OR 2007
GAMS - Workshop

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GAMS Software GmbH www.gams.de

Saarbrücken, September 4th 2007

Agenda

- GAMS Development / GAMS Software
- Working with GAMS – A Guided Tour
- GAMS Grid Computing
- Compressed and Encrypted Input Files
- Summary

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GAMS

- Roots: Research project World Bank, 1976
- Pioneer in Algebraic Modeling Systems
- Went commercial in 1987
- GAMS Development Corp. (Washington, D.C)
- GAMS Software GmbH (Cologne)

- Used for economic modeling
- 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 Solutions Specialists Network

TELEGYR SYSTEMS

UNIVERSITY APPS. INC.

Verbund

JK

OPTIENCE

ETSAP

EcoMod Net

Profit Point Inc.

PCS

VA TECH SAT

SAT AUTOMATION

COPENHAGEN ECONOMICS

BARKAWI

ECOPLAN

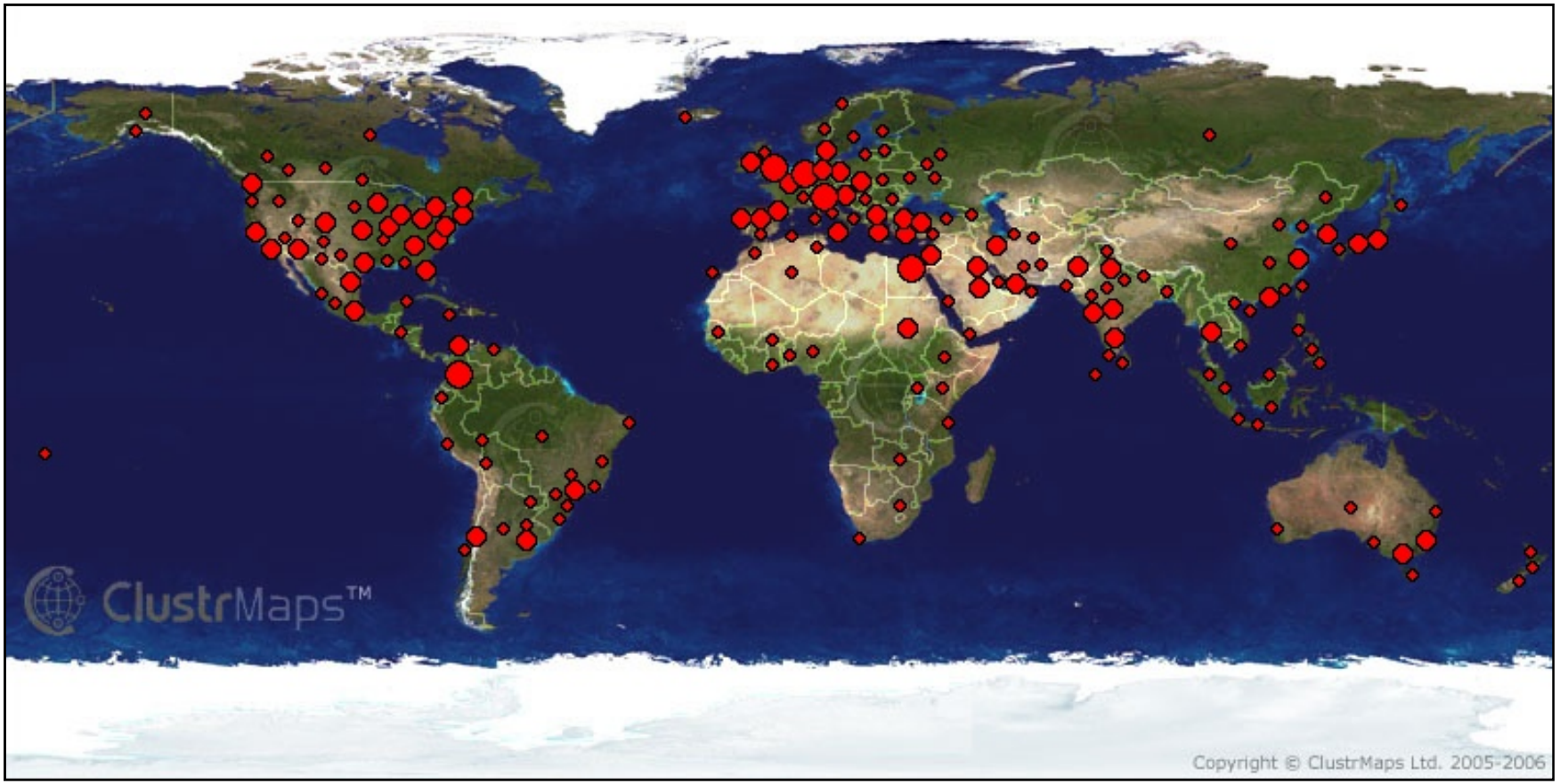
iiT

BALMOREL

Companies with wide experience in GAMS modeling

à Details at: http://www.gams.com/specialists/

Academic + Commercial Users Worldwide



Downloads

Total Downloads of Distribution 22.5 since 2007-06-01: 5848

Sorted by Platform:

- 17 AIX
- 20 AXU
- 116 Darwin
- 91 Linux64
- 236 Linux32
- 45 Solaris (x86)
- 35 Solaris (Sparc)
- 4576 Windows32
- 712 Windows64

