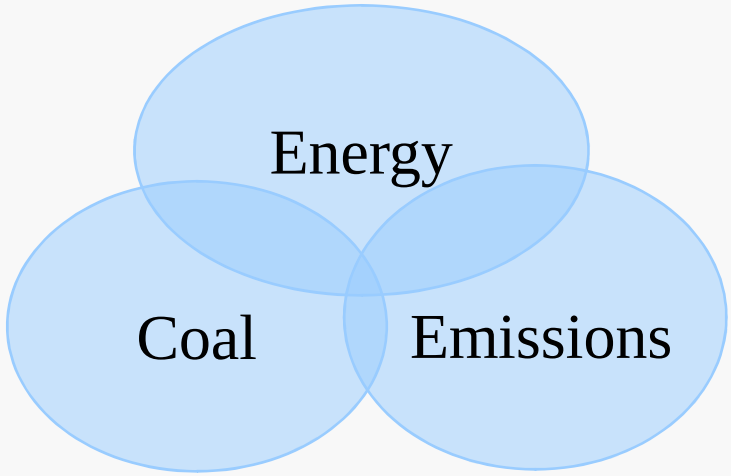
Import

Export

U.S. Energy Model

Goal:

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



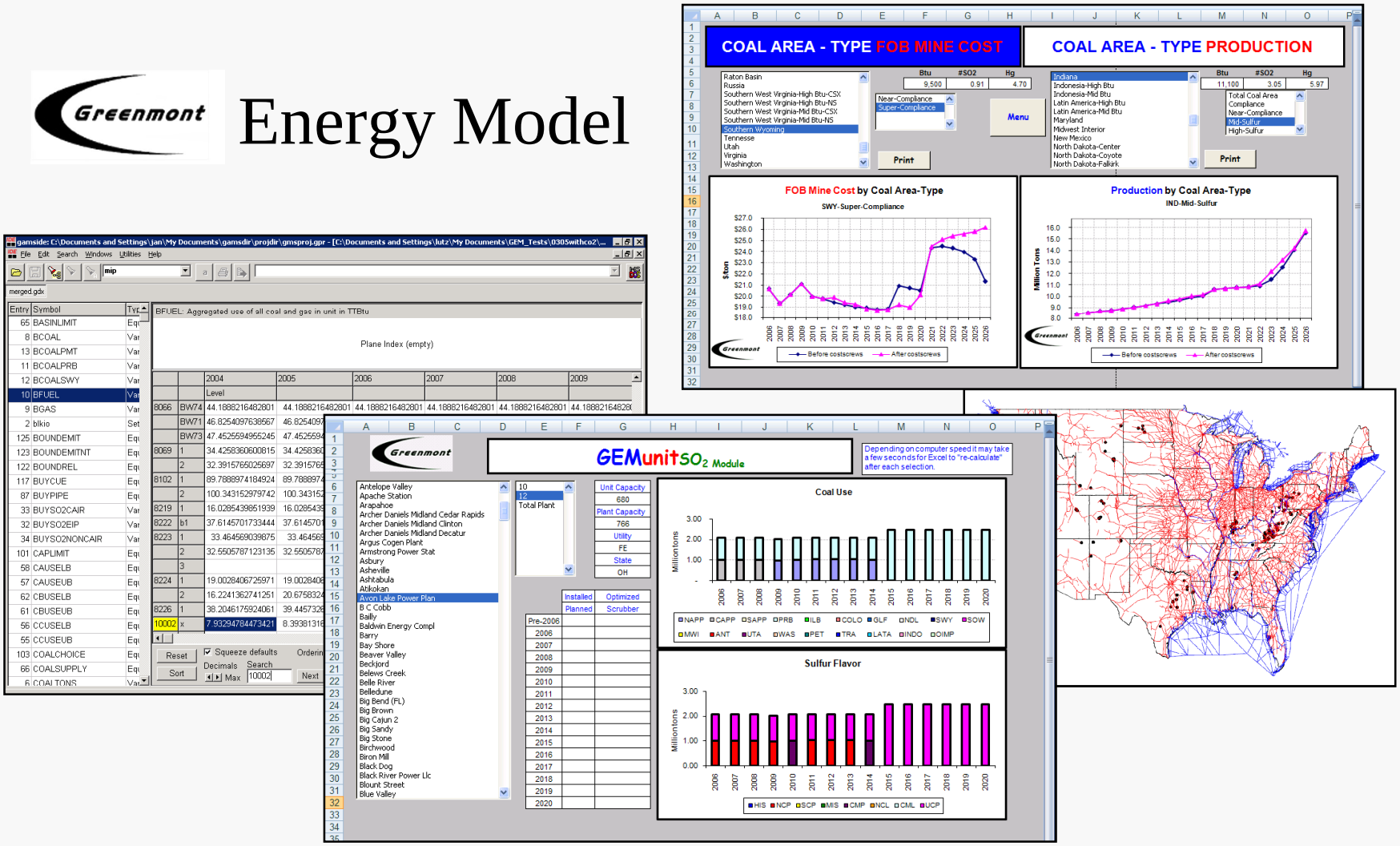
Size:

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

TECHNISCHE UNIVERSITÄT CAROLO-WILHELMINA ZU BRAUNSCHWEIG

How Clients want to use our interfaces

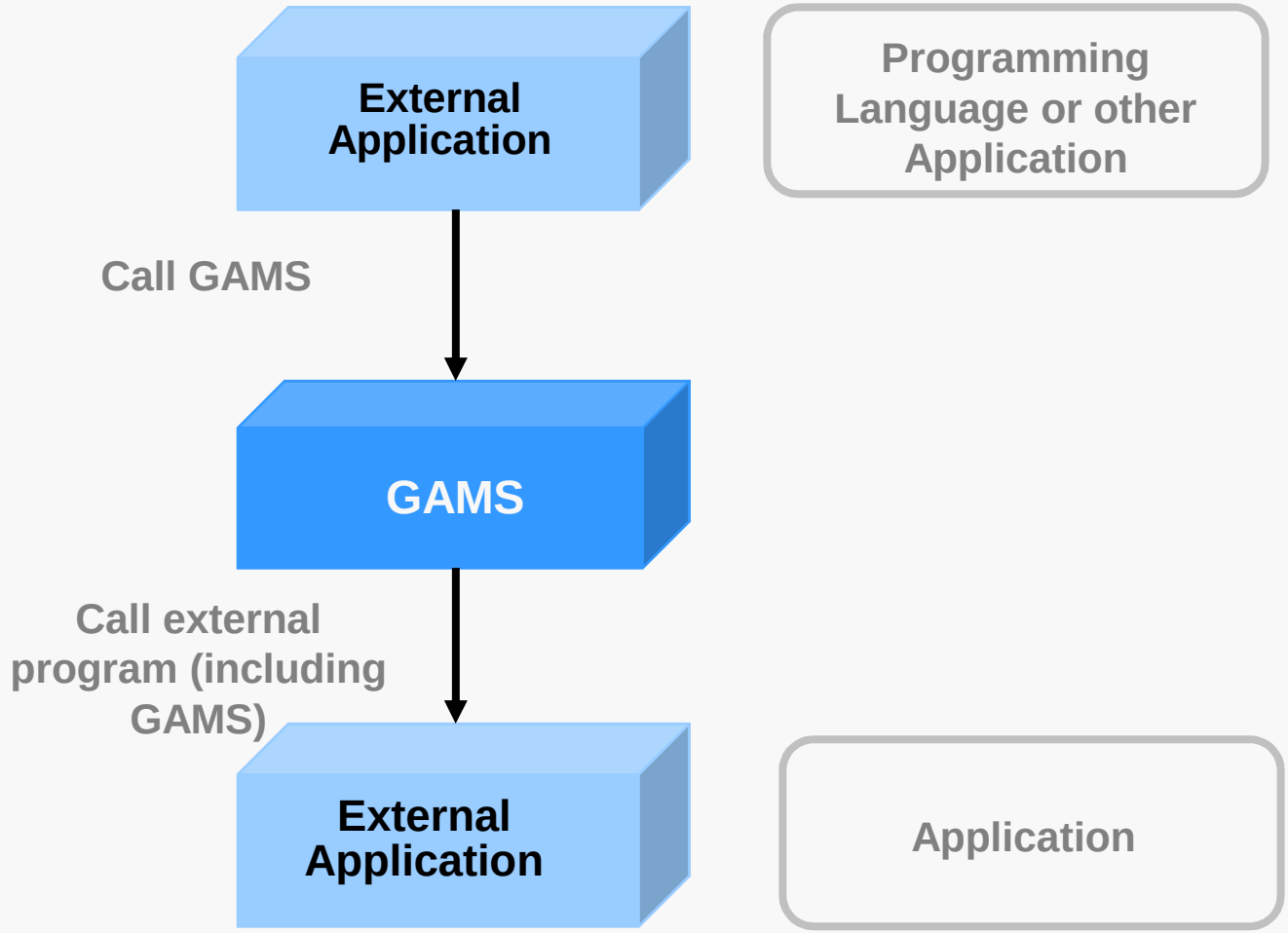
Greenmont Energy Model



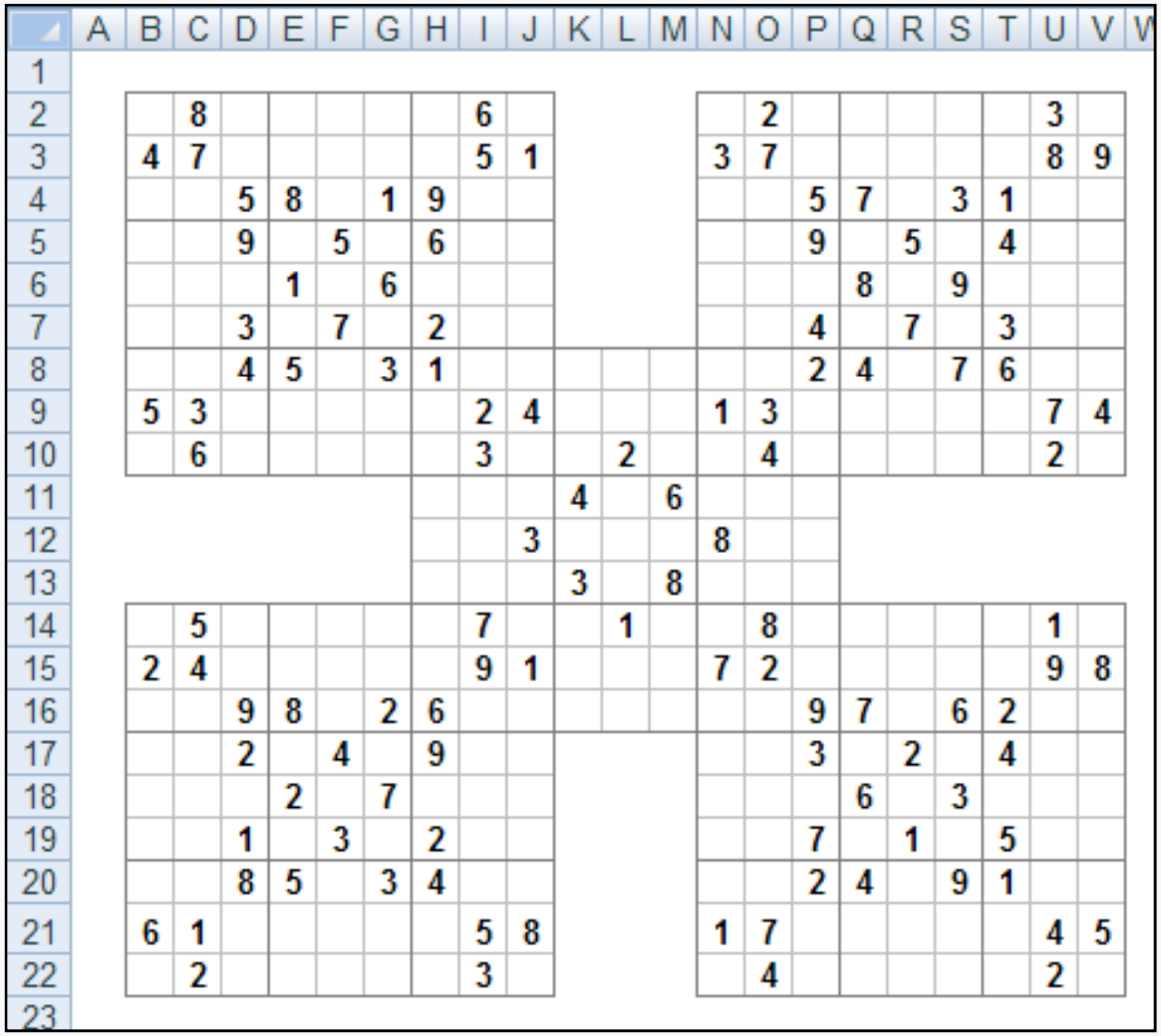
GAMS in Control

è DEMO

Application in Control



Samurai Sudoku

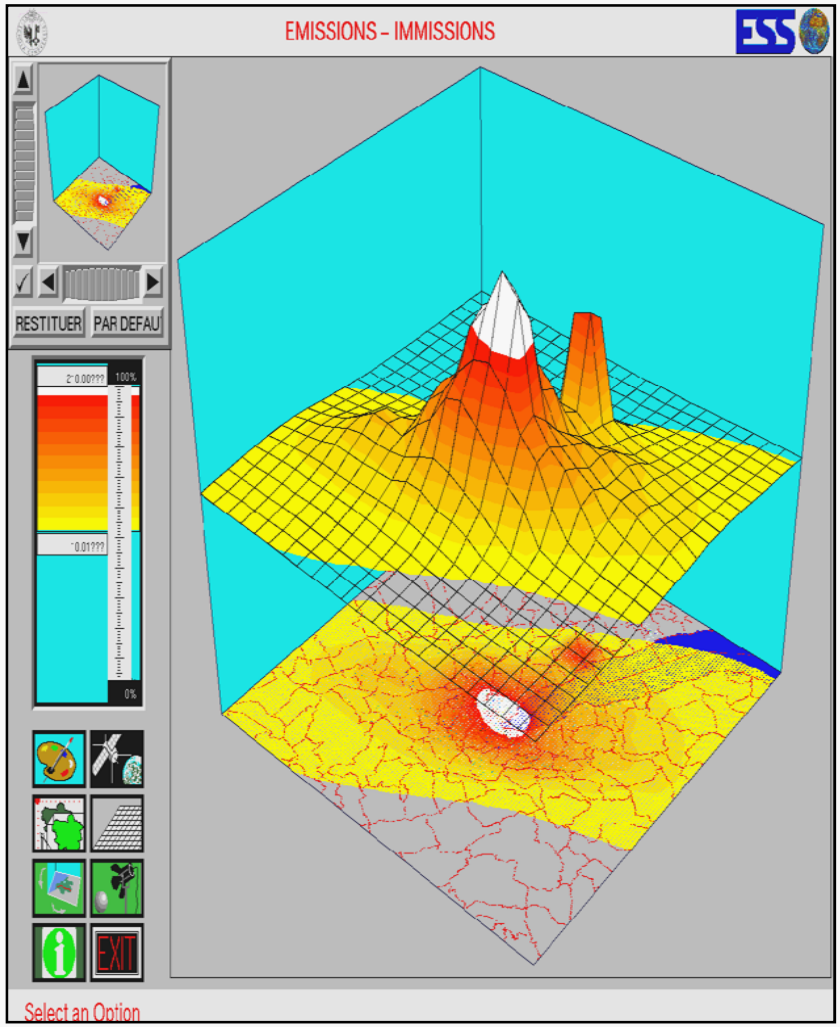


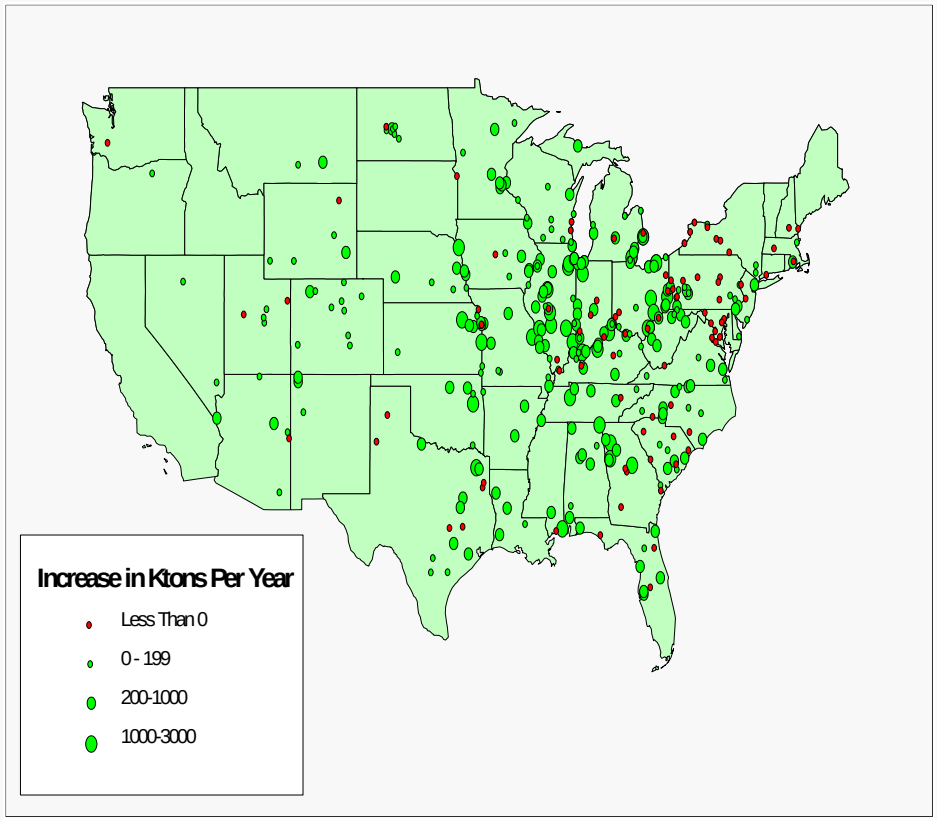
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
1																							
2			8						6						2						3		
