Recent Enhancement in GAMS

Jan-Hendrik Jagla jhjagla@gams.com

Lutz Westermann lwestermann@gams.com

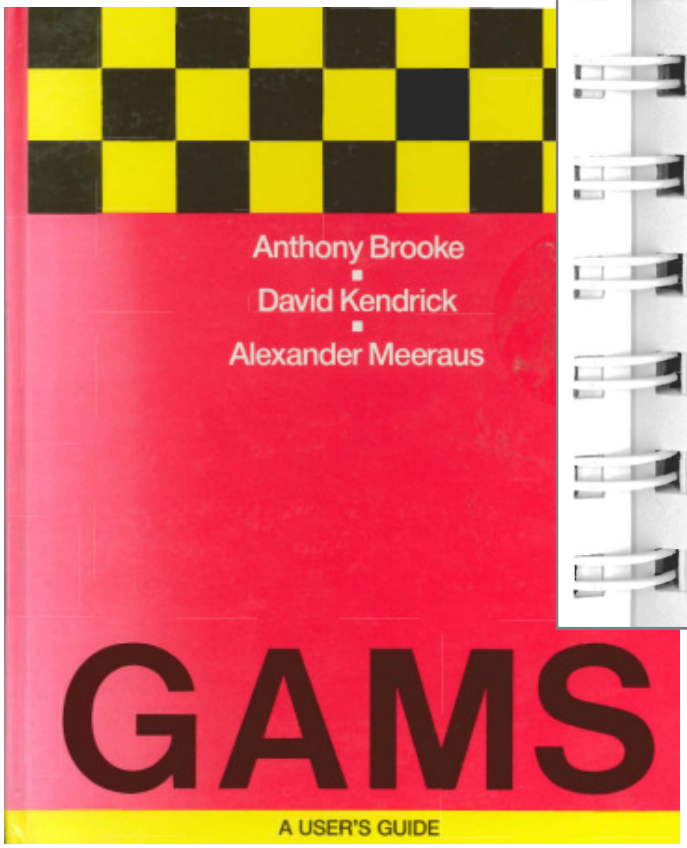
GAMS Software GmbH

www.gams.de

GAMS Development Corp.

www.gams.com

Then …



In Table 17.1 we list sizes and attributes of representative models that are "large" in the sense that they are near the limit of what is practical on a personal computer, along with the model generation time (GAMS) and solution time (solver), both in minutes. These examples were run on an 8 MHz AT with an 80287 coprocessor and 640K of RAM. The times shown are to give you a rough idea of what is possible: these are not precisely controlled benchmarks, and we have a host of performance improvements in mind for the near future.

Table 17.1: Problem Characteristics

Name	*Number of Rows*	*Number of Columns*	*Number of Nonzeroes*	*Generation Time*[a]	*Solution Time*[a]	*Iterations*	*Solver*
DINAMICO	318	425	4156	3.0	30.1	628	MINOS
SARF	532	542	3949	37.7	115.8	2775	MINOS
FERTD[b]	458	2968	7252	11.4	28.3	1368	ZOOM
CAMCGE[c]	243	280	1356	0.8	7.0	189	MINOS
GANGES[d]	274	357	1405	1.8	7.3	187	MINOS
YEMCEM[e]	168	258	953	0.9	7.6	600	ZOOM
EGYPT[f]	281	618	3168	4.0	25.3	1551	ZOOM

[a] Measured in minutes.
[b] The problem is too big for MINOS. ZOOM was used instead.
[c] A nonlinear problem. 63% of the non-zeroes are nonlinear.
[d] A nonlinear problem. 58% of the non-zeroes are nonlinear.
[e] A mixed binary problem, with 55 binary variables (solved with a relative termination criterion of 10%).
[f] A linear problem, solved using XMP which is contained within ZOOM.

GAMS Users Guide (1988)

… and now

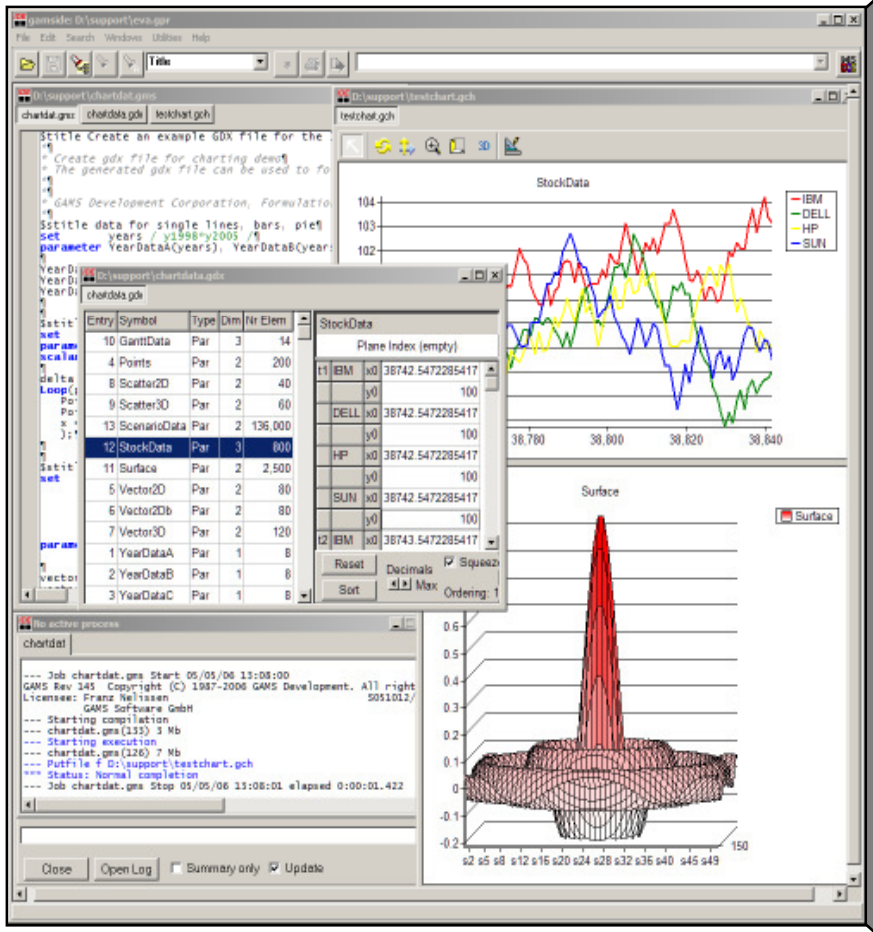
	Type	s in 1988	s in 2008	Improvement Factor
camcge	NLP	468	0.031	15097
dinamico	LP	1986	0.125	15888
egypt*	LP	1758	0.015	117200
fertd*	MIP	2382	0.062	38419
ganges	NLP	546	0.109	5009
sarf	LP	9210	0.139	66259
yemcem*	MIP	510	0.140	3643

* 1988 solver ZOOM, 2008 solver CPLEX 11.0.1

Agenda

- GAMS – An Introduction
- Solver Technology
- Productivity and Connectivity Tools
- Interfacing GAMS with other Applications

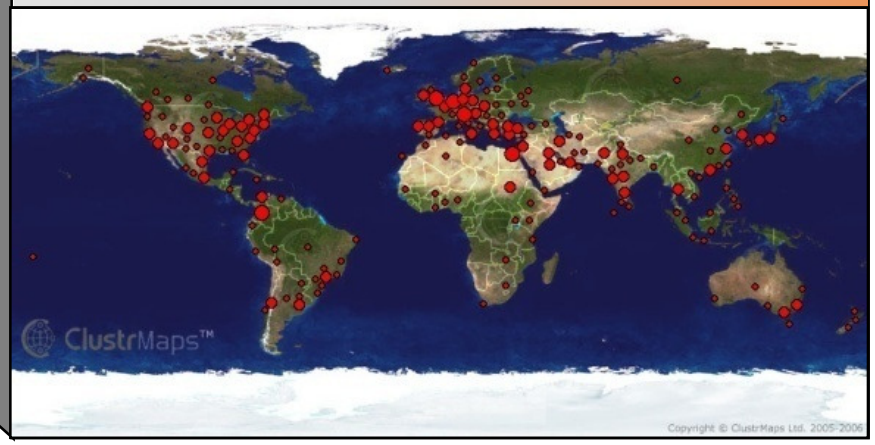
GAMS at a Glance



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

- Roots: World Bank, 1976
- Went commercial in 1987
- GAMS Development Corp.
- GAMS Software GmbH

- Broad academic & commercial user community and network



GAMS' Fundamental concepts

Deployed models have often 15+ years lifecycle

- Changing environment (Hardware, OS, Interface)
- Improving solver technology

→ Different layers with separation of

- model and data
- model and solution methods
- model and operating system
- model and interface

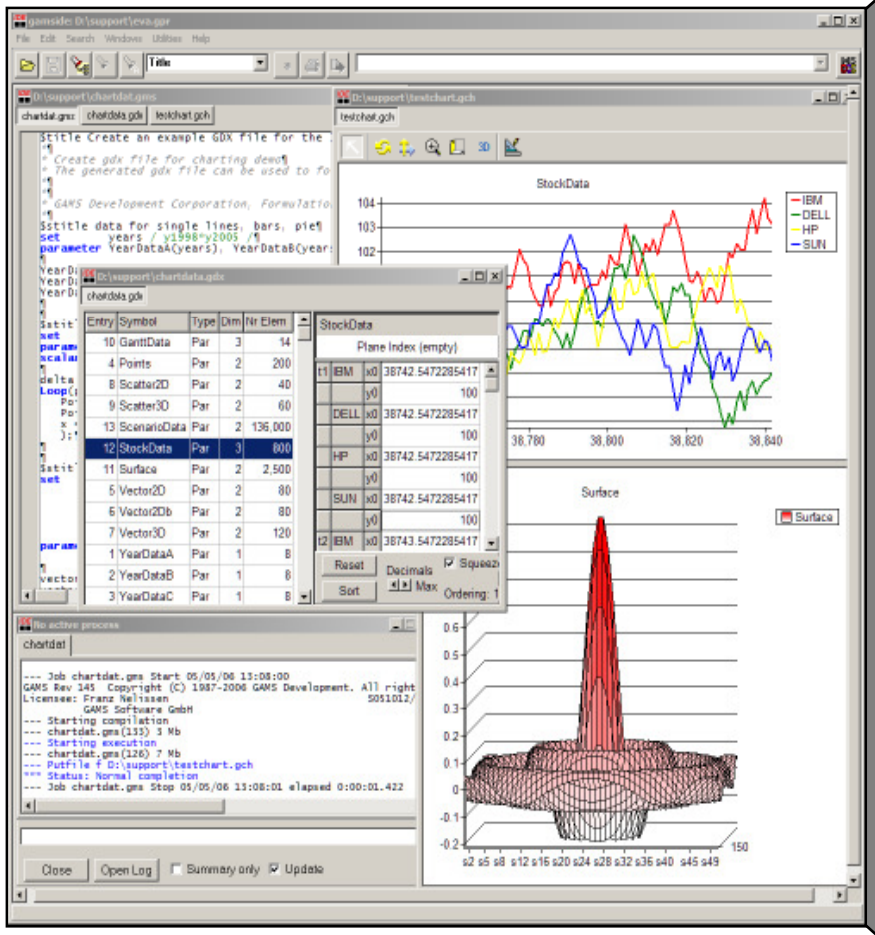
GAMS' Fundamental concepts

→ Models benefit from
- Advancing hardware
- Enhanced / new solver technology
- Improved / upcoming interfaces to other systems

→ Backward compatibility

→ Protection of user investments

GAMS at a Glance



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

- Algebraic Modeling Language
- 25+ Integrated Solvers
- 10+ Supported MP classes
- 10+ Supported Platforms
- Connectivity- & Productivity Tools
  - IDE
  - Model Libraries
  - GDX, Interfaces & Tools
  - Grid Computing
  - Benchmarking
  - Compression & Encryption
  - Deployment System
  - …

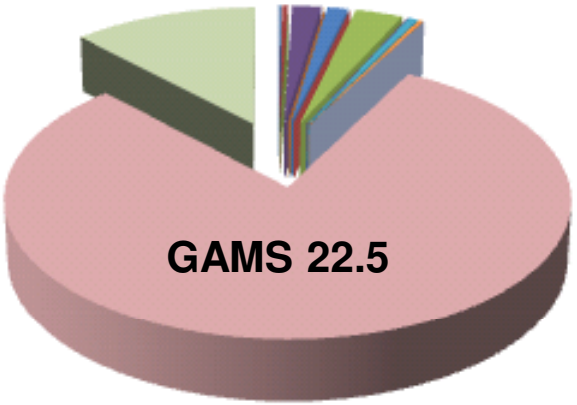
Supported Model Types (GAMS 22.7)