~ 500 downloads per Week

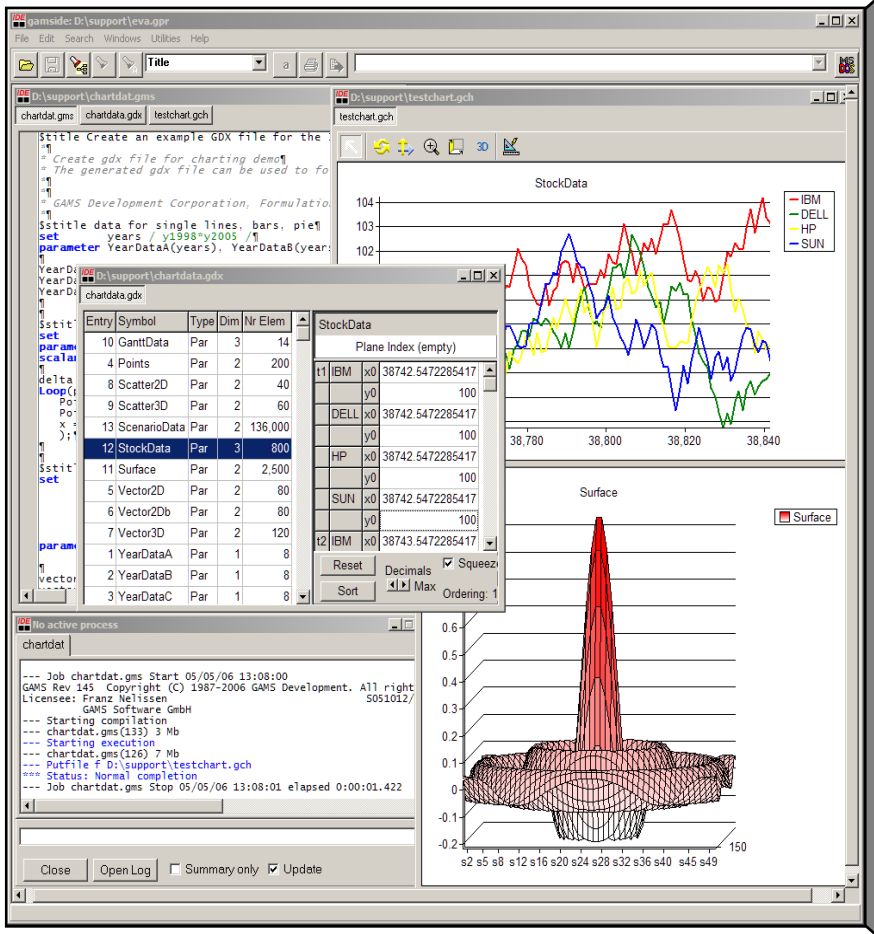
Algebraic Modeling Languages

- High-level programming languages for large scale mathematical optimization problems
- Algebraic formulation
  - § Syntax similar to mathematical notation
  - § Does not contain any hints how to process it
- Do not solve optimization problems directly, but call appropriate external algorithms (solvers)

Goals

- Support of decision making process
- Efficient handling of mathematical optimization problems
- Simplify model building and solution process
- Increase productivity and support maintainable models

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

System Overview

Interactive | **API / Batch**

Connectivity Tools

- Uniform Data Exchange:
  - ASCII
  - GDX (ODBC, SQL, XLS, XML)
- GDX Tools
- Component Library with Interfaces to C++, Java, .NET,…
- Distributed Execution (Grid Computing)
- Ext. programs
  - EXCEL
  - MATLAB
  - GNUPLOT, …
- CONVERT

User Interfaces

GAMS Language Compiler and Execution System

Solvers

LP/MIP-QCP-MIQCP-NLP/DNLP-MINLP-CNS-MCP-MPEC, global, and stochastic

Productivity Tools

- **I**ntegrated **D**evelopment **E**nvironment (**IDE**)
- Integrated Data Browser and Charting Engine
- Model Libraries
- Benchmarking and Deployment
- Model Debugger and Profiler
- Transparent and reproducible Quality Assurance and Testing System
- Data and Model Encryption
- Grid Computing
- Scenario Reduction
- MPSGE for general equilibrium modeling