3		4	7						5	1				3	7						8	9	
4				5	8		1	9								5	7		3	1			
5				9		5		6								9		5		4			
6					1		6										8		9				
7				3		7		2								4		7		3			
8				4	5		3	1								2	4		7	6			
9		5	3						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





Interfacing with MATLAB

Figure 1: US dollar short rate scenarios

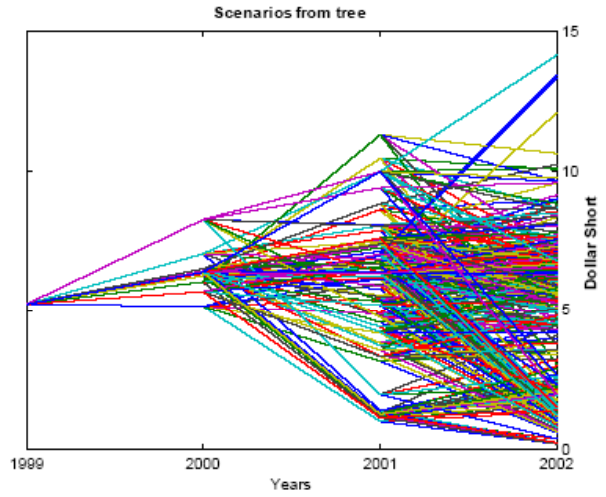
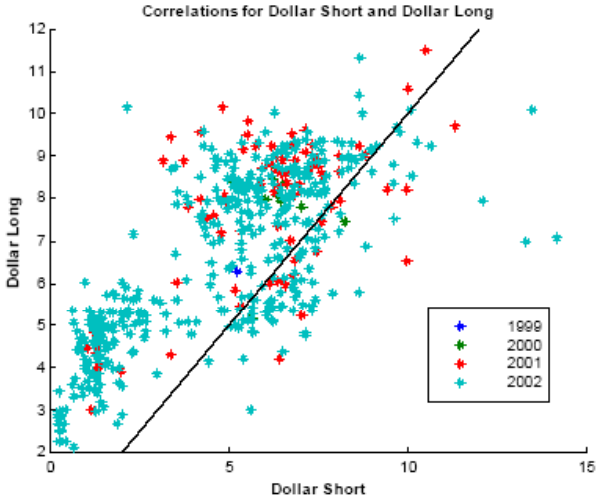
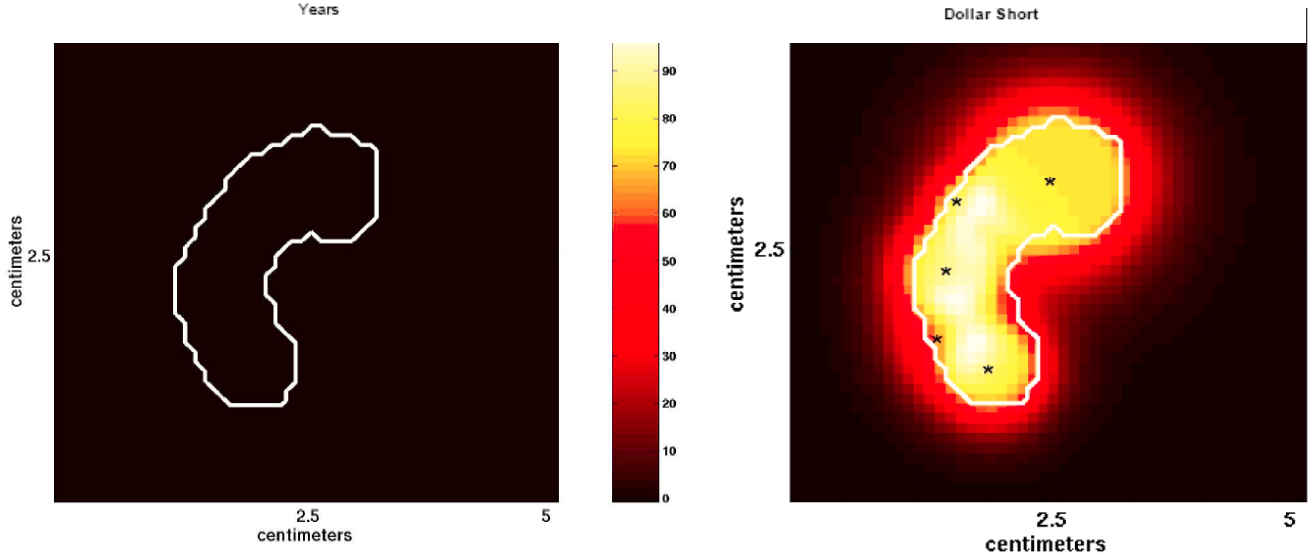
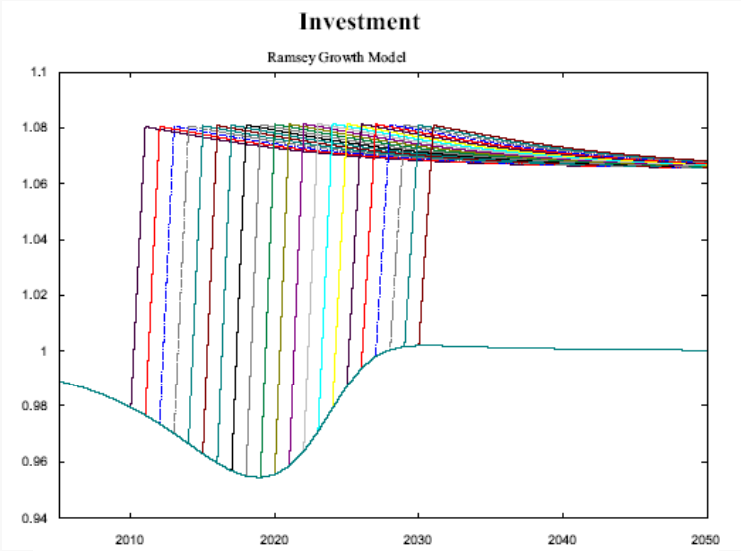