Solver/Model type availability - 22.7 May 1, 2008												
	LP	MIP	NLP	MCP	MPEC	CNS	DNLP	MINLP	QCP	MIQCP	*Stock.*	*Global*
ALPHAECP								✔		✔		
BARON 8.1	✔	✔	✔				✔	✔	✔	✔		✔
BDMLP	✔	✔										
COIN	✔	✔										
CONOPT 3	✔		✔			✔	✔		✔			
CPLEX 11.0	✔	✔							✔	✔		
DECIS	✔										✔	
DICOPT								✔		✔		
KNITRO 5.1	✔		✔				✔		✔			
LINDOGLOBAL 5.0	✔	✔	✔				✔	✔	✔	✔		✔
LGO	✔		✔				✔		✔			✔
MILES				✔								
MINOS	✔		✔				✔		✔			
MOSEK 5	✔	✔	✔				✔		✔	✔		
MPSGE												
MSNLP			✔				✔		✔			✔
NLPEC				✔	✔							
OQNLP			✔				✔	✔	✔	✔		✔
OSL V3	✔	✔										
OSLSE	✔										✔	
PATH				✔		✔						
SBB								✔		✔		
SNOPT	✔		✔				✔		✔			
XA	✔	✔										
XPRESS 18.00	✔	✔							✔			
Contributed Plug&Play solvers												
AMPLwrap	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
DEA	✔	✔										
Kestrel	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔

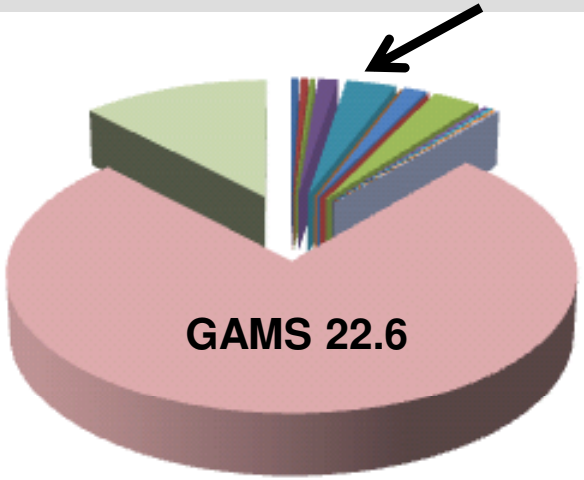
Supported Platforms (GAMS 22.7)

Solver/Platform availability - 22.7: May 1, 2008													
	x86 MS Windows	x86_64 MS Windows	x86 Linux	x86_64 Linux	Sun Sparc SOLARIS	Sun Sparc64 SOLARIS	Sun Intel SOLARIS	HP 9000 HP-UX 11[1]	DEC Alpha Digital Unix 4.0	IBM RS-6000 AIX 4.3	Mac PowerPC Darwin	Mac Intel32 Darwin	SGI IRIX[2]
ALPHAECP	✔	✔	✔	✔	✔	✔	✔		✔	✔	✔	✔	
BARON 8.1	✔	32bit	✔	32bit						✔			
BDMLP	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
COIN	✔	✔	✔	✔			✔				✔	✔	
CONOPT 3	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
CPLEX 11.0	✔	✔	✔	✔	✔	✔	✔	10.0	8.1	✔		✔	9.1
DECIS	✔	✔	✔	✔	✔	32bit	✔	✔	✔	✔			✔
DICOPT	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
EMP	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
KNITRO 5.1	✔	32bit	✔	✔	✔	32bit					✔	✔	
LINDOGLOBAL 5.0	✔	✔	✔	✔	✔	✔					✔	✔	
LGO	✔	✔	✔	✔	✔	✔	✔	✔	✔		✔	✔	✔
LOGMIP	✔	✔									✔	✔	
MILES	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
MINOS	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
MOSEK 5	✔	✔	✔	✔	✔	✔	✔	3.2			✔	✔	
MPSGE	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
MSNLP	✔	✔	✔	✔	✔	32bit		✔			✔	✔	
NLPEC	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
OQNLP	✔	32bit	✔	32bit									
OSL V3	✔	32bit	✔	32bit	✔	32bit		V2		✔			V2
OSLSE	✔	32bit	✔	32bit	✔	32bit				✔			
PATH	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
SBB	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
SNOPT	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
XA	✔	32bit	✔	✔	✔	32bit		✔	✔	✔			
XPRESS 18.00	✔	32bit	✔	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	✔								

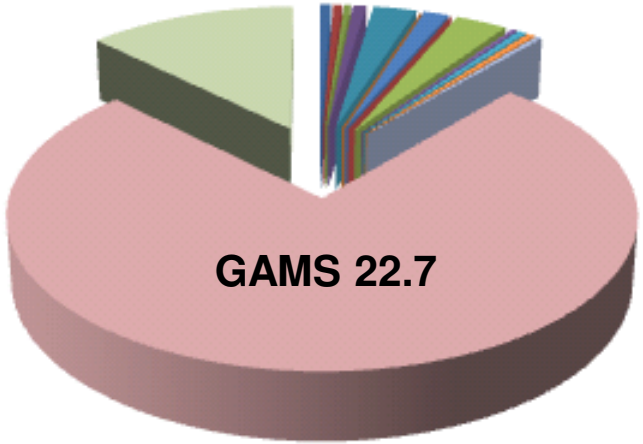
Downloads by Platform



~525 downloads/week



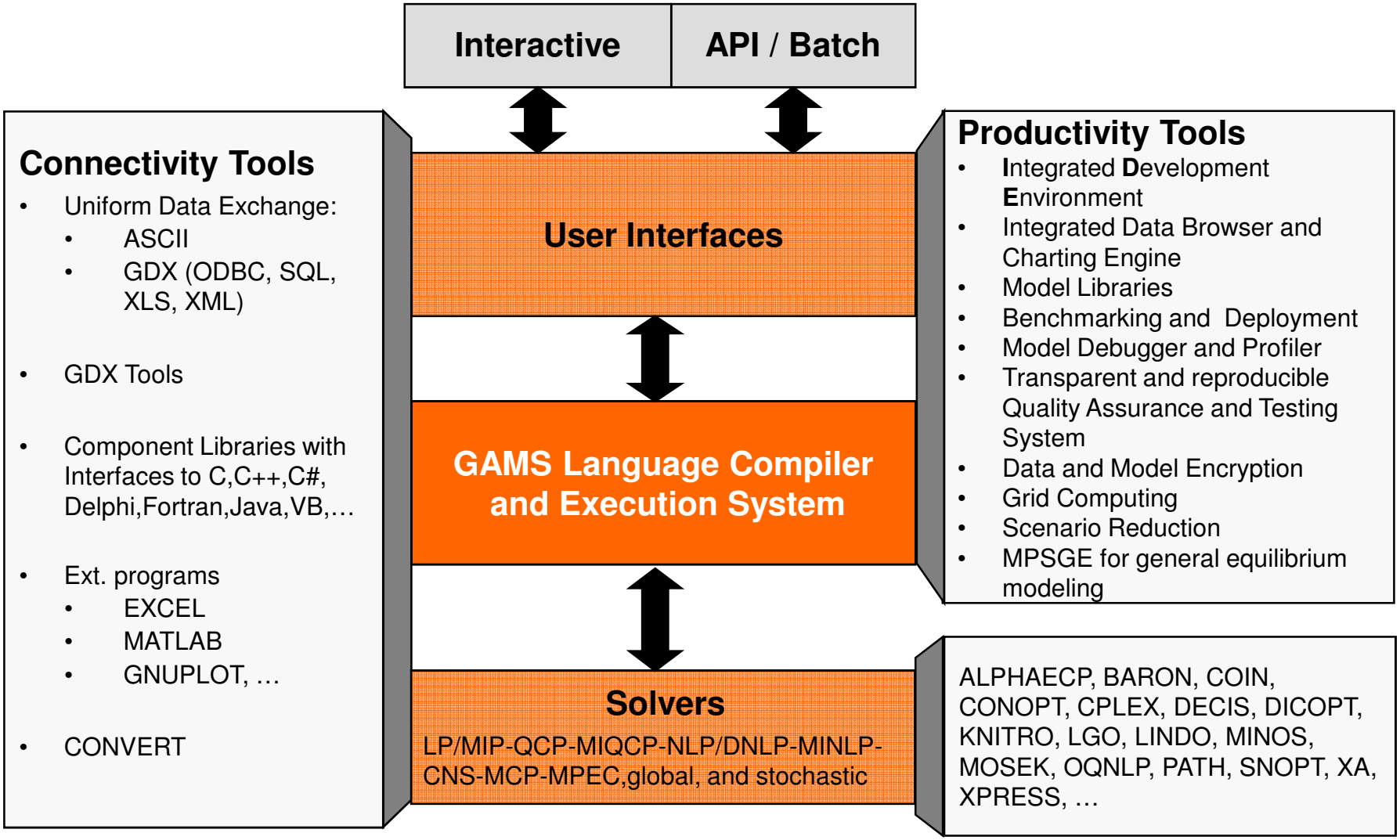
~590 downloads/week



~590 downloads a week

aix
axu
hp7*
dar
dii
leg
lei
lnx
lx3
sgi**
sig
sol
sox
vis
wei

System Overview



Improvements on all Frontiers

- **Solver Technology**
  - Updates for existing solvers
  - New solvers
- **Productivity Tools**
  - IDE improvements
  - Documentation and Wikis
- **Connectivity Tools**
  - **G**ams **D**ata e**X**change and GDX Tools
  - Component Libraries/APIs

Agenda

- GAMS – An Introduction
- **Solver Technology**
- Productivity and Connectivity Tools
- Interfacing GAMS with other Applications

Solver Updates

Continuous updates of existing solvers

- BARON 8.1
- Coin-OR Solvers
  - CoinCBC 2.1
  - CoinGLPK 4.22
  - CoinIpopt 3.3
  - CoinBonmin 0.99
- CPLEX 11.1
- LINDOGLOBAL 5.0
- MOSEK 5.0
- XPRESS 18.0
- …

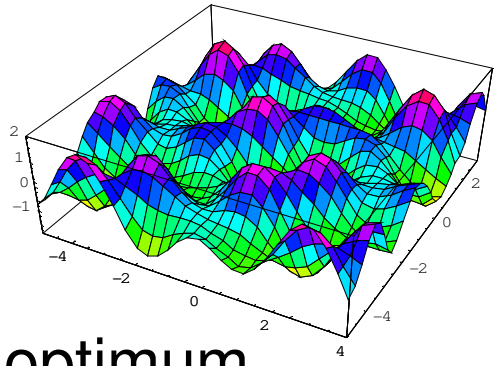
New Solvers

Continuous addition of new solvers, e.g.