ALPHAECP, BARON, COIN, CONOPT, CPLEX, DECIS, DICOPT, KNITRO, LGO,LINDO, MINOS, MOSEK, OQNLP, PATH, SNOPT, XA, XPRESS, …

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- GAMS Development / GAMS Software
- Working with GAMS – A Guided Tour
  - **Installation & Basics**
- GAMS Grid Computing
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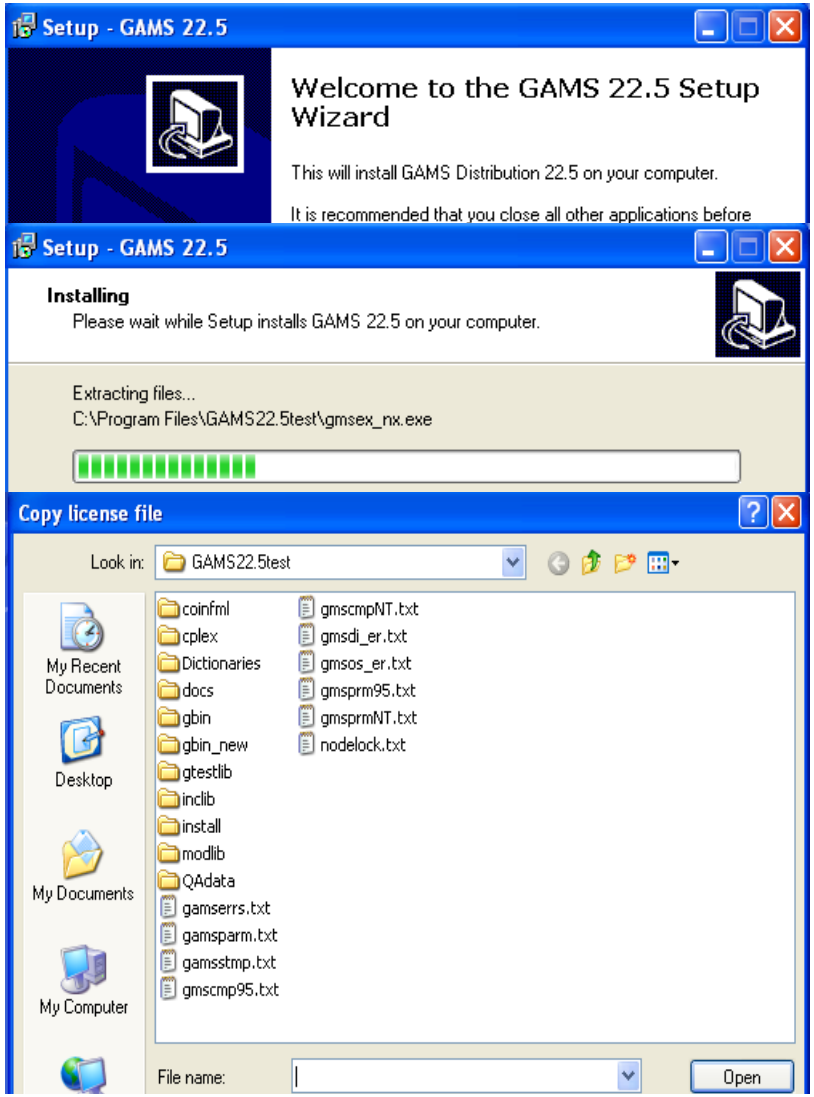
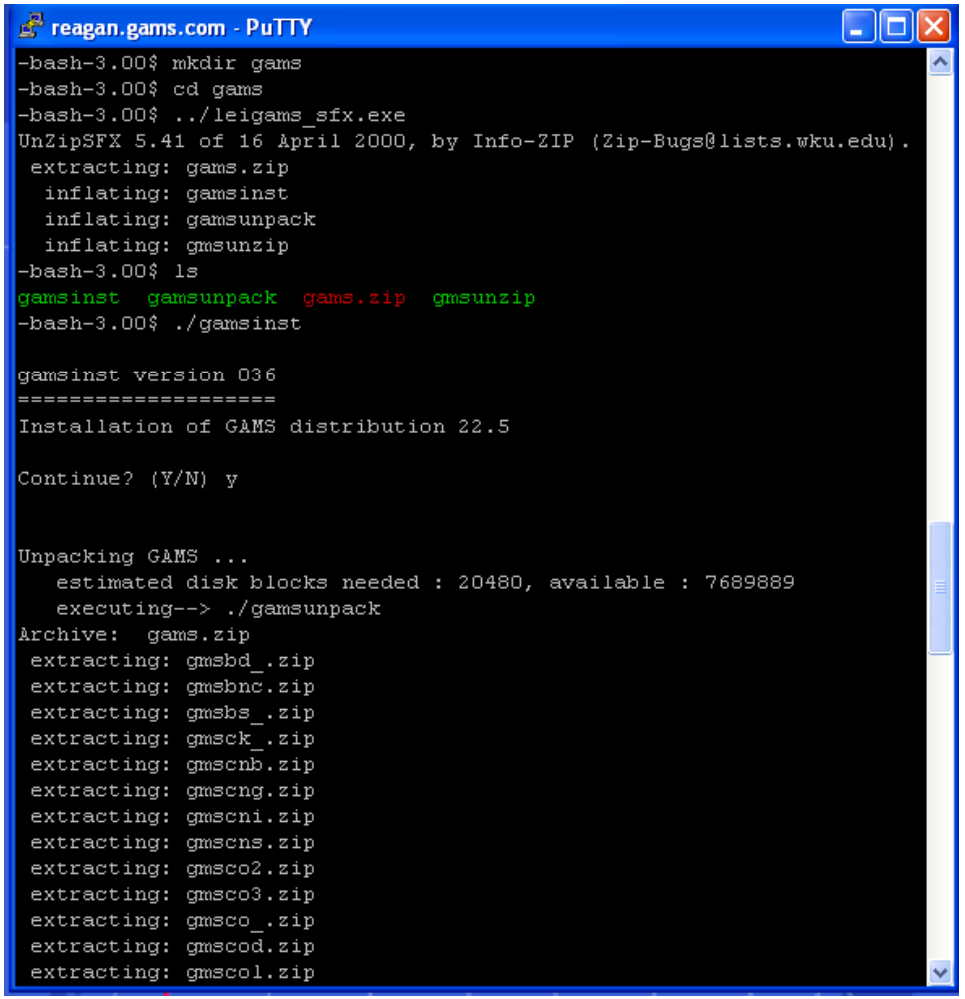
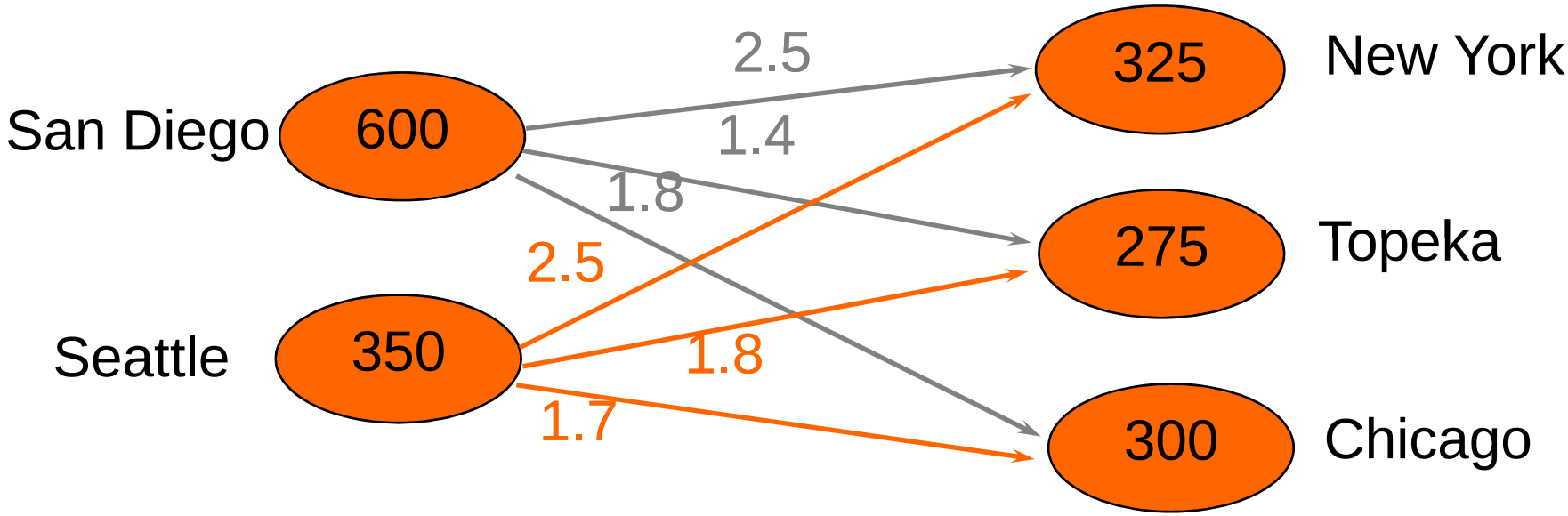
Hands-on! Installing GAMS





export PATH=/home/jhjagla/gams:$PATH

A few Words about GAMS Syntax



Minimize	Transportation cost
subject to	Demand satisfaction at markets
	Supply constraints

Mathematical Algebra

$$
\begin{aligned}
\sum_{\substack{c,p:\\(c,p)\in\mathcal{N}}} tcost \cdot dist(c,p) \cdot x_p^c &\rightarrow \min \\
\sum_{\substack{c,p:\\(c,p)\in\mathcal{N}}} x_p^c &\leq sup(c) \quad \forall c \\
\sum_{\substack{c,p:\\(c,p)\in\mathcal{N}}} x_p^c &\geq dem(p) \quad \forall p \\
x_p^c &\geq 0 \quad \forall c,p:\ (c,p)\in\mathcal{N}
\end{aligned}
$$

GAMS Algebra

gamside: C:\Documents and Settings\bussieck\My Documents\gamsdir\project.gpr - [c:\documents an...