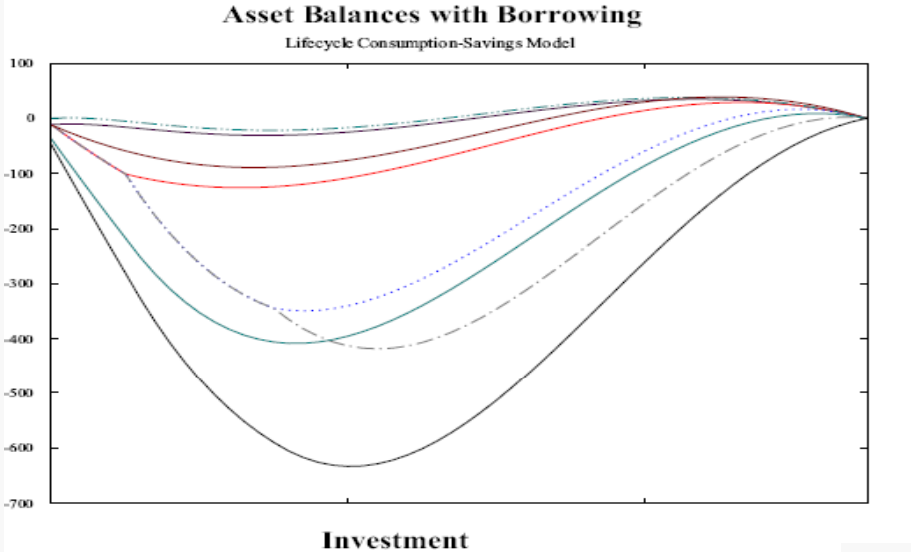
Figure 2: Short vs. long rates

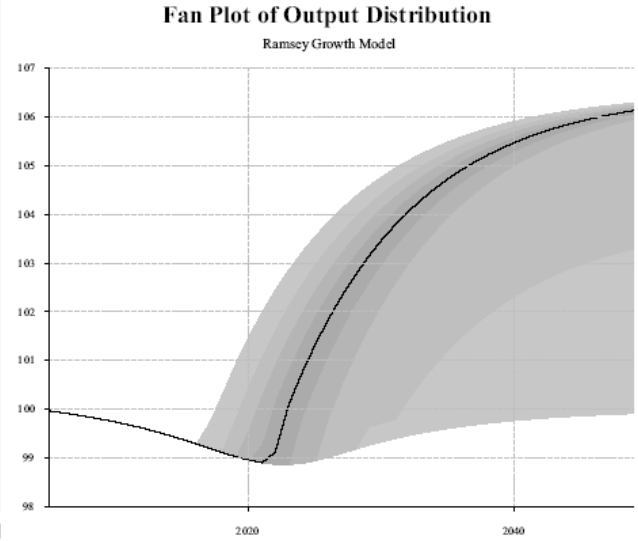


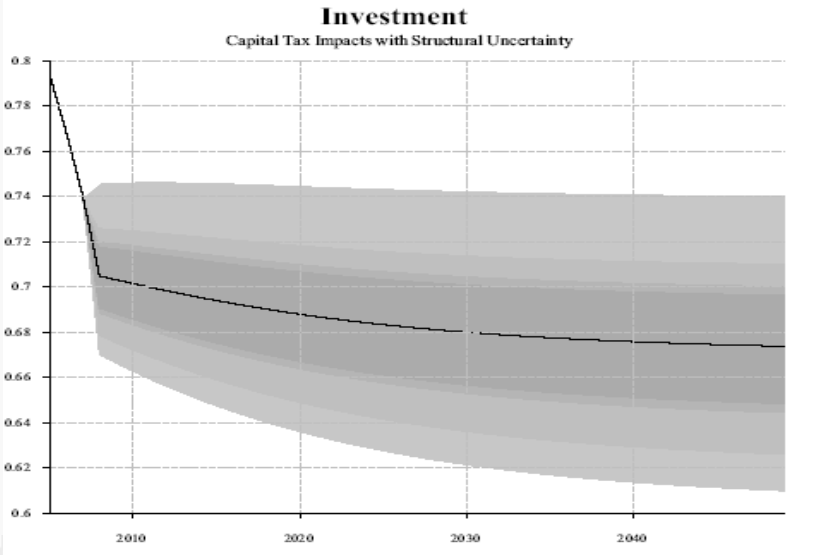


Interfacing with GNUPLOT

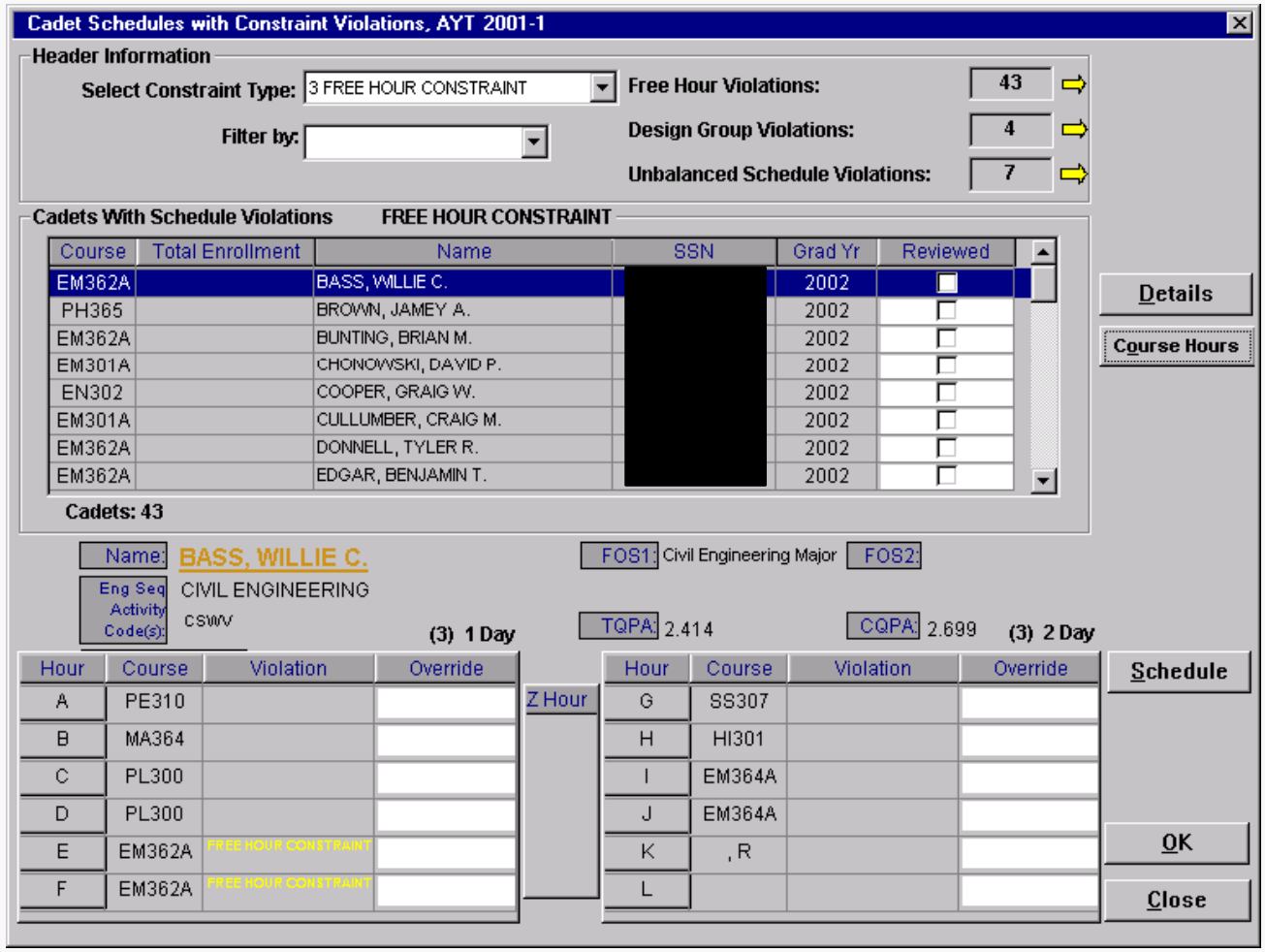




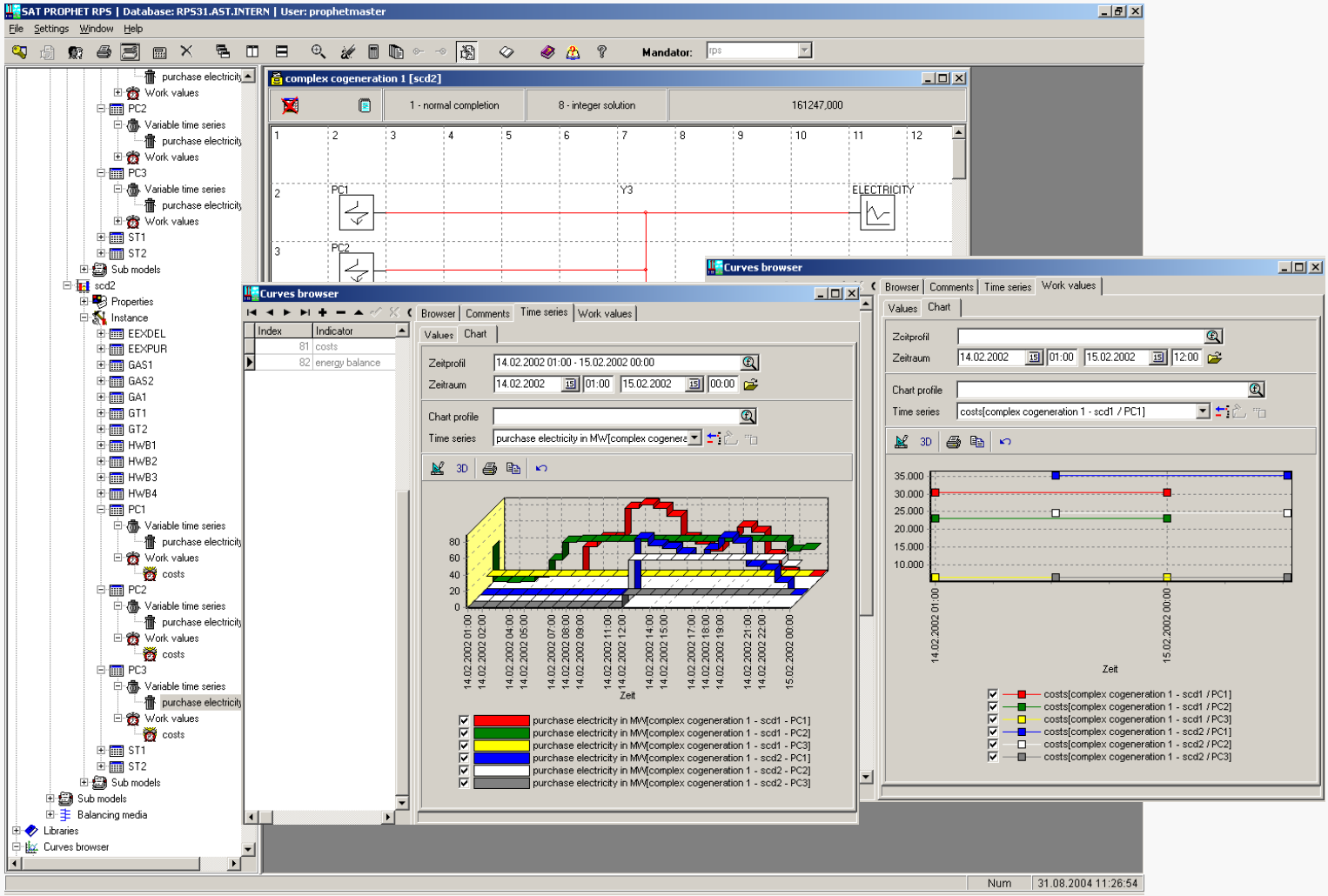




Interfacing with Web Applications

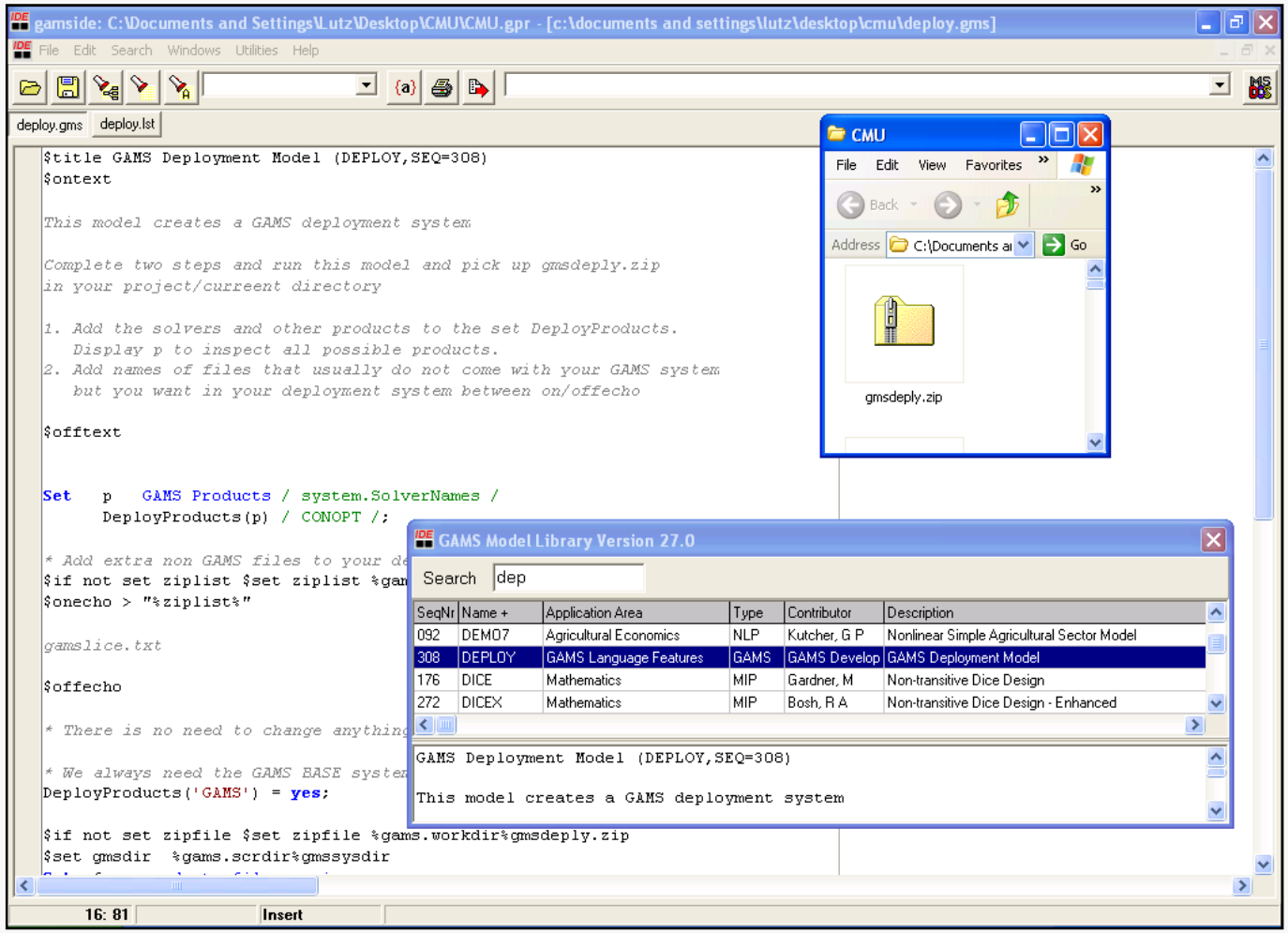


Individual Front Ends



SAT-PROPHET

Deployment


gamside: C:\Documents and Settings\Lutz\Desktop\CMU\CMU.gpr - [c:\documents and settings\lutz\desktop\cmu\deploy.gms]
File Edit Search Windows Utilities Help
deploy.gms
deploy.lst
$title GAMS Deployment Model (DEPLOY,SEQ=308)
$ontext
This model creates a GAMS deployment system
Complete two steps and run this model and pick up gmsdeply.zip