- CoinScip http://scip.zib.de/
  - LP/MIP solver developed at Zuse Institute Berlin (ZIB)
  - Branch-and-cut framework
  - Supports GAMS/BCH facility to allow additional control of the solution process
  - free for academic users
- In-core communication solvers
  - Bdmlpd, Conoptd, Cplexd, …
- (Experimental) Extended Mathematical Programming

Improved Global Optimizers in GAMS

- Practical optimization problems are often nonlinear and non-convex, with discrete variables
- They may contain disconnected feasible regions with multiple local optima



→ Find the best of all local optima

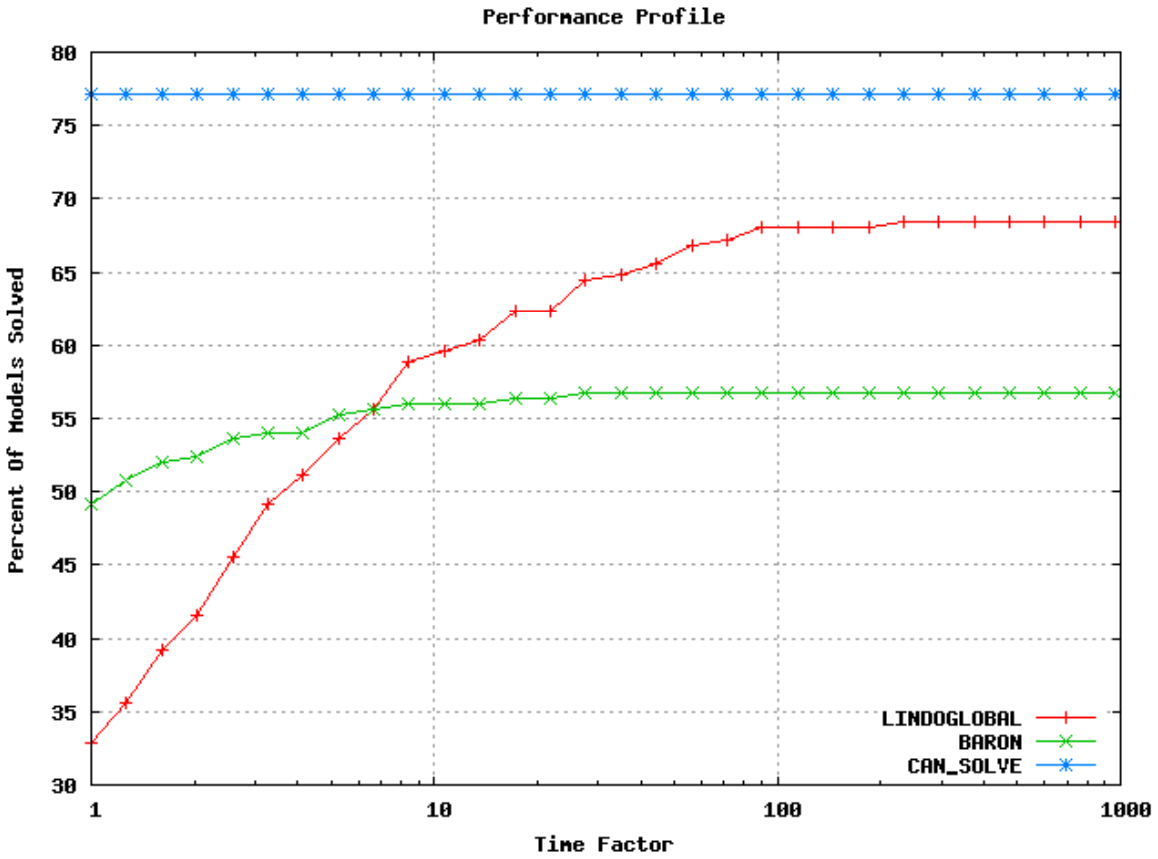
- **BARON**
- **LINDOGLOBAL**

} Proven global optimum

- LGO
- OQNLP/MSNLP

} Stochastic convergence to global optimum

Global Benchmark Summary



- 250 models

  MINLPs from MINLIB
- timelimit: 600 sec
- gap tol.: 0%

- **Lindoglobal 5.0.1**
- **Baron 7.8.1**

Coin-OR

An initiative to spur the development of open-source software for the OR community

http://www.coin-or.org/

- A repository of currently ~30 open-source projects
  - Solvers
  - Interfaces
  - Tools
- An active OR community
  - Mailing lists
  - Google group
  - Wikis

The Coin-OR / GAMSLinks Project

https://projects.coin-or.org/GAMSlinks

Stefan Vigerske (Humboldt-University Berlin)

Goals

- easy access to COIN-OR solvers via GAMS
- broadening the audience of COIN-OR
- broadening the audience of GAMS
- help developers to connect their solvers to GAMS
- provide access to GAMS benchmarking and quality assurance tools

The Coin-OR / GAMSLinks Project

GAMS interfaces to open-source Solvers

- COIN-OR Linear Programming (**CLP**) and Branch and Cut (**CBC**)
  - state of the art LP and MIP solver from J. Forrest
- Gnu Linear Programming Kit (**GLPK**)
  - LP and MIP solver from A. Makhorin
- Interior Point Optimizer (**IPOPT**)
  - large scale NLP solver from A. Wächter

The Coin-OR / GAMSLinks Project

GAMS interfaces to open-source Solvers

- Basic Open-source Nonlinear Mixed Integer programming (**BONMIN**)
  - Branch and Cut based MINLP solver from P. Bonami et.al.
- Lagrangian Global Optimizer (**LaGO**)
  - Convexification and Branch and Cut based MINLP solver from I. Nowak and S. Vigerske
- Solving Constraint Integer Programs (**SCIP**)
  - LP/MIP solver developed at Zuse Institute Berlin (ZIB)

The Coin-OR / GAMSLinks Project

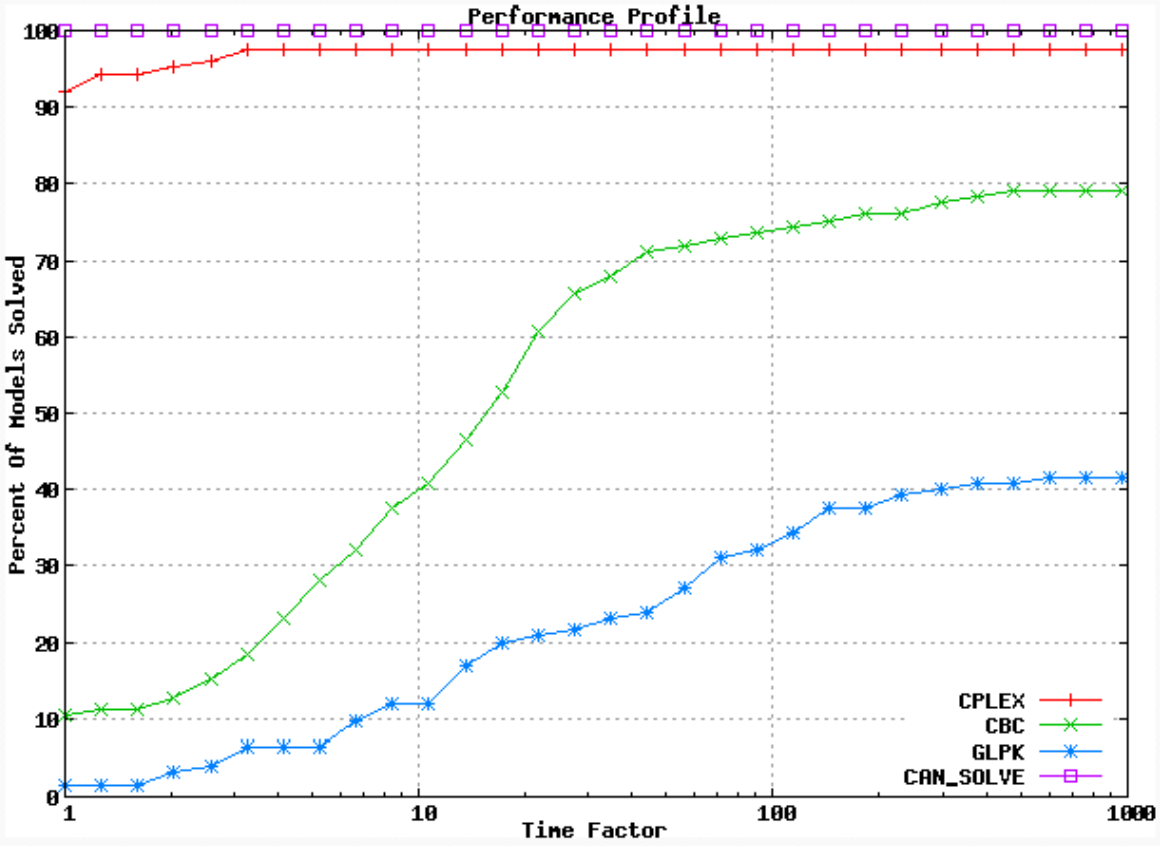
Available on

- Linux (32- and 64-bit x86-CPUs)
- MacOS Darwin (PowerPC-based G4/G5)
- Solaris (64-bit x86-CPUs)
- Windows (32-bit and 64-bit x86-CPUs)

Corresponding GAMS Systems distribute free coin solvers

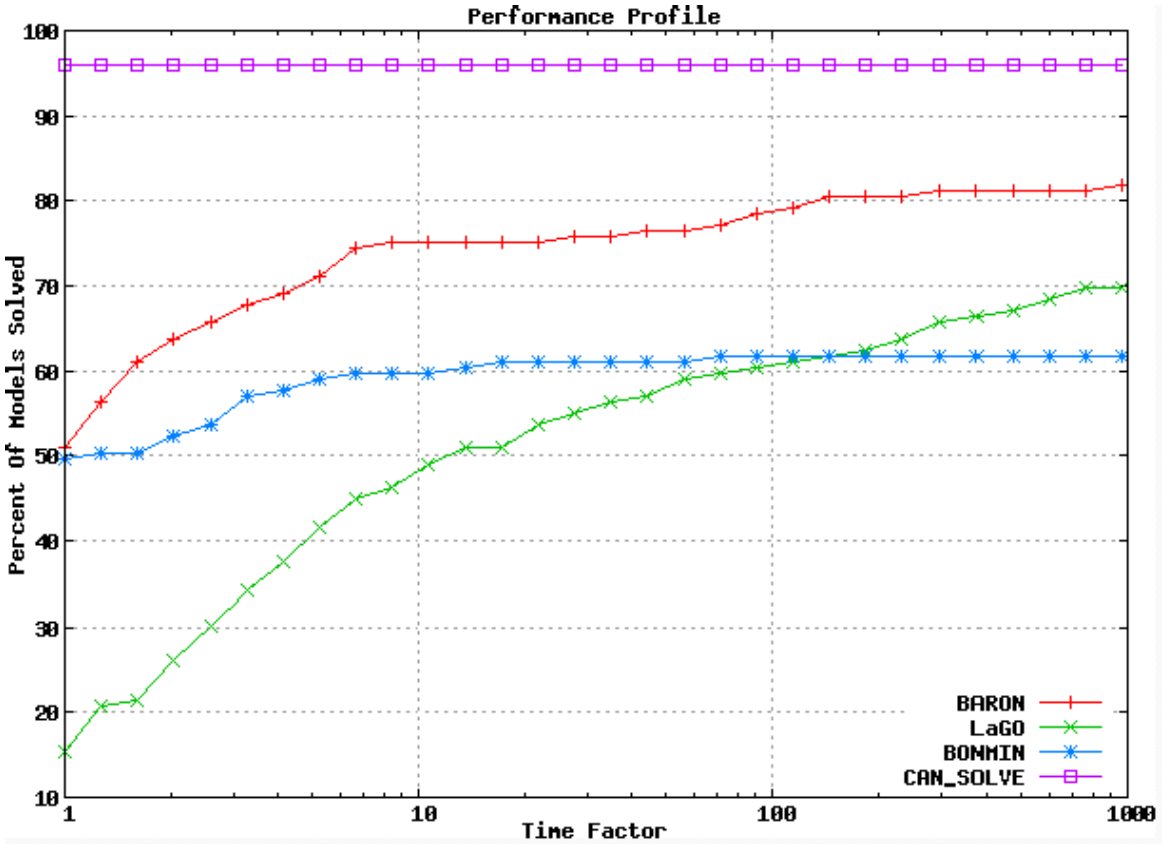
- CoinIpopt
- CoinBonmin
- CoinCbc
- CoinGlpk
- CoinScip (academic only)

MIP Benchmark Summary



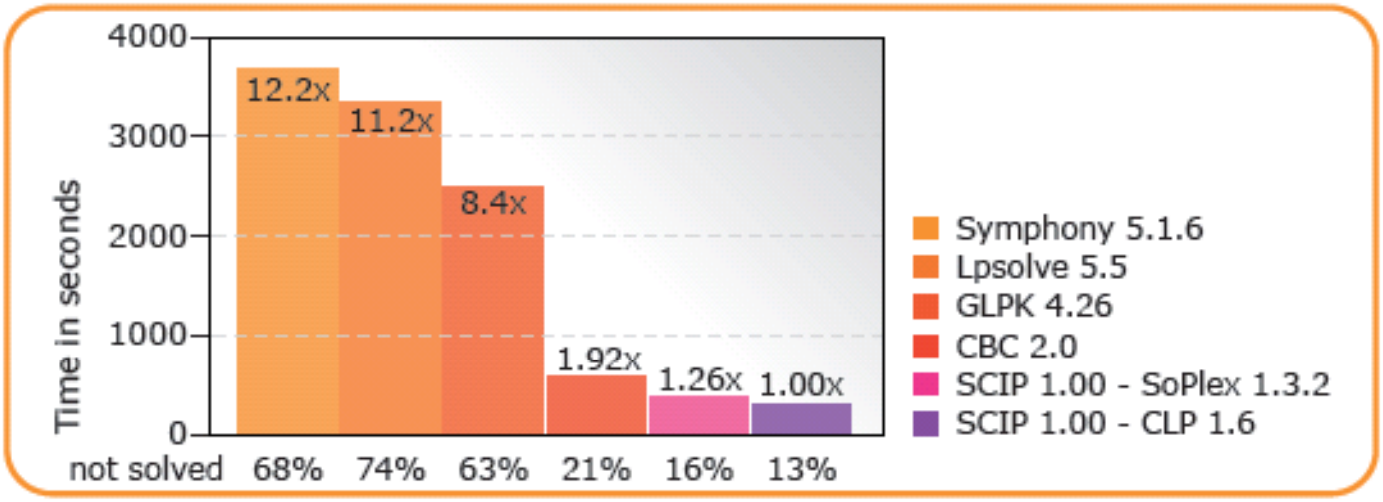
- 125 models: **MIP**s from LINLib
- timelimit: 1 hour
- gap tol.: 0.01%
- CPLEX 10.20
- CBC (Aug. '07)
- GLPK 4.20