File Edit Search Windows Utilities Help

call

trnsport.gms

```
Variables
     x(i,j)  shipment quantities in cases
     z       total transportation costs in thousands of dollars ;

Positive Variable x ;

Equations
     cost         define objective function
     supply(i)    observe supply limit at plant i
     demand(j)    satisfy demand at market j ;

cost ..         z  =e=  sum((i,j), c(i,j)*x(i,j)) ;

supply(i) ..    sum(j, x(i,j))  =l=  a(i) ;

demand(j) ..    sum(i, x(i,j))  =g=  b(j) ;

Model transport /all/ ;
```

1: 1 Insert

GAMS Syntax

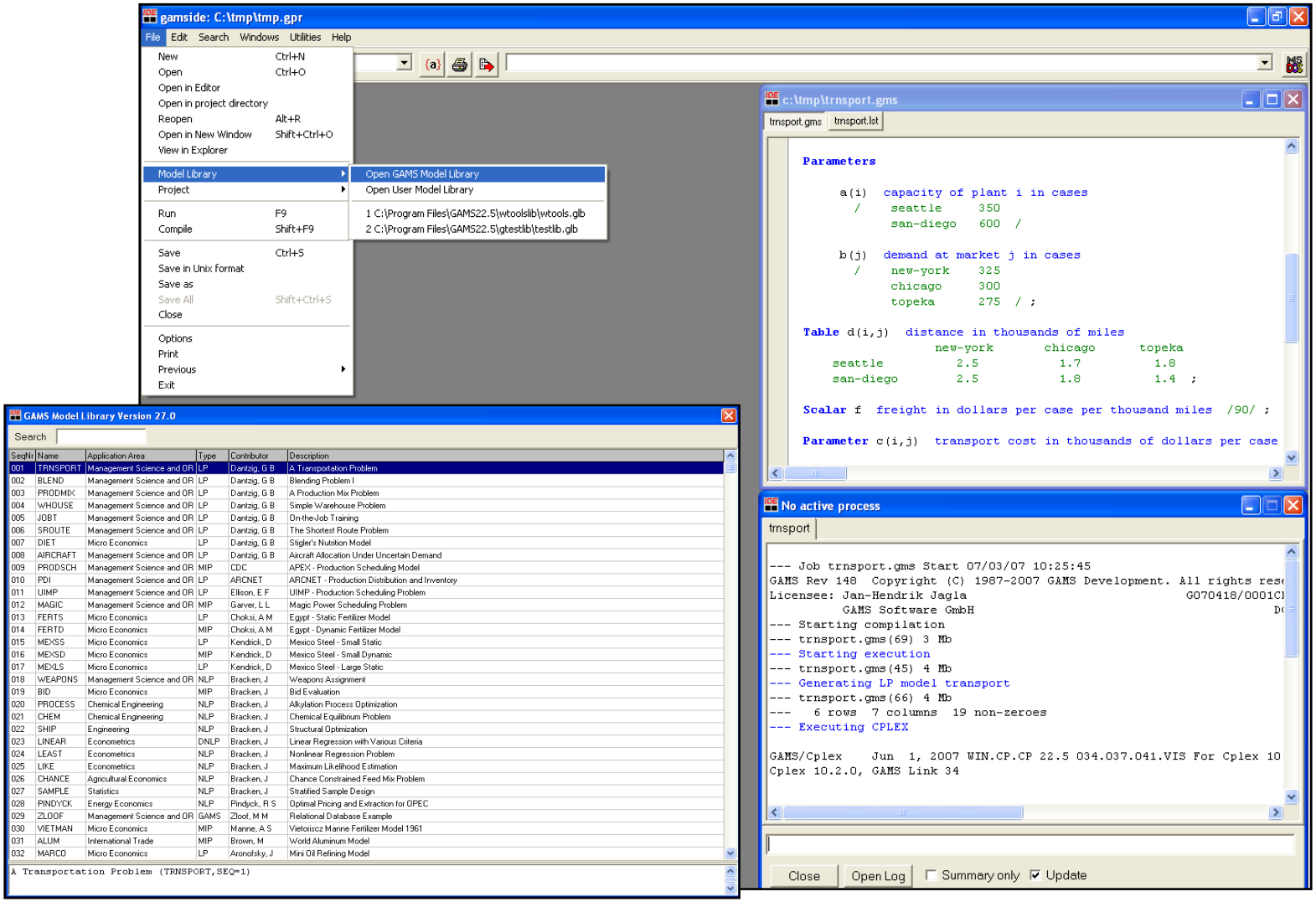
- Symbols:
  - Sets
  - Parameters
  - Variables
  - Equations
  - Models
  - ASCII Output Files

```
Sets        i          canning plants   / seattle, san-diego /;
Parameters  a(i)       capacity of plant i in cases
       /    seattle     350
            san-diego   600  /;
Variables   x(i,j)     shipment quantities in cases;
Equations   supply(i)  observe supply limit at plant i;
Model       transport  /all/ ;
File        fx         some file / 'c:\t\text.txt' /
```

- Statements
  - Declarations
  - Data Assignments
  - Equation Definition
  - Programming Flow Control
  - Option statement

```
Parameter c(i,j);
c(i,j) = f * d(i,j) / 1000 ;
supply(i) ..   sum(j, x(i,j))  =l=  a(i);
loop(i, put fx i.tl);
option reslim=10;
```