in your project/curreent directory
1. Add the solvers and other products to the set DeployProducts.
Display p to inspect all possible products.
2. Add names of files that usually do not come with your GAMS system
but you want in your deployment system between on/offecho
$offtext
Set p GAMS Products / system.SolverNames /
DeployProducts(p) / CONOPT /;
$if not set ziplist $set ziplist %gam
$onecho > "%ziplist%"
gamslice.txt
$offecho
* There is no need to change anything
* We always need the GAMS BASE syste
DeployProducts('GAMS') = yes;
$if not set zipfile $set zipfile %gams.workdir%gmsdeply.zip
$set gmsdir %gams.scrdir%gmssysdir
16: 81
Insert
CMU
File Edit View Favorites
Back
Address C:\Documents a
Go
gmsdeply.zip
GAMS Model Library Version 27.0
Search dep
SeqNr Name + Application Area Type Contributor Description
092 DEMO7 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
GAMS Deployment Model (DEPLOY,SEQ=308)
This model creates a GAMS deployment system

Deployment

è DEMO

Agenda

- GAMS
- Productivity
- **Performance**
- Reliability

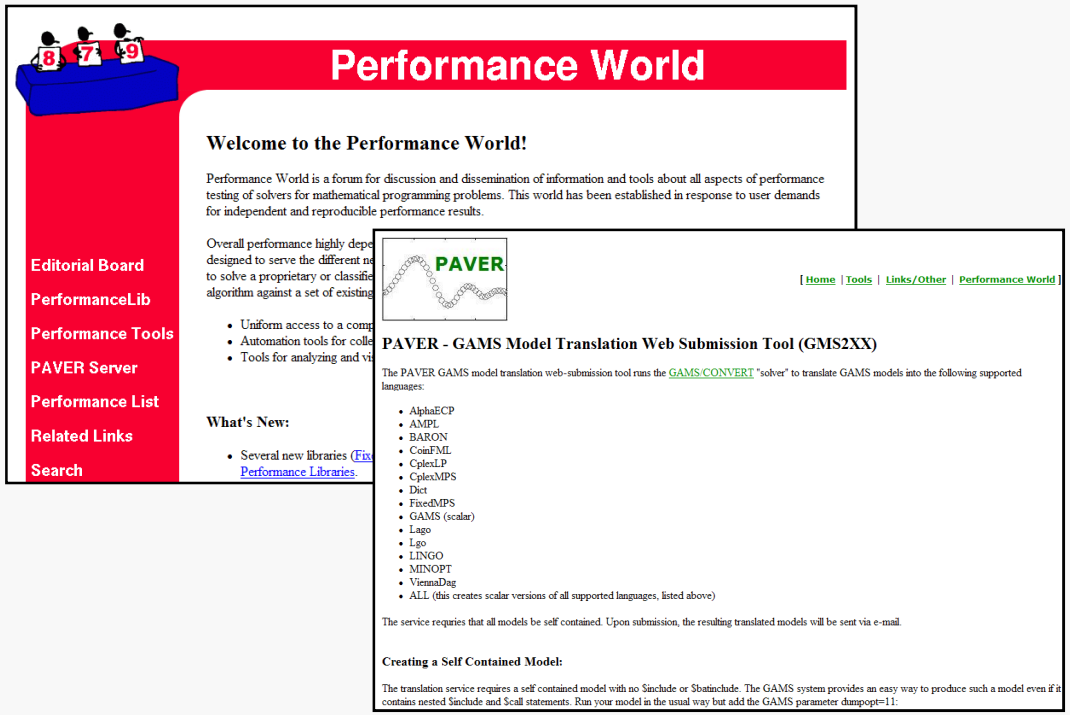
Performance Analysis

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

à Cross comparison of solver resource times

GAMS World

- Cone World
- Global World
- MINLP World
- MPEC World
- MPSGE World
- Performance World à PAVER
- Translation World à Convert



PAVER

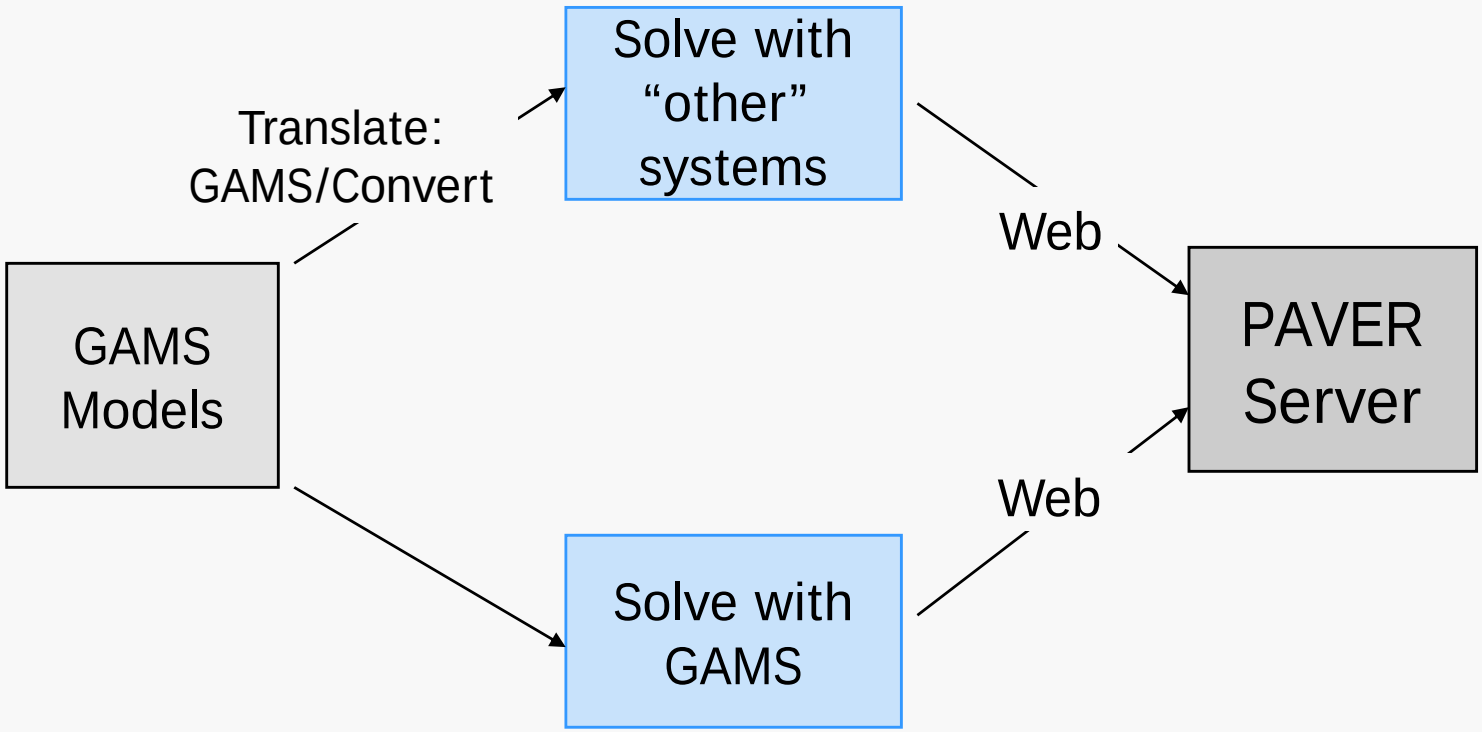
- **P**erformance **A**nalysis and **V**isualization for **E**ffortless **R**eproducibility