MINLP Benchmark Summary



- 149 models MINLPLib **MINLPs** with ≤ 1000 var.
- timelimit: 1 hour
- gap tol.: 1%
- BARON 7.8.1
- LaGO (Aug. '07)
- BONMIN (Aug. '07)

The Coin-OR / GAMSLinks Project



Performance Benchmark of MIP codes free for academic use by H. Mittelmann. Solution times are geometric means where unsolved instances were assigned a 2 hours solution time (time limit). Details at scip.zib.de

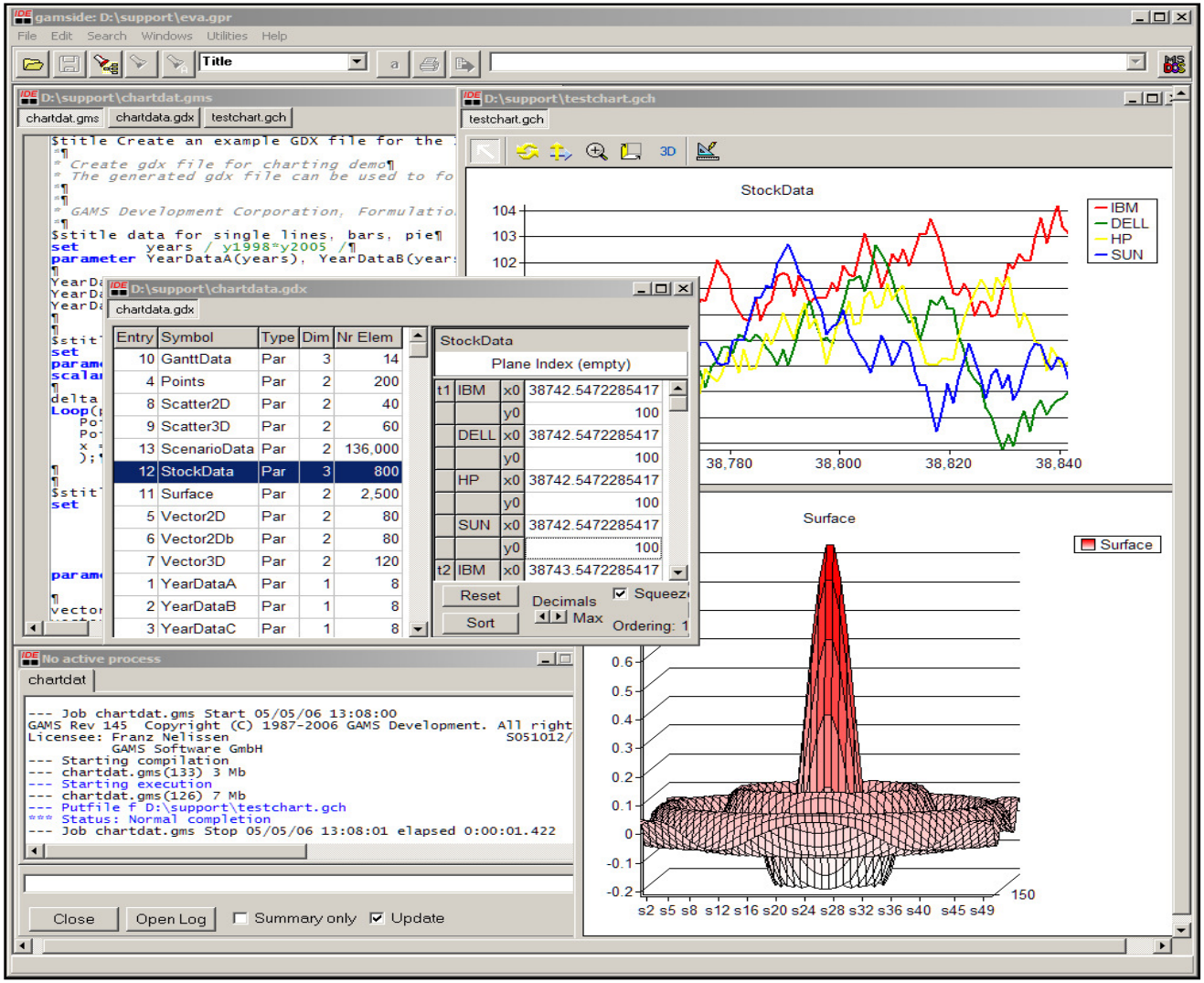
GAMS QA and testing supports maturing of COIN-OR solvers!

Coin-OR solvers enable GAMS to offer dependable free solvers!

Agenda

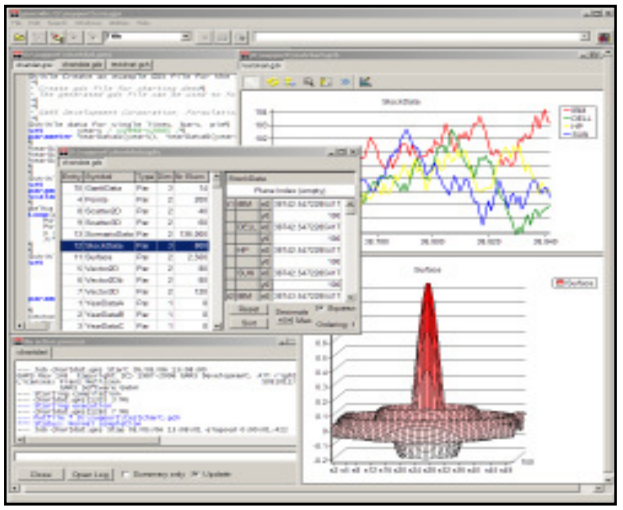
- GAMS – An Introduction
- Solver Technology
- **Productivity and Connectivity Tools**
- Interfacing GAMS with other Applications

Integrated Development Environment



Integrated Development Environment

- Project management
- Editor / Syntax coloring / Spell checking
- Launching and monitoring of (multiple) GAMS processes
- Listing file / Tree view / Syntax-error navigation
- Solver selection / Option selection
- GDX viewer
  - Data cube
  - Data export (e.g. to MS Excel)
  - Charting facilities
- Documentation
- Model libraries



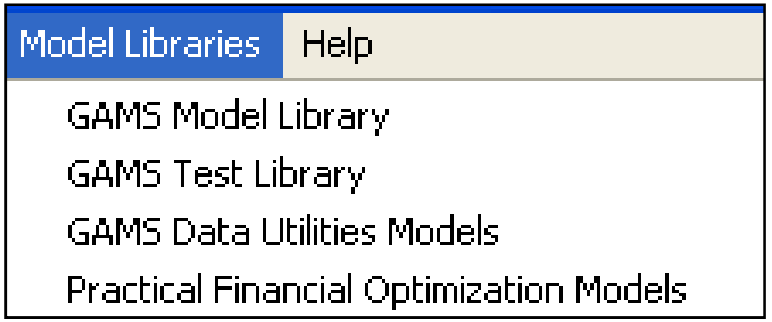
Documentation

- Distributed Documentation
  - GAMS Users Guide
  - Expanded GAMS Users Guide (McCarl)
  - Solver Manuals
  - GAMS Utility Manuals

- Wikis
  - Support Wiki http://support.gams-software.com
  - Interfaces Wiki http://interfaces.gams-software.com

Distributed Model Libraries

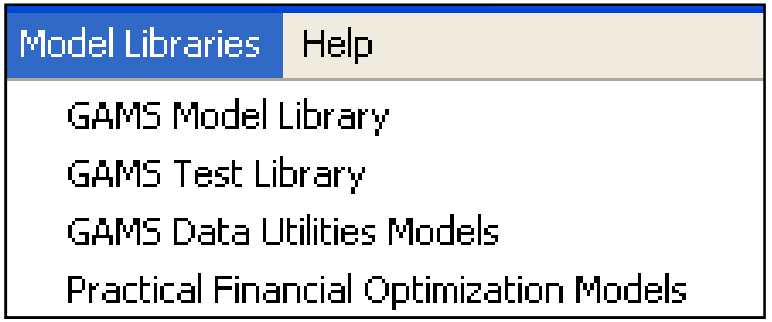
- **GAMS Model Library**
  - Example and user-contributed models
  - Very often used as templates
  - Tests for
    - Solver robustness and correctness
    - Backward compatibility

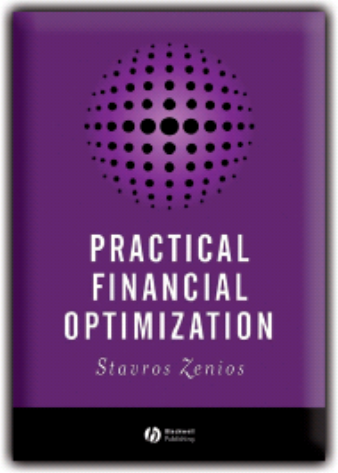


- **GAMS Test Library**
  - Transparent and reproducible Quality Assurance Tests
  - Tests for
    - Solver correctness
    - Special functions
    - GAMS utilities

Distributed Model Libraries

- **GAMS Data Utilities Library**
  - Demonstration of the various utilities interfacing GAMS with other applications
  - e.g. GDX utilities





- **Practical Financial Optimization Models**
  Models of the forthcoming book

  "PRACTICAL FINANCIAL OPTIMIZATION – A Library of GAMS Models"

  by Consiglio, Nielsen and Zenios

GAMSworld Model Libraries

GAMS World

The Worlds
- CONE
- GLOBAL
- MINLP
- MPEC
- MPSGE
- Performance
- Translation

Search

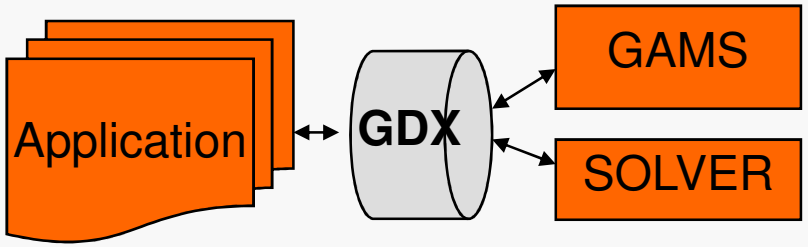
Contact

Maintained libraries of established and varied set of both theoretical and practical test models:

- CONELib
- GLOBALLib
- LinLib
- MINLPLib
- MPECLib
- MPSGELib
- PrincetonLib
- XPRESSLib
- …