Hands-on! Testing the installation



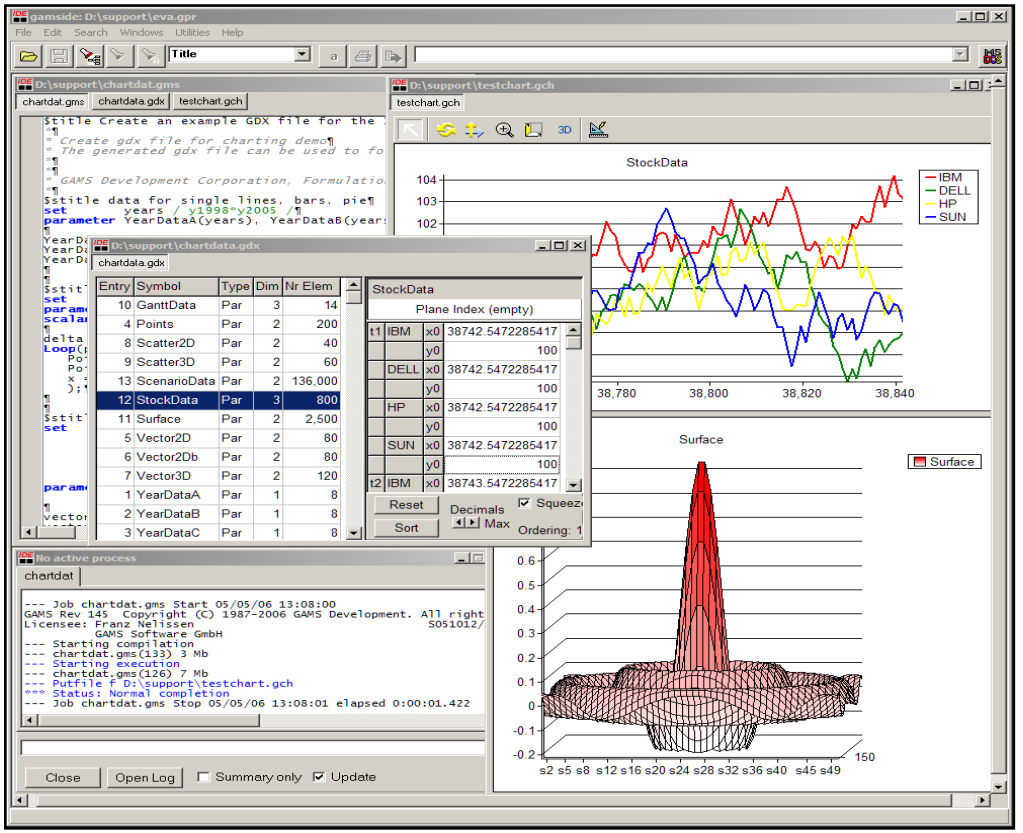
Hands-on! Testing the installation

reagan.gams.com - PuTTY

```
-bash-3.00$ gamslib trnsport
Model trnsport.gms retrieved
-bash-3.00$ gams trnsport
--- Job trnsport Start 07/03/07 10:33:08
GAMS Rev 148  Copyright (C) 1987-2007 GAMS Development. All rights reserved
Licensee: GAMS Development Corporation, Washington, DC   G871201/0000CA-ANY
          Free Demo,  202-342-0180,  sales@gams.com,  www.gams.com   DC0000
--- Starting compilation
--- trnsport.gms(69) 3 Mb
--- Starting execution
--- trnsport.gms(45) 4 Mb
--- Generating LP model transport
--- trnsport.gms(66) 4 Mb
---   6 rows  7 columns  19 non-zeroes
--- Executing CPLEX

GAMS/Cplex    Jun  1, 2007 LEX.CP.NA 22.5 034.037.041.LEI For Cplex 10.2
Cplex 10.2.0, GAMS Link 34

Reading data...
Starting Cplex...
Tried aggregator 1 time.
LP Presolve eliminated 1 rows and 1 columns.
Reduced LP has 5 rows, 6 columns, and 12 nonzeros.
Presolve time =    0.00 sec.

Iteration      Dual Objective            In Variable           Out Variable
     1             73.125000    x(seattle.new-york) demand(new-york)  slack
     2            119.025000     x(seattle.chicago)  demand(chicago)  slack
     3            153.675000    x(san-diego.topeka)   demand(topeka)  slack
     4            153.675000  x(san-diego.new-york)   supply(seattle)  slack
```

Hands-on! IDE - A Guided Tour

- IDE Project Management
- Documentation
  - User's Guide
  - McCarl User's Guide
  - Solver Manuals
- Model Library
- Solver Selection
- Option Editor
- Listing file
  - Tree view
  - Error navigation
- Spell checking



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  - **Solvers**
- GAMS Grid Computing
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Multiple Solvers & Platforms

Solver/Platform availability - 22.5 June 1, 2007											
	x86 MS Windows	x86_64 MS Windows	x86 Linux	x86_64 Linux	Sun Sparc 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	SGI IRIX[2]
ALPHAECP	✔	✔	✔	✔	✔	✔		✔	✔	✔	
BARON 7.8	✔	32bit	✔	32bit					✔		
BDMLP	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
COIN	✔	32bit	✔	✔						✔	
CONOPT 3	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
CPLEX 10.2	✔	✔	✔	✔	✔	✔	10.0	8.1	✔		9.1
DECIS	✔	✔	✔	✔	✔		✔	✔	✔		✔
DICOPT	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
KNITRO 5.1	✔	32bit	✔	✔						✔	
LINDOGLOBAL 4.1	✔	✔	✔	✔	✔					✔	
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		✔		

Multiple Model Types

- LP Linear Programs
- MIP Mixed Integer Programs
- QCP Quadratically Constrained Programs
- MIQCP Quadratically Constrained MIPs
- NLP Nonlinear Programs
- DNLP NLP with Discontinuous Derivatives
- MINLP Mixed Integer Nonlinear Programs
- MCP Mixed Complementarity Programs
- MPEC NLP with Complementarity Constraints
- CNS Constrained Nonlinear Systems
- Stochastic Optimization
- Global Optimization