  www.gamsworld.org/performance/paver

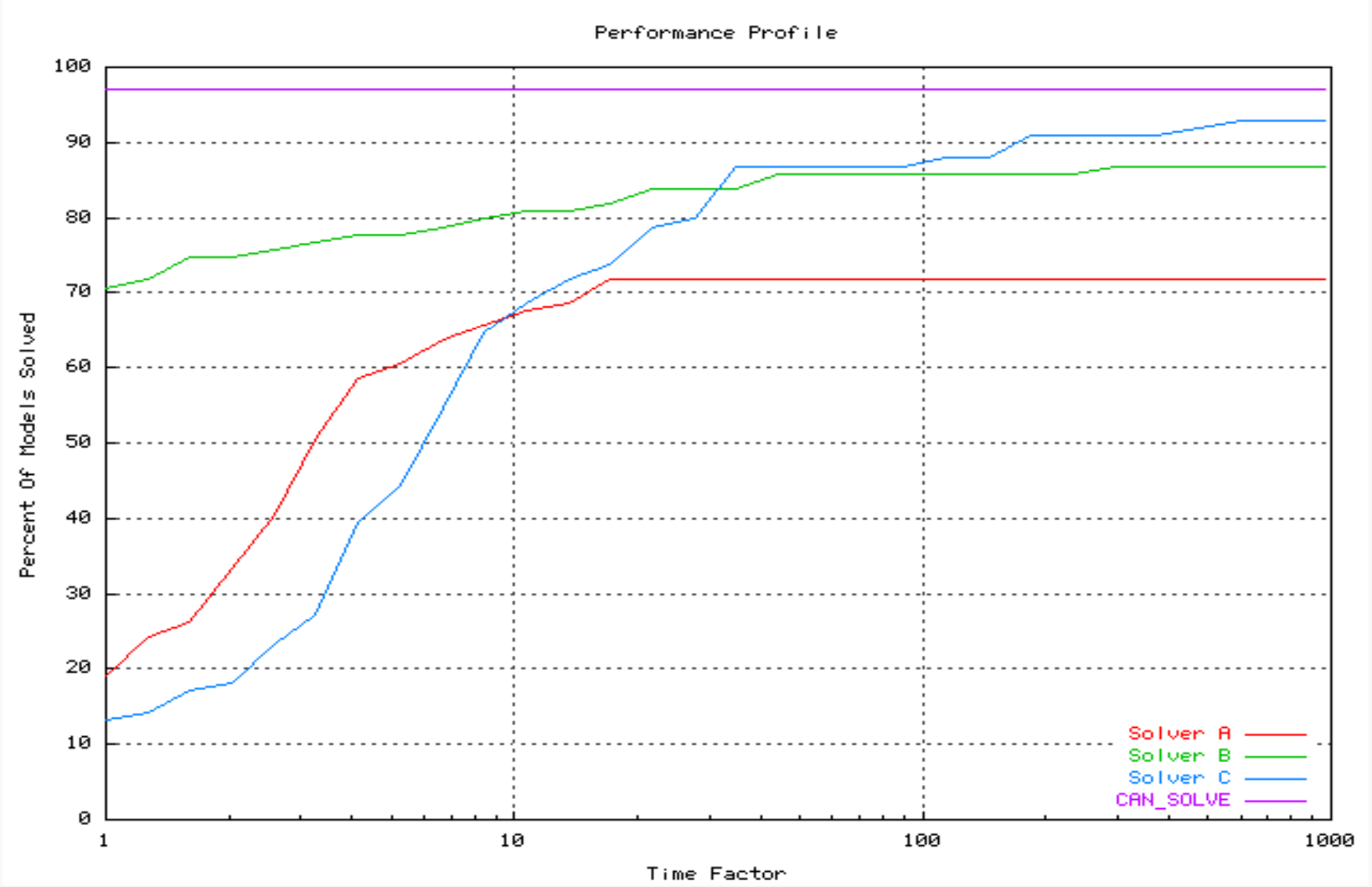
- Online server to facilitate performance testing and analysis/visualization

- Results sent via e-mail in HTML format
  - **System independent**

Open Testing Architecture



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

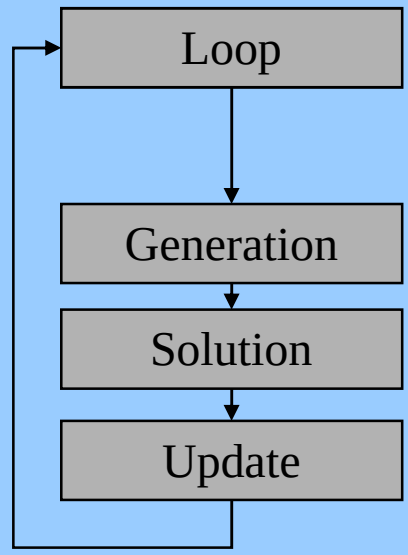
What is Grid Computing?

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

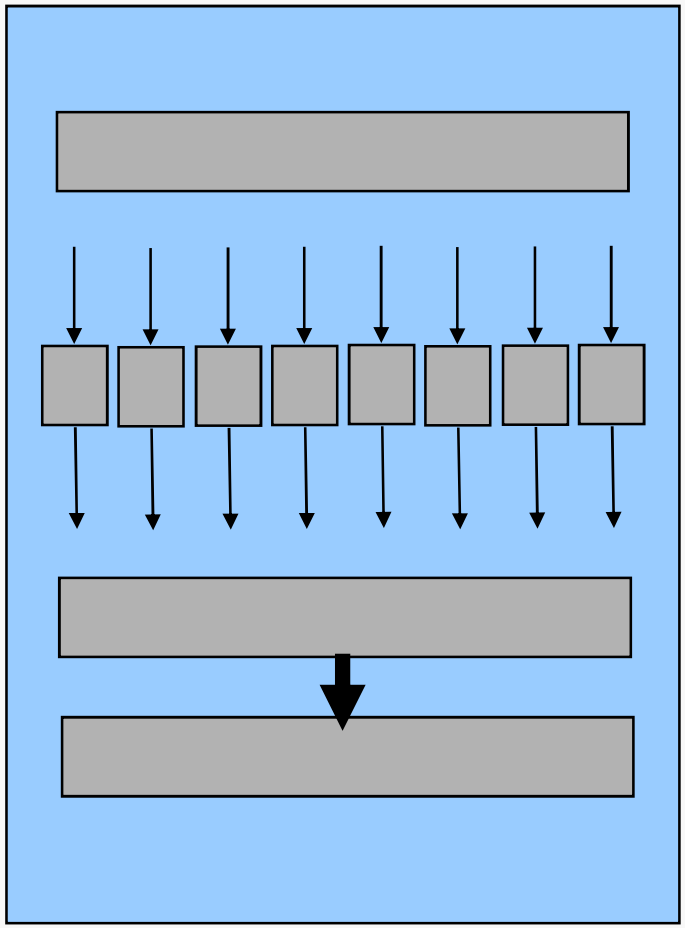
```
Loop(p(pp),
   ret.fx = rmin +(rmax-rmin)
     /(card(pp)+1)*ord(pp) ;
   Solve minvar min var using miqcp;
   xres(i,p)          = x.l(i);
   report(p,i,'inc') = xi.l(i);
   report(p,i,'dec') = xd.l(i)
  );
```



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

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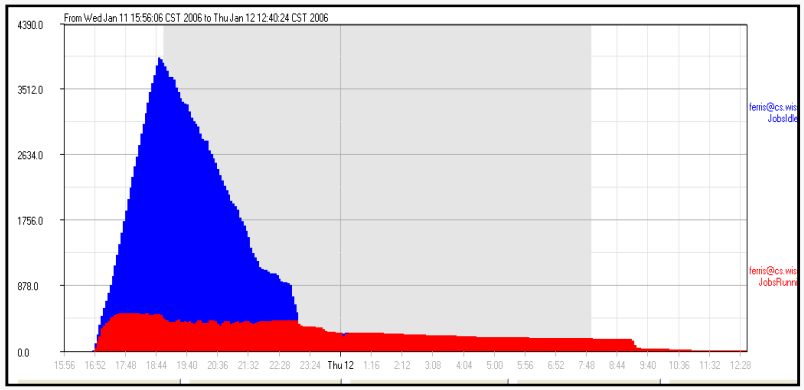
GAMS & Grid Computing

- **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
  à Model stays **maintainable**