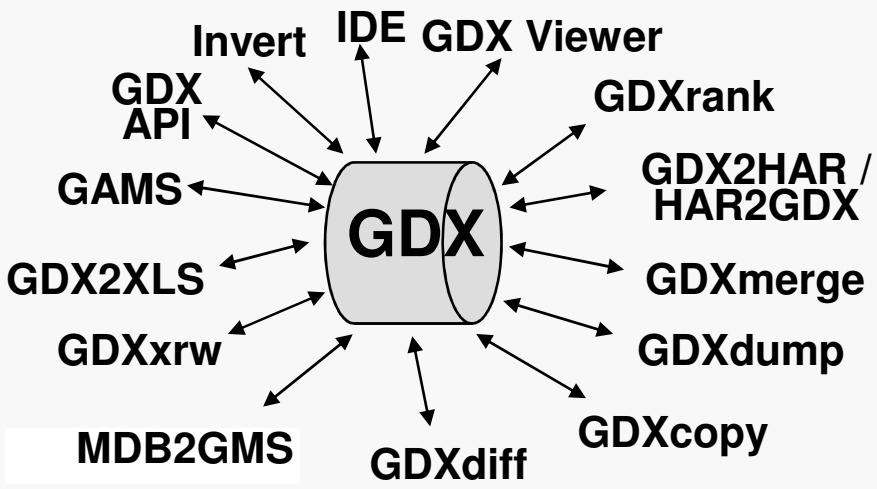
Gams Data eXchange

Binary Data Exchange

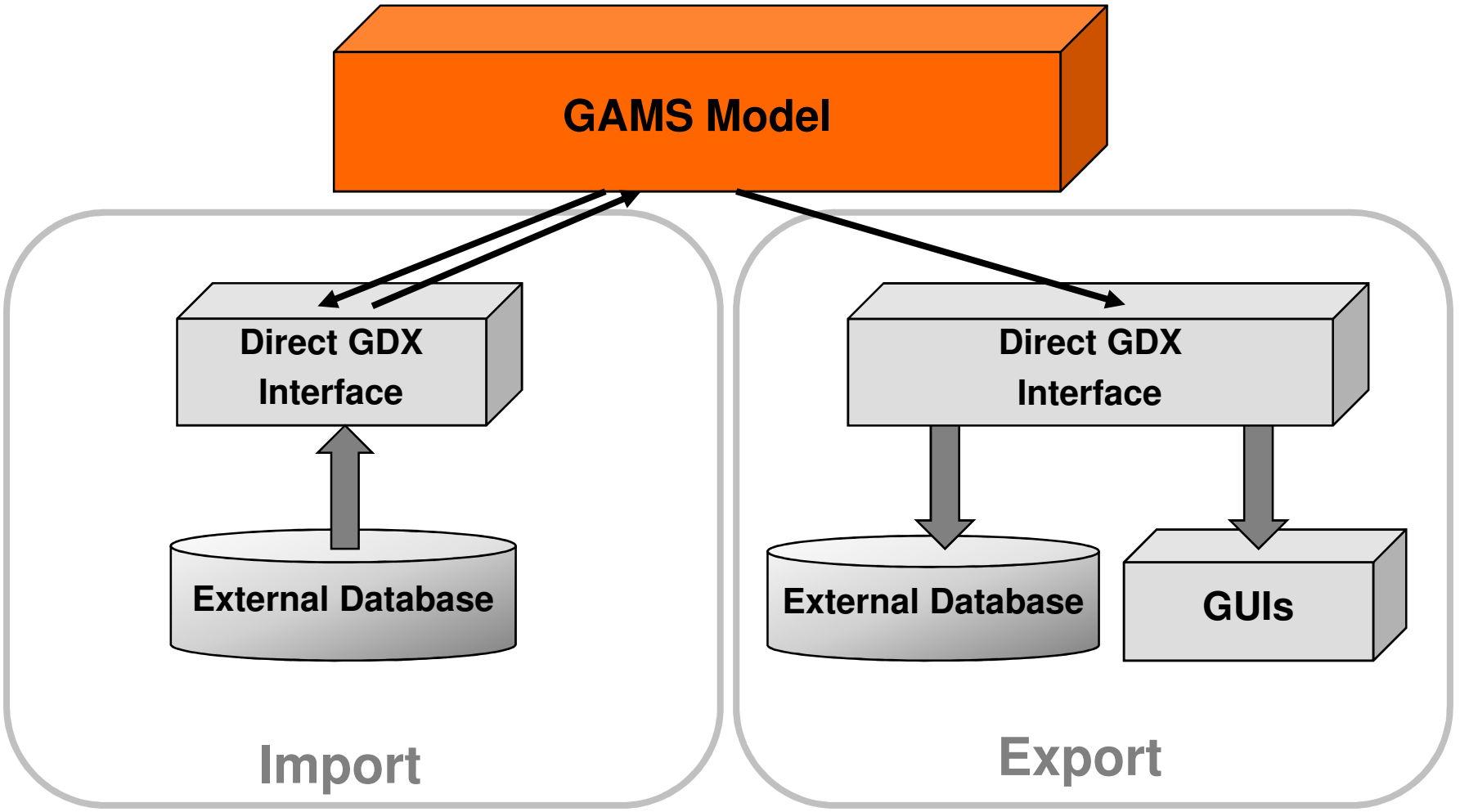


- Fast exchange of data
- Syntactical check on data before model starts
- Data Exchange at any stage (Compile and Run-time)
- Platform Independent
- Direct GDX interfaces and general API
- Scenario Management Support
- Full Support of Batch Runs

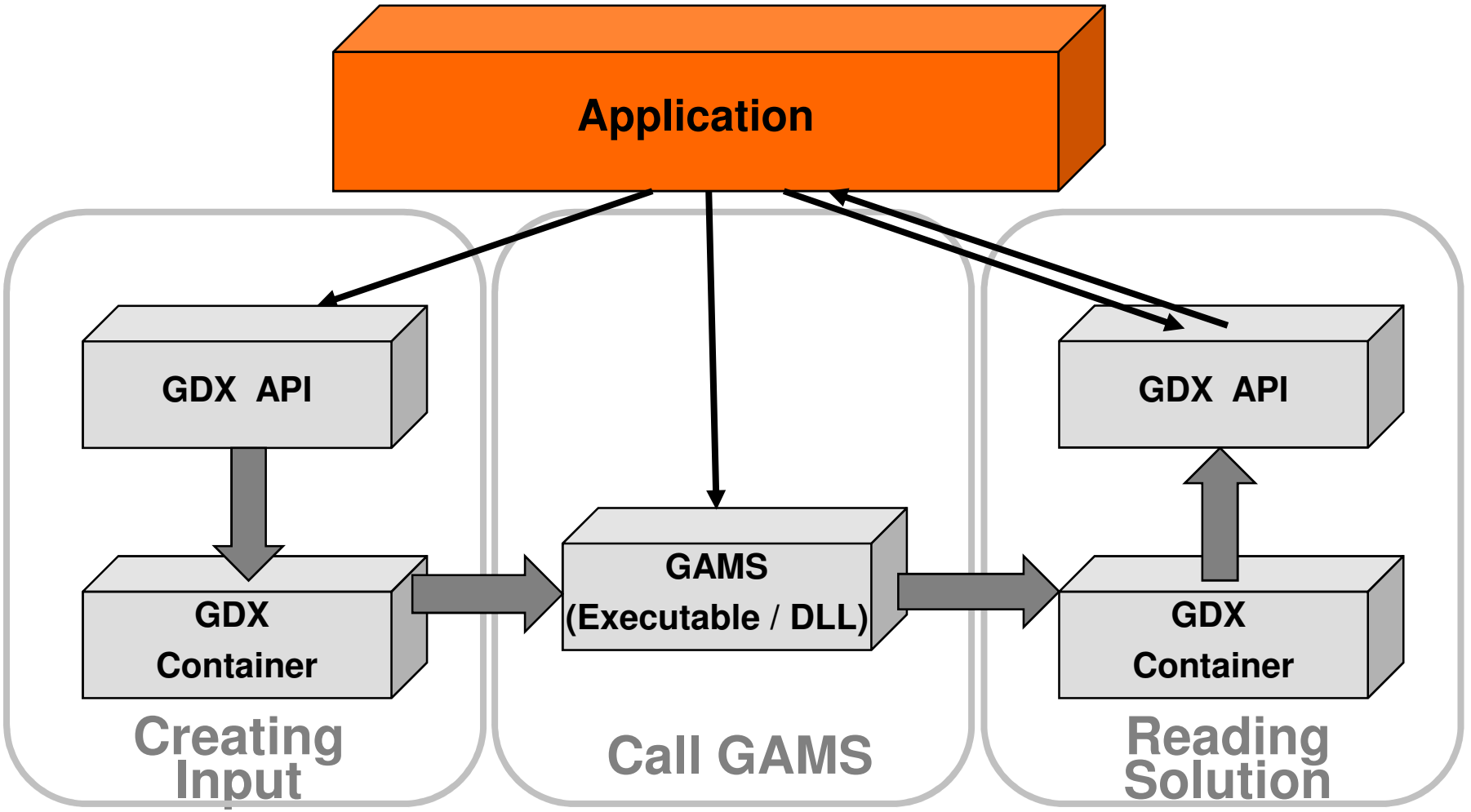
GDX Tools



GAMS in Control



Application in Control

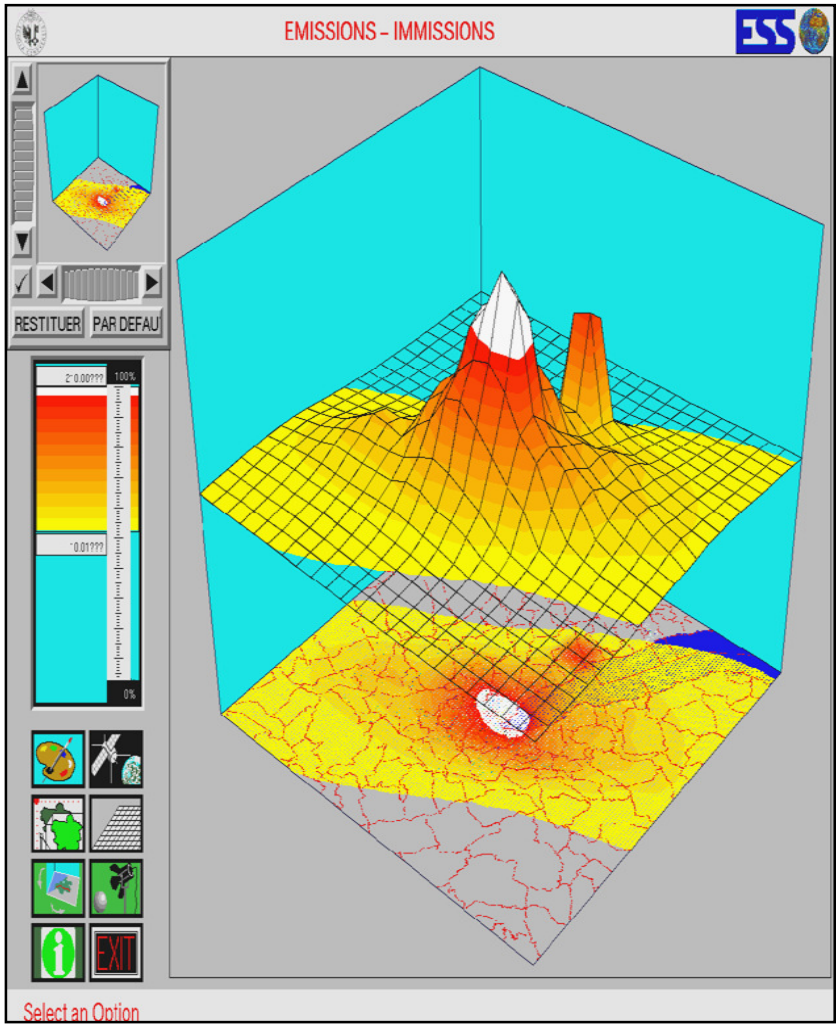


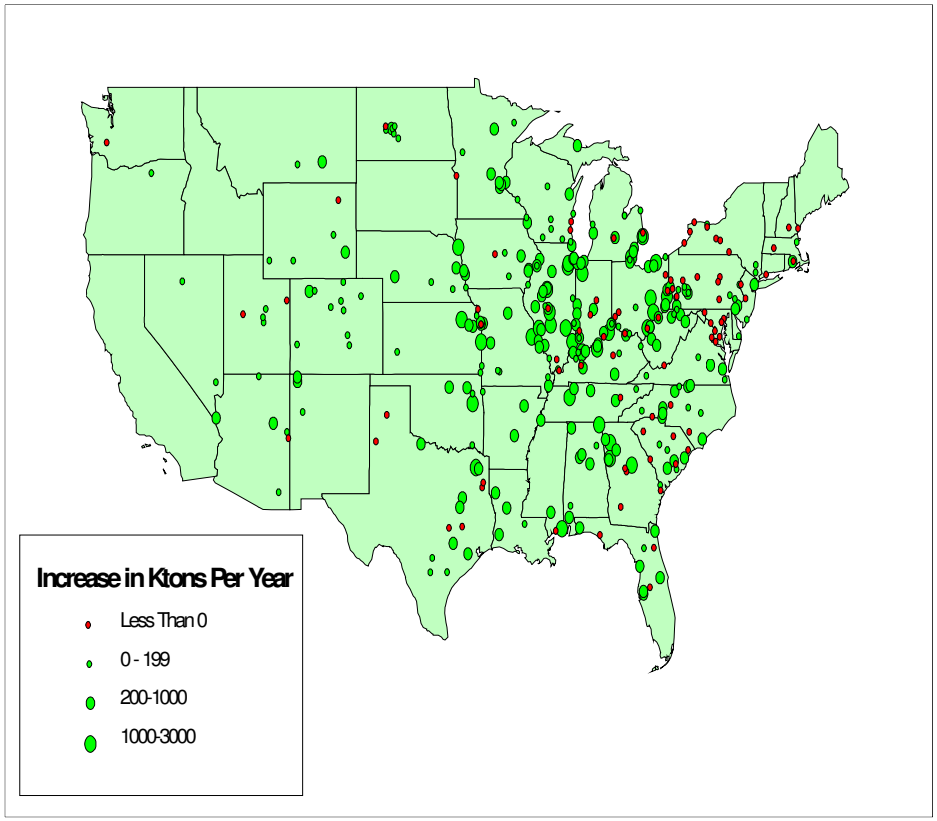
Calling GAMS from an Application

Works from basically every environment

- MS Office Application / VBA
- Programming languages:
  - C,C++,C#
  - Delphi
  - Java
  - VB.NET
  - Fortran
- Web application (server side)
- ERP Systems: Oracle, SAP
- …