Multiple Solver & Model Types

Solver/Model type availability - 22.5 June 1, 2007												
	LP	MIP	NLP	MCP	MPEC	CNS	DNLP	MINLP	QCP	MIQCP	*Stoch.*	*Global*
ALPHAECP								✔		✔		
BARON 7.8	✔	✔	✔				✔	✔	✔	✔		✔
BDMLP	✔	✔										
COIN	✔	✔										
CONOPT 3	✔		✔			✔	✔		✔			
CPLEX 10.2	✔	✔							✔	✔		
DECIS	✔										✔	
DICOPT								✔				
KNITRO 5.1	✔		✔				✔		✔			
LINDOGLOBAL 4.1	✔	✔	✔				✔	✔	✔	✔		
LGO	✔		✔				✔		✔			✔
MILES				✔								
MINOS	✔		✔				✔		✔			
MOSEK 4	✔	✔	✔				✔		✔	✔		
MPSGE												
MSNLP			✔				✔		✔			✔
NLPEC				✔	✔							
OQNLP			✔				✔	✔	✔	✔		✔
OSL V3	✔	✔										
OSLSE	✔										✔	
PATH				✔		✔						
SBB								✔		✔		
SNOPT	✔		✔				✔		✔			
XA	✔	✔										
XPRESS 17.10	✔	✔							✔			
Contributed Plug&Play solvers												
AMPLwrap	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
DEA	✔	✔										
Kestrel	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔

Special Solvers

Solvers that do not *solve* the problem:

- **CONVERT**
  - Converts the model into different formats
- **BENCH**
  - Benchmarking solvers
- **EXAMINER**
  - Checks quality of solutions found by different solver

Hands-on! “Solver” Convert

gamside: C:\Documents and Settings\Jan\My Documents\cmu\cmu.gpr

File Edit Search Windows Utilities Help

lp=convert optfile=1

c:\documents and settings\jan\my documents\cmu\trnsport.gms

trnsport.gms trnsport.lst

```
$Title  A Transportation Problem (TRNSPORT,SEQ=1)
$Ontext

This problem finds a least cost shipping schedule that m
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 U
The Scientific Press, Redwood City, California, 1988.

The line numbers will not match those in the book becaus
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
```

No active process

trnsport

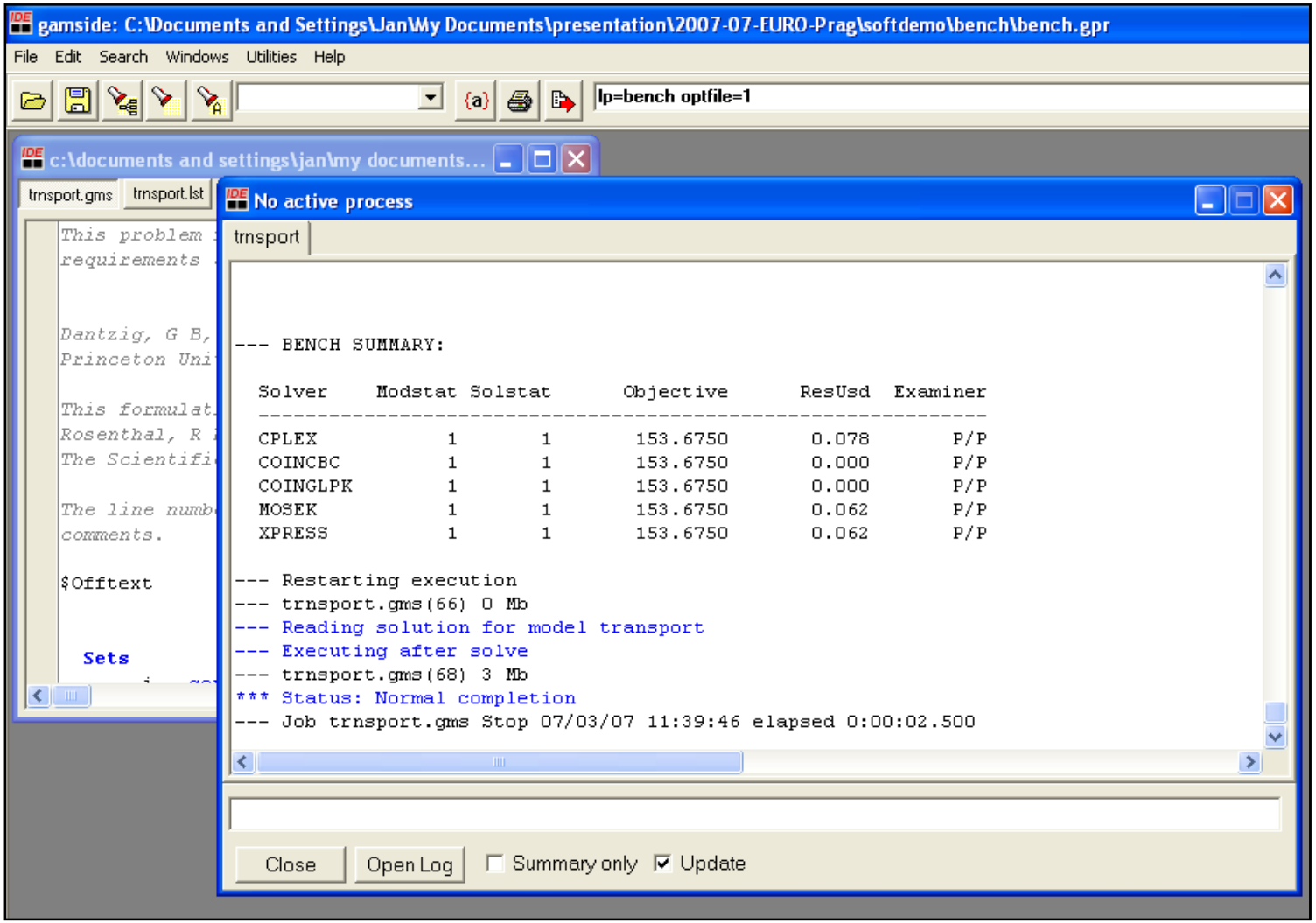
```
Reading parameter(s) from "C:\Documents and Settings\Jan\My
>>  All
Finished reading from "C:\Documents and Settings\Jan\My Doc
--- Writing Ampl       : ampl.mod
--- Writing AmplNLC    : amplnlc.c
--- Writing Baron      : gams.bar
--- Writing CplexLP    : cplex.lp
--- Writing CplexMPS   : cplex.mps
--- Writing FixedMPS   : fixed.mps
--- Writing Gams       : gams.gms
--- Writing Lago       : lago.gms
--- Writing LindoMPI   : lindo.mpi
--- Writing Lingo      : lingo.lng
--- Writing AlphaECP   : alpha.ecp
--- Writing Minopt     : minopt.dat
--- Writing NLP2MCP    : gamsmcp.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
```