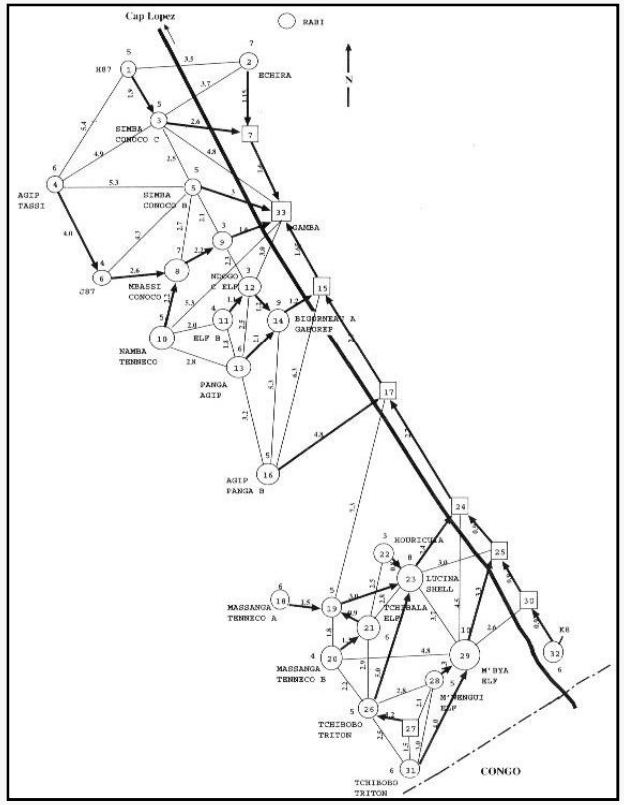
Agenda

- GAMS
- Productivity
- Performance
  ↪ **Branch & Cut & Heuristic Facility**
- Reliability

Example

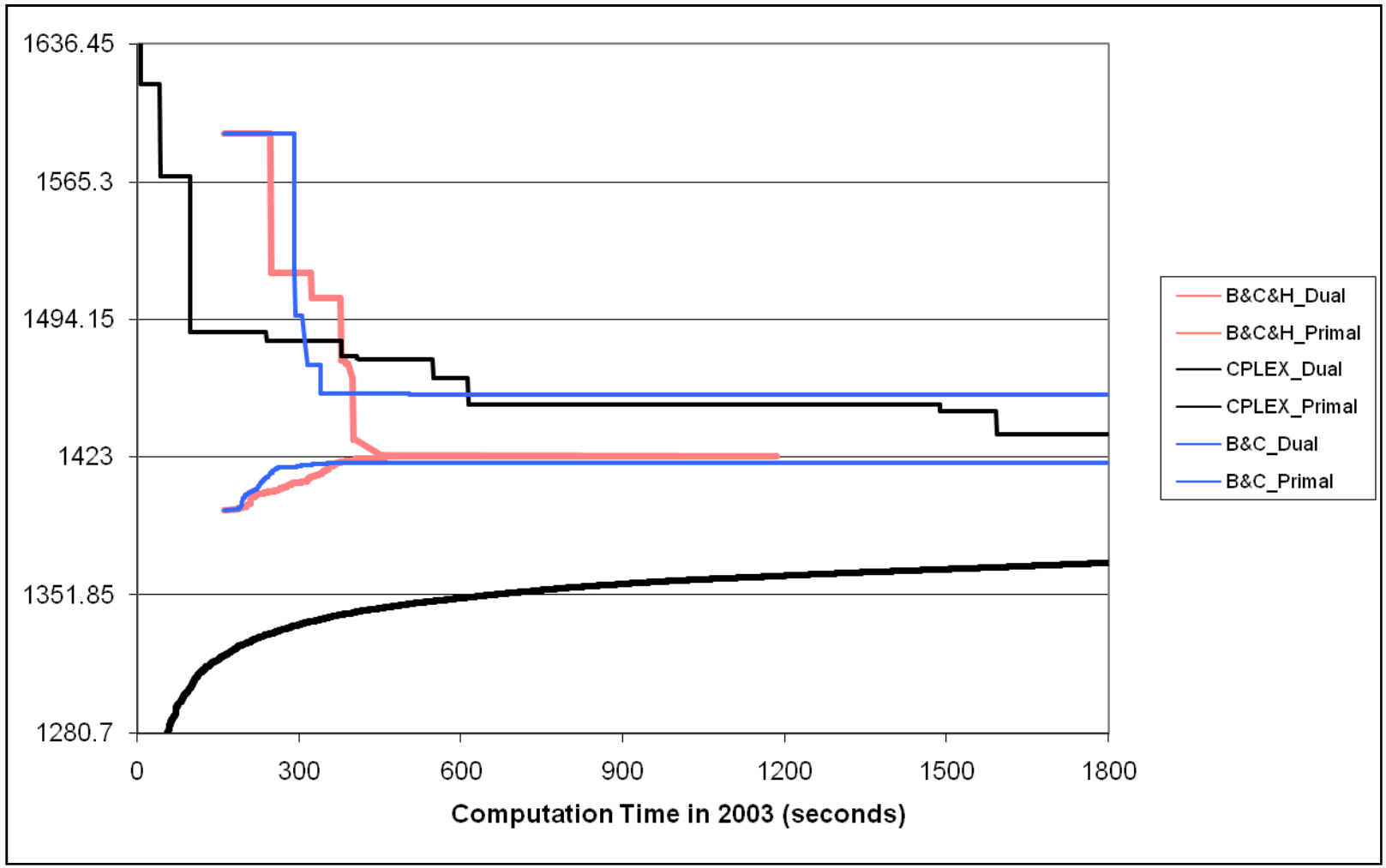
Oil Pipeline Design Problem

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

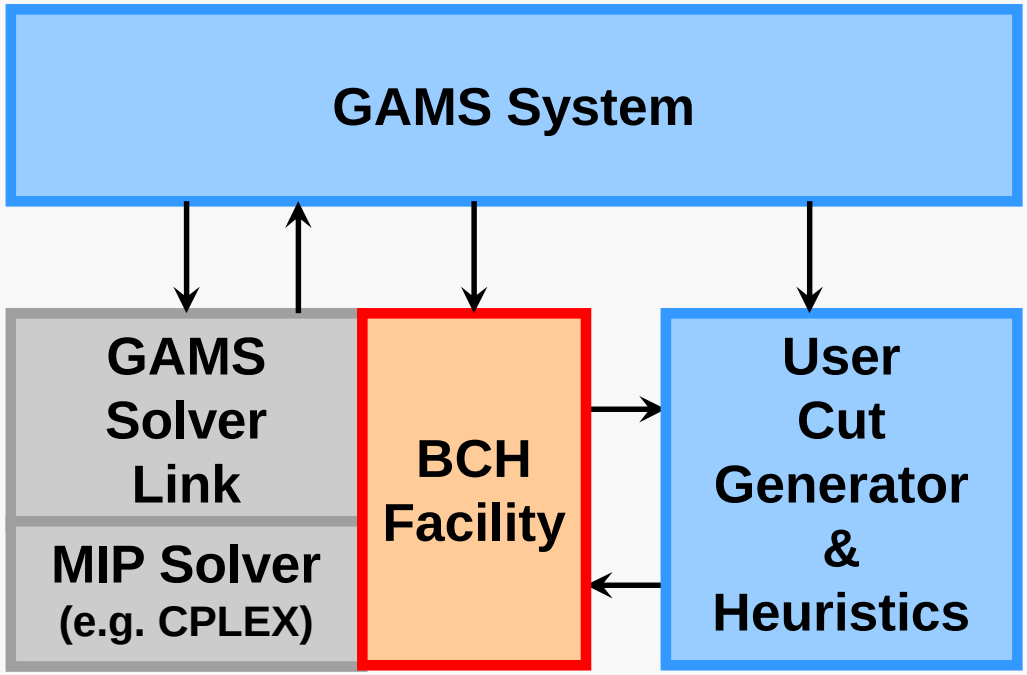
Convergence – Pipeline Design



BCH Facility

- 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
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- **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

à SQA becomes more and more important for MP industry

SQA at GAMS
SCM

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 ressources 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

à 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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