Interfacing with GIS Applications





Interfacing with MATLAB

Figure 1: US dollar short rate scenarios

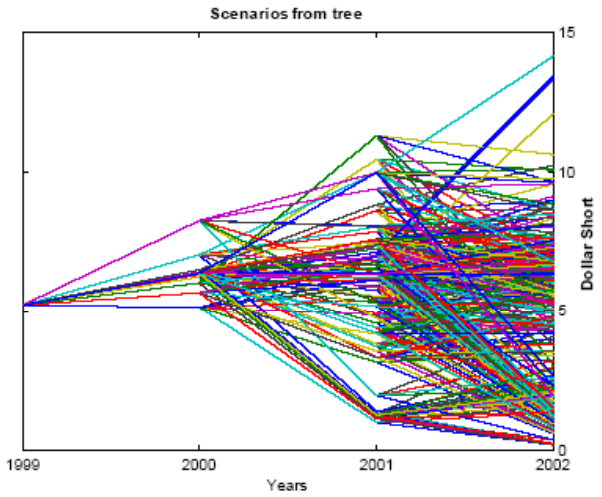
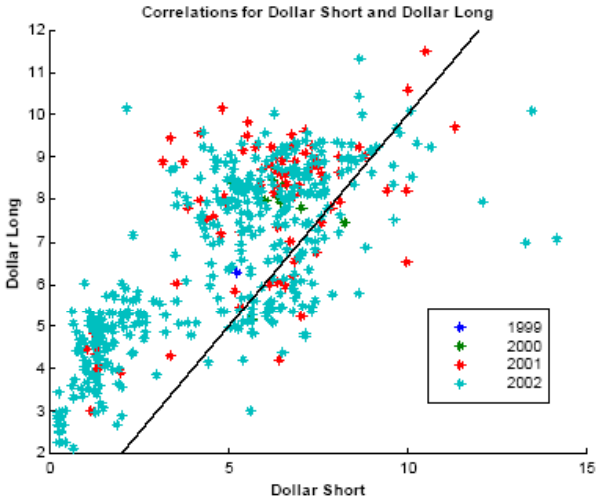
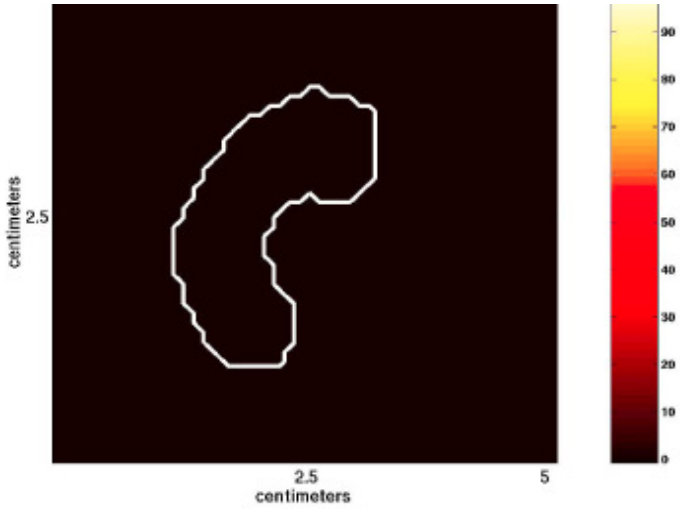
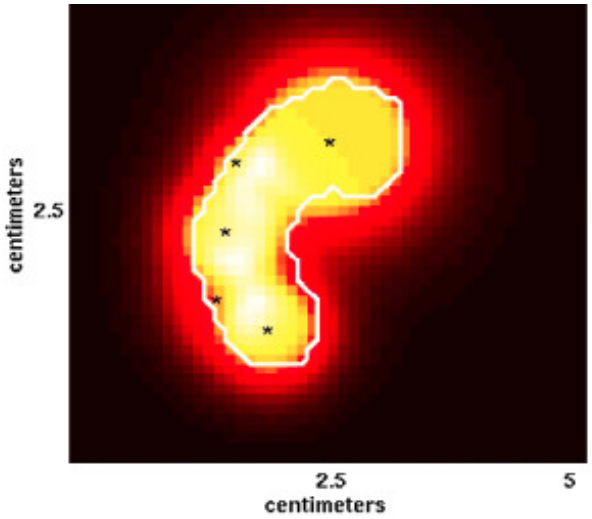