Close Open Log Summary only Update

1: 1 Insert

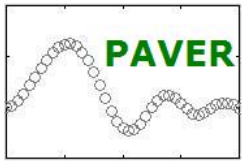
Hands-on! ”Solver” Bench



Solver Option Files

- Pass solver specific options
  - e.g. tolerances, limits, algorithm selection
- Solver option file **`solver.opt`** e.g. **`cplex.opt`** with solver specific options (one per line)
- Activate solver option file
  - **`optfile=1`** on command line/parameter window
  - **`<modelname>.optfile=1;`** before solve
- Multiple option files:
  - ***`solver`*`.opt`** **`optfile=1`**
  - ***`solver`*`.op2`** **`optfile=2`**
  - **…**
  - ***`solver`*`.999`** **`optfile=999`**

Convert online - www.gamsworld.org



[Home | Tools | Links/Other | Performance World]

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
- AmplNLC
- BARON
- CoinFML
- CplexLP
- CplexMPS
- Dict
- FixedMPS
- GAMS (scalar)
- Jacobian
- Lago
- Lgo
- LindoMPI
- LINGO
- MINOPT
- NLP2MCP
- ViennaDag
- ALL (this creates scalar versions of all supported languages, listed above)

The service requries 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 $batinclude. 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 dumpopt=11:

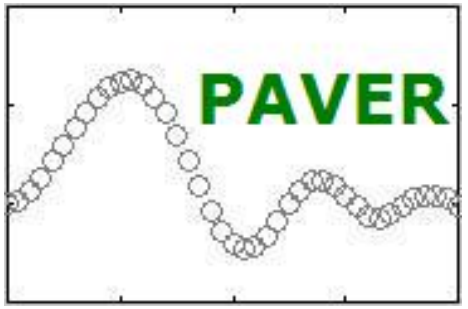
```
gams mymodel dumpopt=11
```

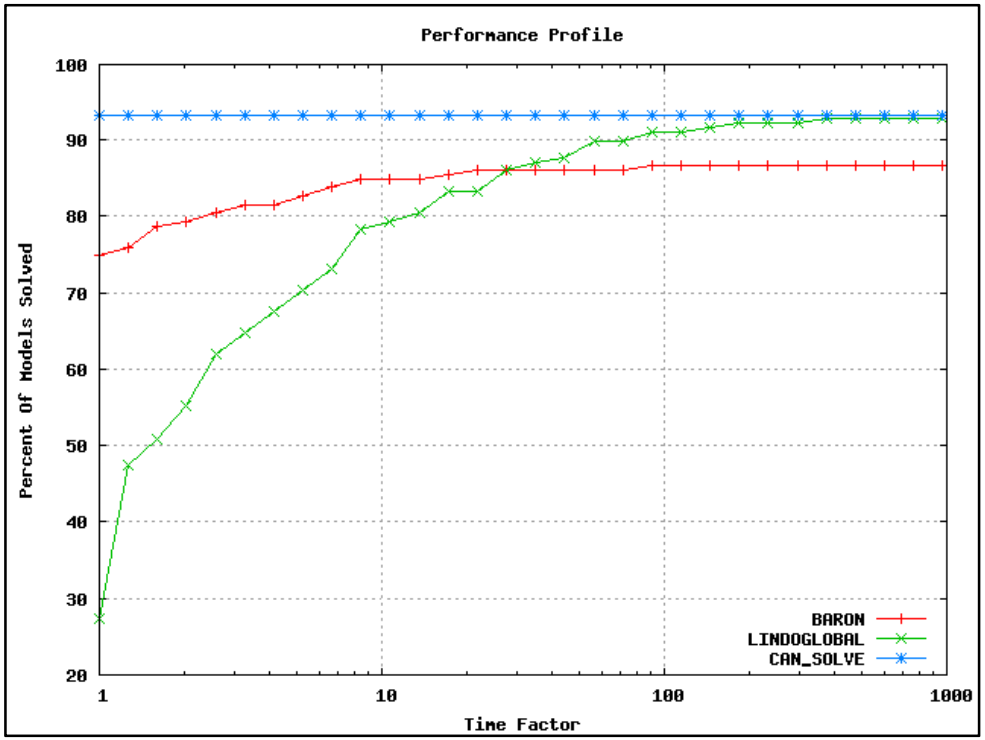
This will create a file mymodel.dmp which represents a self contained version of the original model.

Benchmark online - www.gamsworld.org

PAVER – Server

Performance Analysis and Visualization for Efficient Reproducibility





Excursus: Solver Links

- Standardized Solver Interface
  - Return Codes, Limits, Interrupts, …
  - Common attributes (e.g. time) through GAMS options
  - Specific options through option file

à allows “hassle free” replacement of solvers:

```
option nlp=conopt;
```

- Open architecture assures seamless communication
  - IO Library (C, Fortran, Delphi) provides access to Matrix, Function/Derivative Evaluator, …

à S. Vigerske: “Interfacing COIN-OR solvers with GAMS”
Wednesday 11.45am-12.15pm, Room B3 1 3.18

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- GAMS Development / GAMS Software
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  - **Interfaces**
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Input/Output through ASCII Files

- ASCII Input Data
  - Part of model input (**`$include file.txt`**)
  - Posix Utilities are part of GAMS Windows System
    - Platform independent data file preparation
    - sed, awk, grep, cut, …

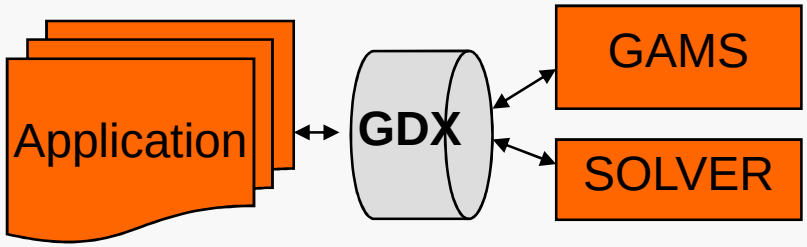
```
$call cut -d, -f1,3- file.txt > filenew.txt
```