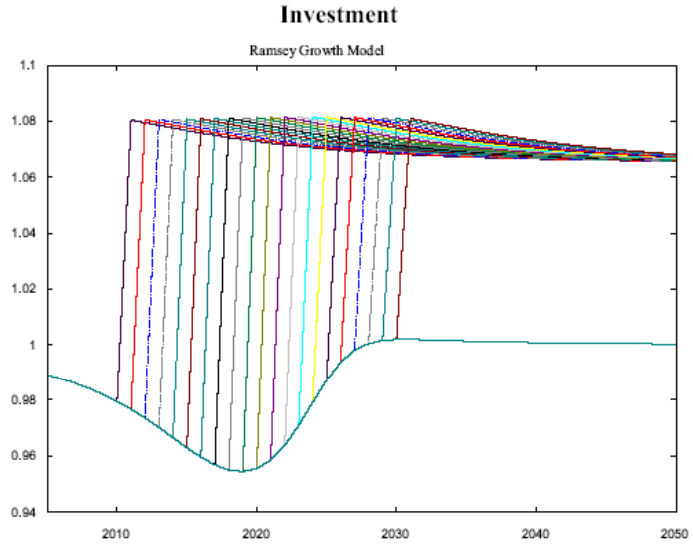
Figure 2: Short vs. long rates

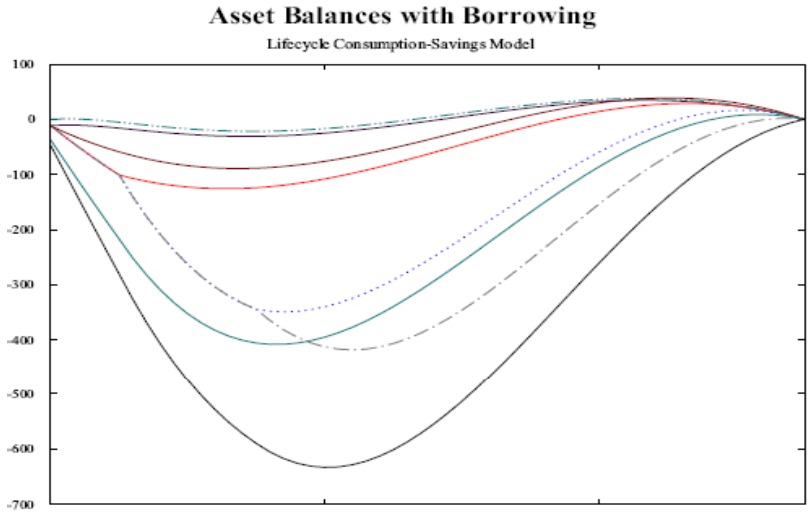


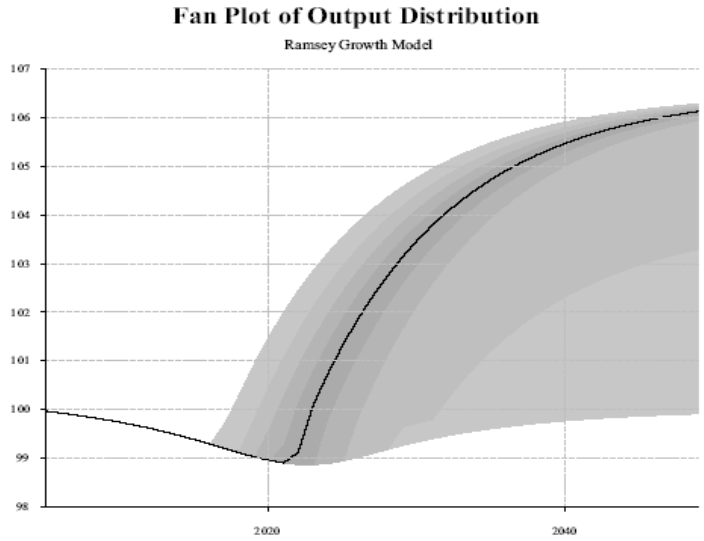


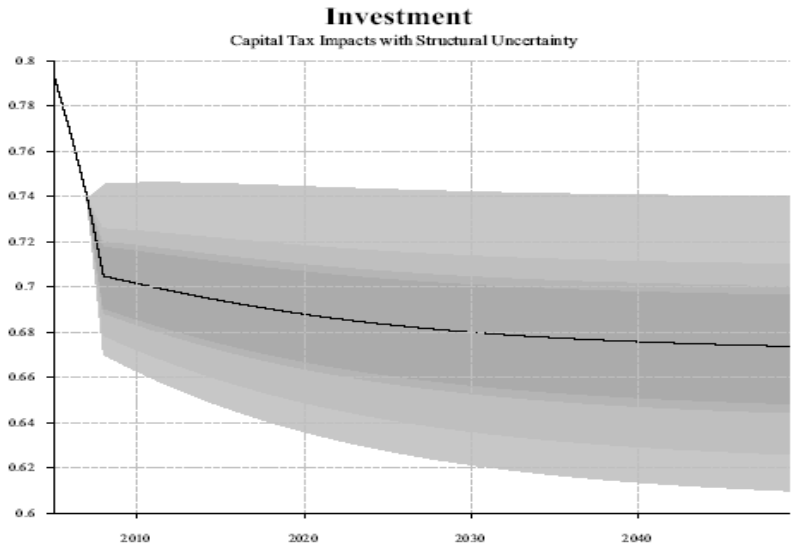


Interfacing with GNUPLOT

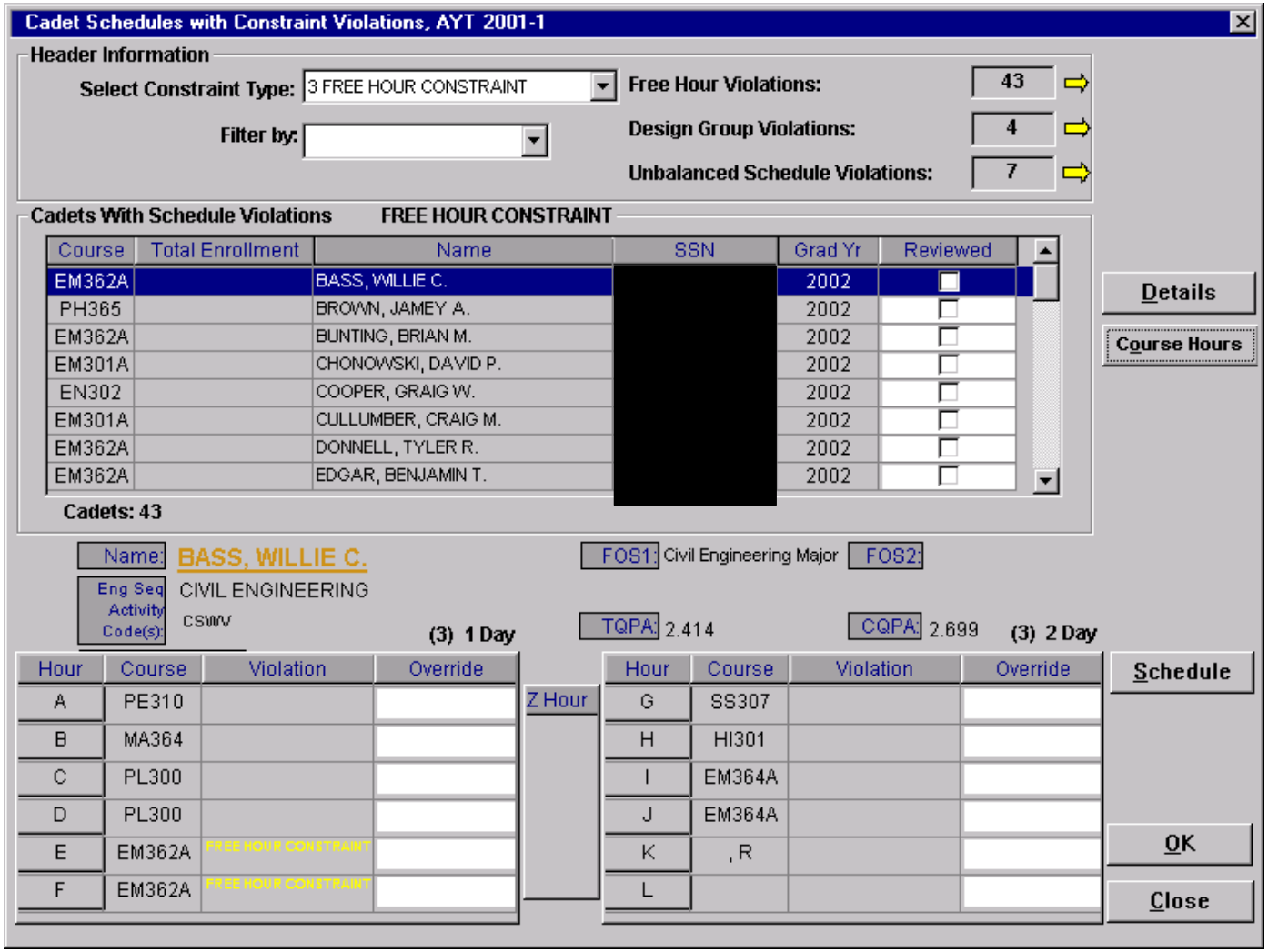




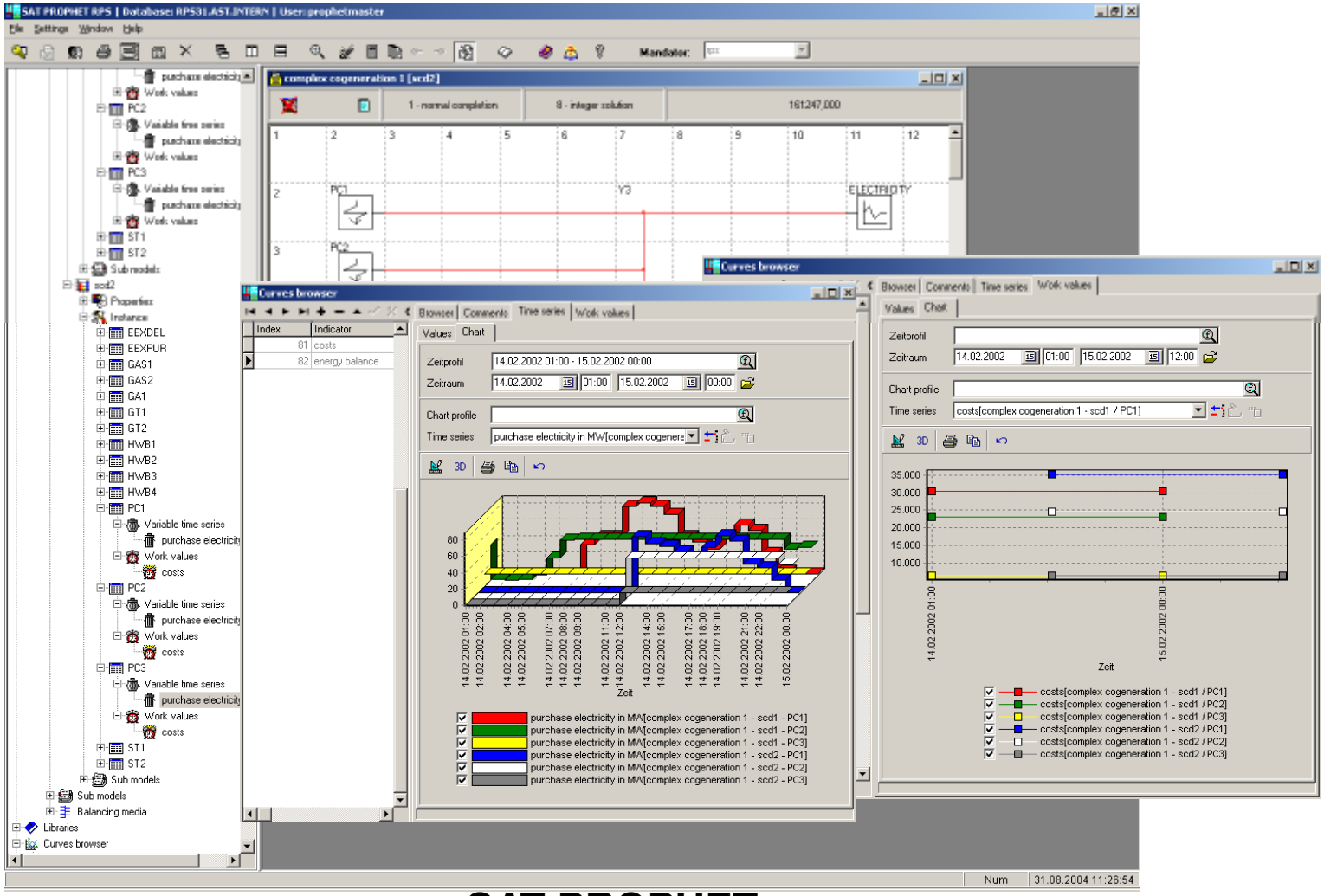




Interfacing with Web Applications



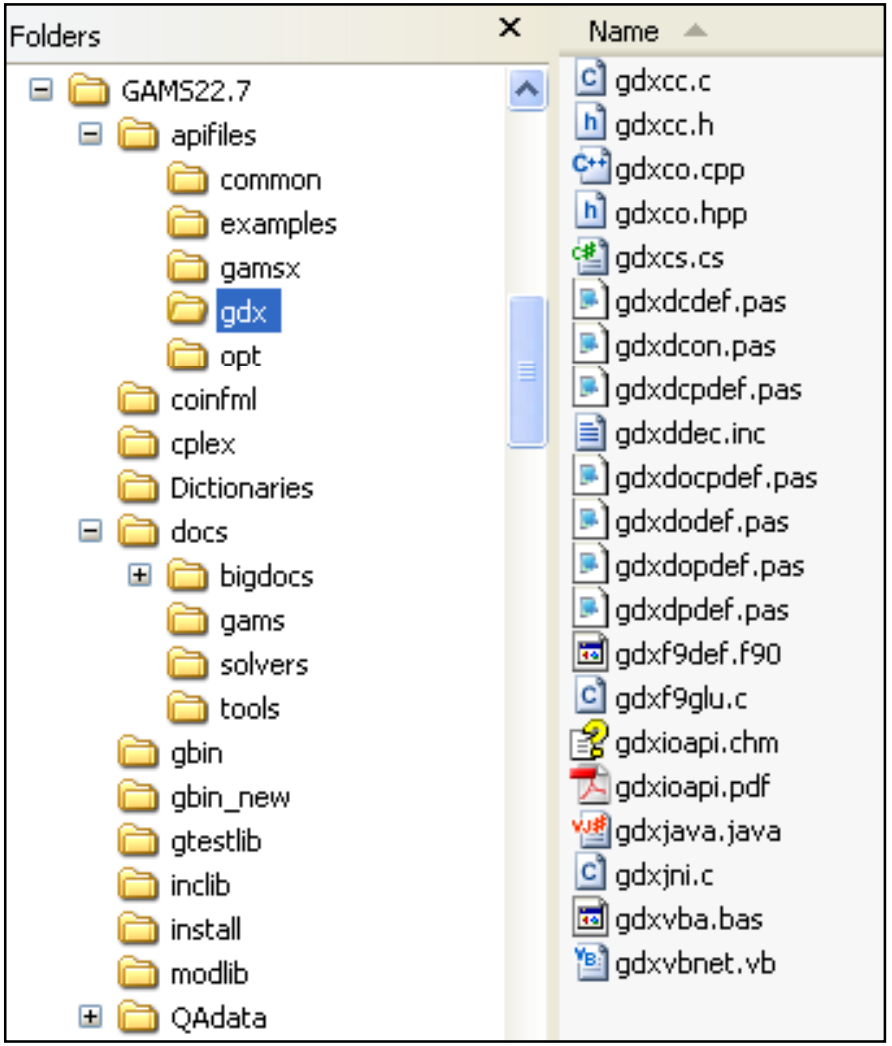
Interfacing with Individual Front Ends



SAT-PROPHET

Distributed APIs

- Component Libraries
  - GAMS
  - GDX
  - Option
- Interfaces for
  - C, C++, C#
  - Delphi
  - Fortran
  - Java
  - VBA, VB.Net
- Examples/Documentation



Agenda

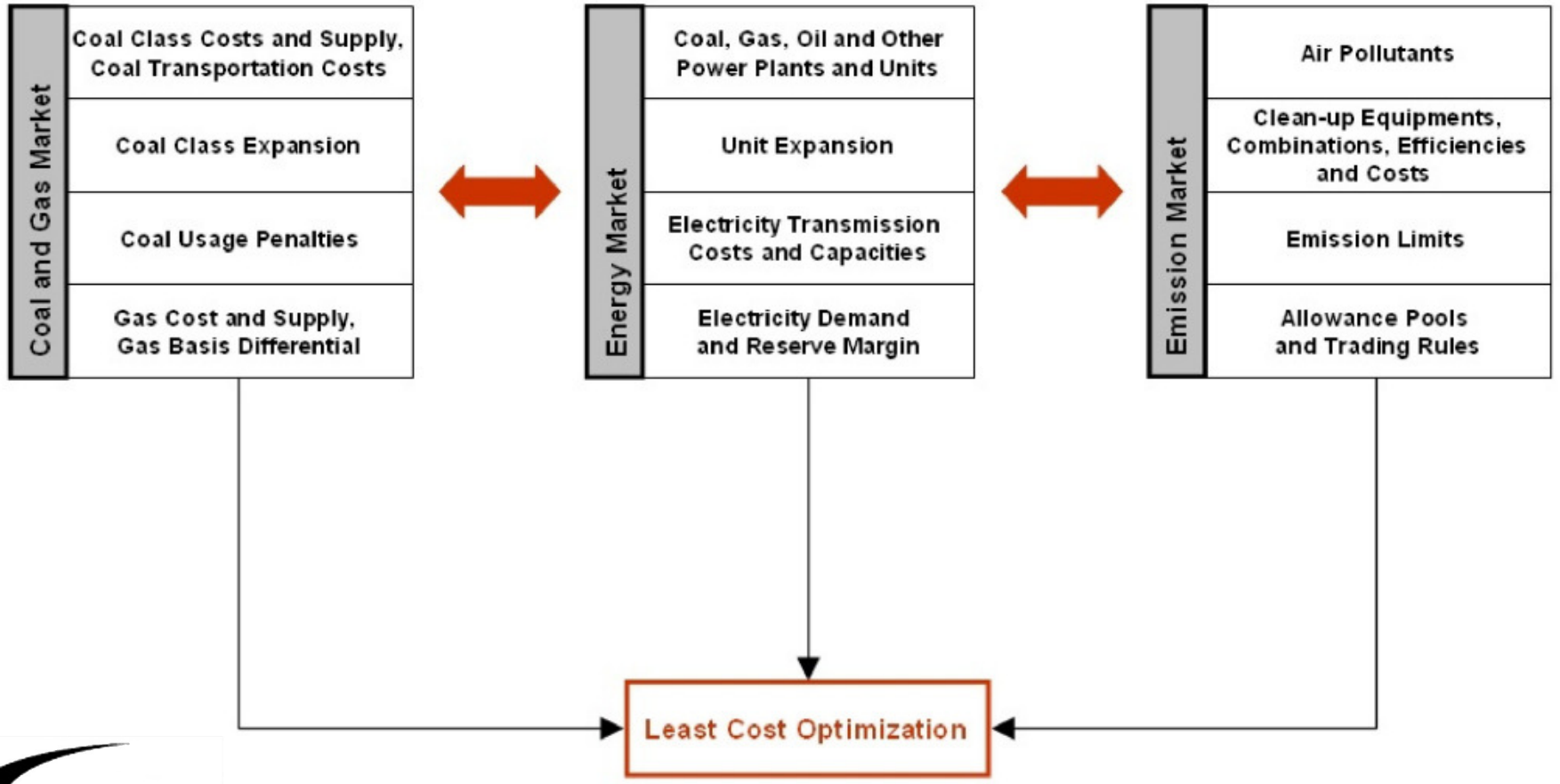
- GAMS – An Introduction
- Solver Technology
- Productivity and Connectivity Tools
- Interfacing GAMS with other Applications

Sample GAMS Applications

- Integrated Model of the US Electricity, Coal and Emission Markets
  → GAMS model is in control

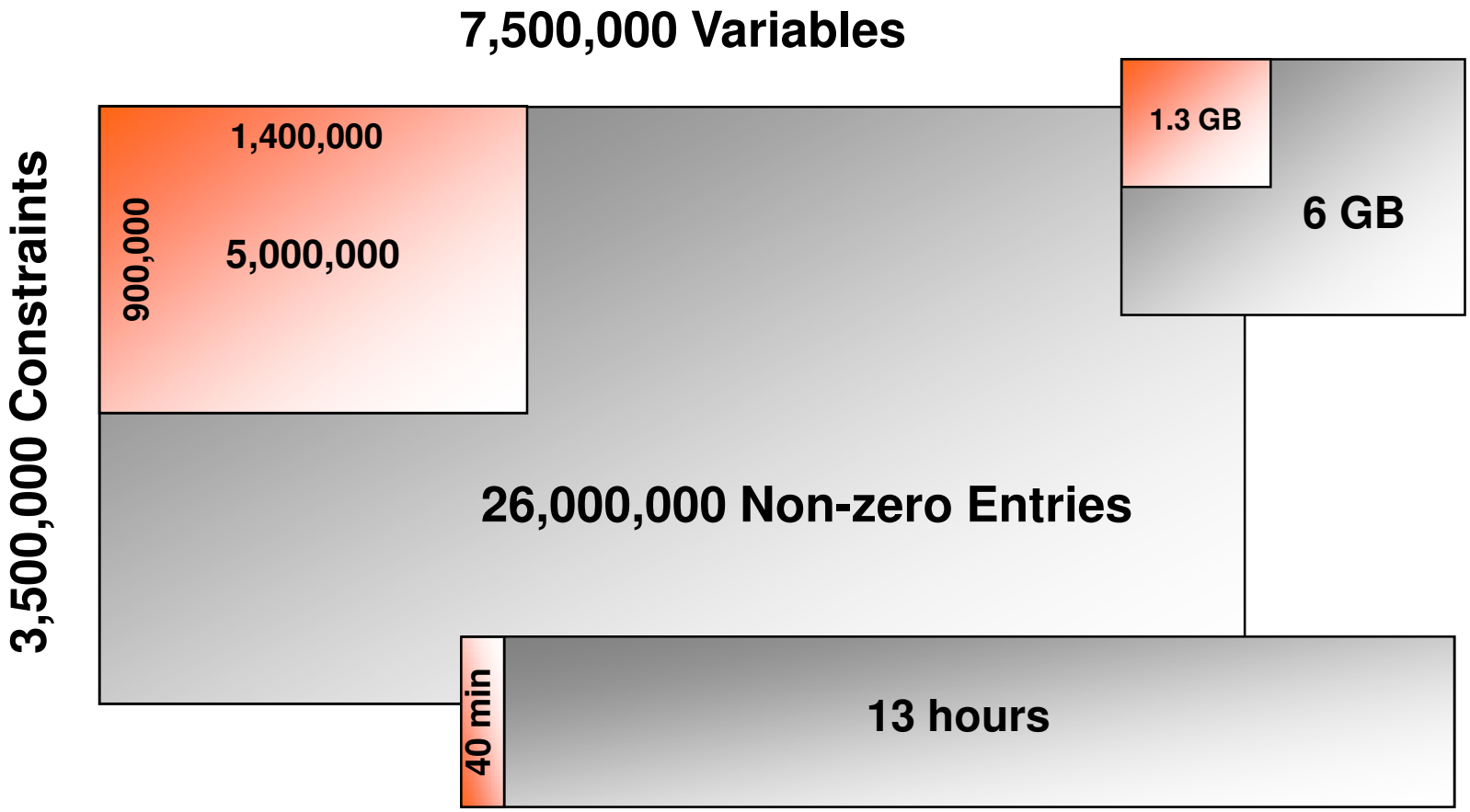
- Hotdip Galvanizing Scheduling Model
  → Application is in control

Integrated US Energy Model

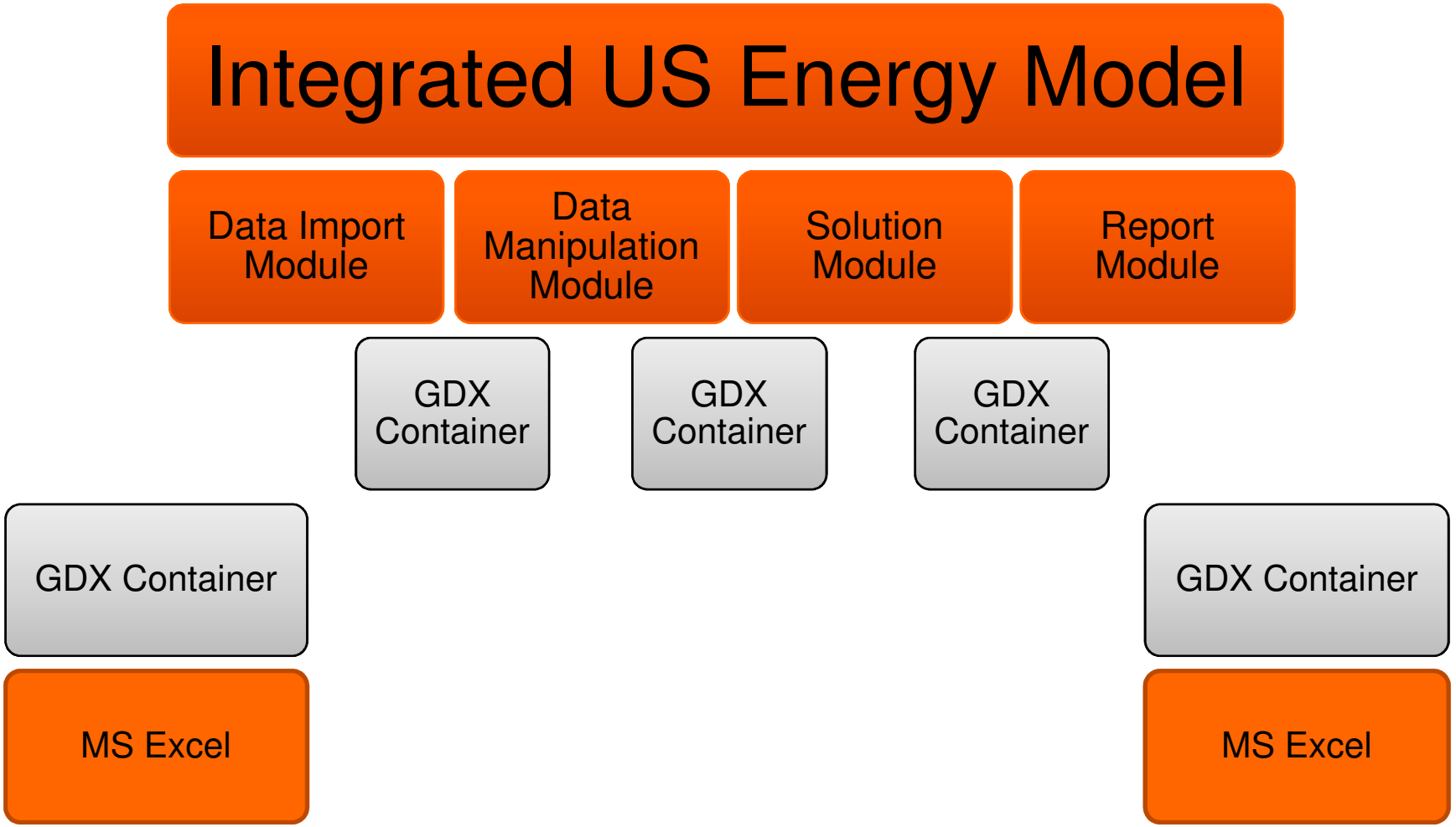


Greenmont

Varying Size of the Problem



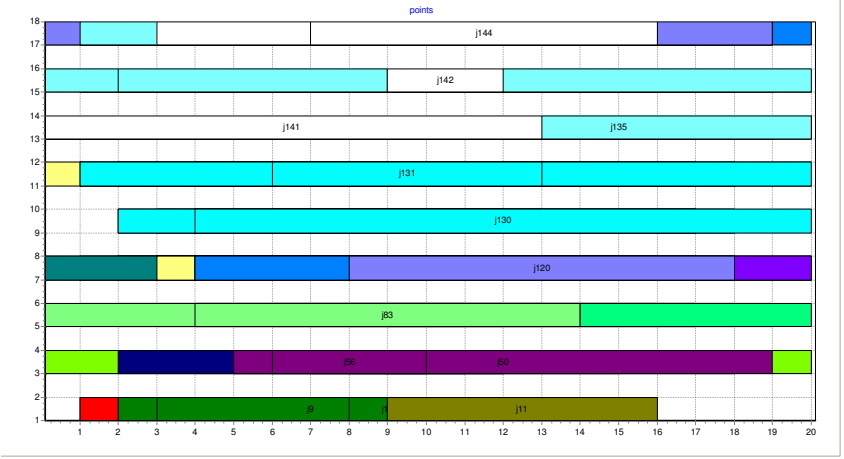
Layout of the Model



Hot-dip Galvanizing Scheduling Problem

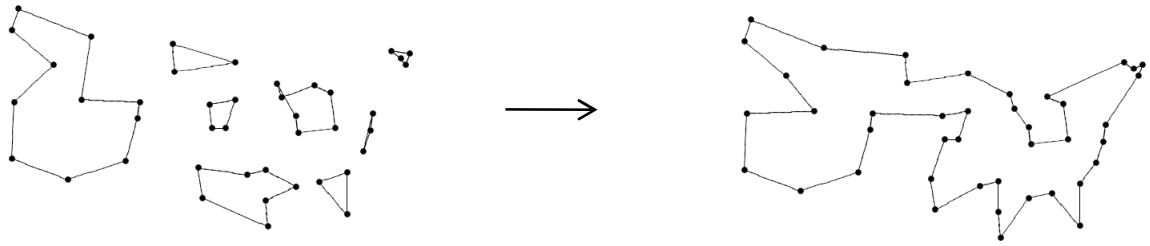
- **Given**
  - Set of jobs
  - Gas usage for reheating job i after job j is completed
  - Set of jobs not allowed to follow each other
  - Gas costs

- **Wanted**:
  - Schedule minimizing total gas costs



Hot-dip Galvanizing Scheduling Problem

- Can be formulated as a TSP like Model
- Need of subtour elimination constraints



- Single ‘Brute force’ model cannot be solved
- Algorithmic Approach using dynamic cuts

GAMS Beta 22.8

GAMS Beta Distribution **22.8** is available for download

http://beta.gams-software.com

- New Solver Libraries, e.g.
  - CPLEX 11.1
  - Coin-OR Solvers
- Experimental Solvers offering in-core communication
- Two new Model Libraries
- New utilities (gdx2xls, invert, xlstalk)
- …

Contacting GAMS

Europe

GAMS Software GmbH
Eupener Str. 135-137
50933 Cologne
Germany

Phone: +49 221 949 9170
Fax: +49 221 949 9171
http://www.gams.de

info@gams.de
support@gams-software.com

USA

GAMS Development Corp.
1217 Potomac Street, NW
Washington, DC 20007
USA

Phone: +1 202 342 0180
Fax: +1 202 342 0181
http://www.gams.com

sales@gams.com
support@gams.com