- ASCII File Output
  - GAMS Put Facilities

```
file fx / result.txt /;
fx.pc=5; fx.lw=0; fx.nw=10; fx.nd=4;
loop((i,j)$(x.l(i,j)>0),
  put fx i.tl j.tl x.l(i,j) /;
);
```

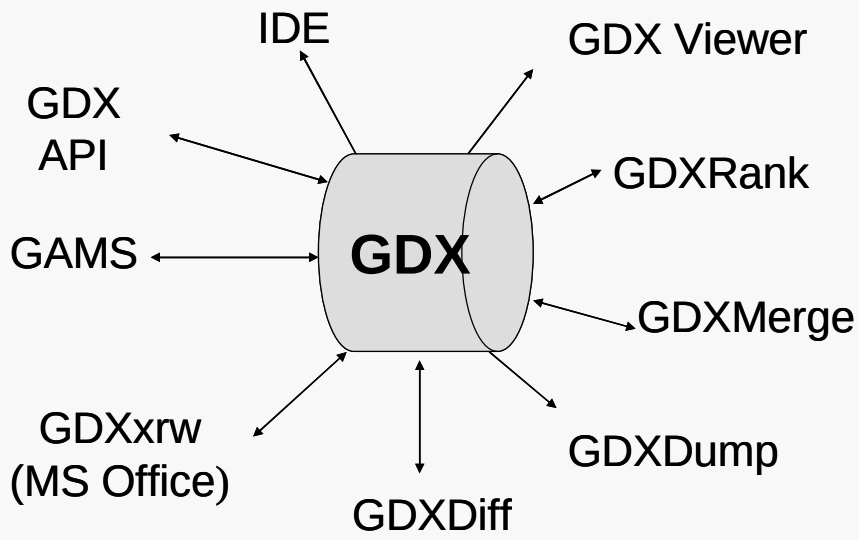
Gams Data eXchange

Binary Data Exchange

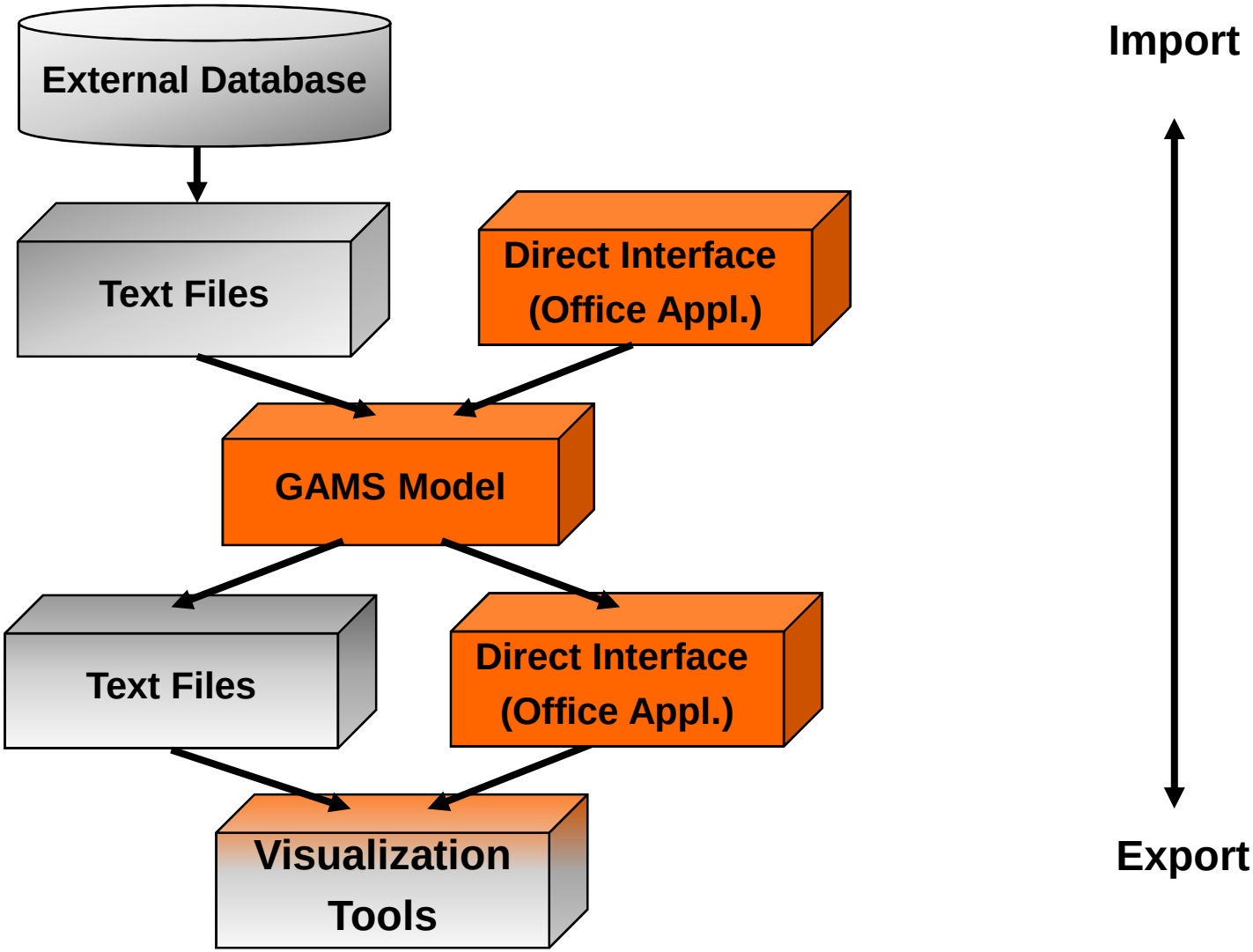


- Fast exchange of data
- Syntactical check on data before model starts
- Data Exchange at any stage (Compile and Run-time)
- Platform Independent
- Direct Excel connectivity
- General API
- Scenario Management Support
- Full Support of Batch Runs

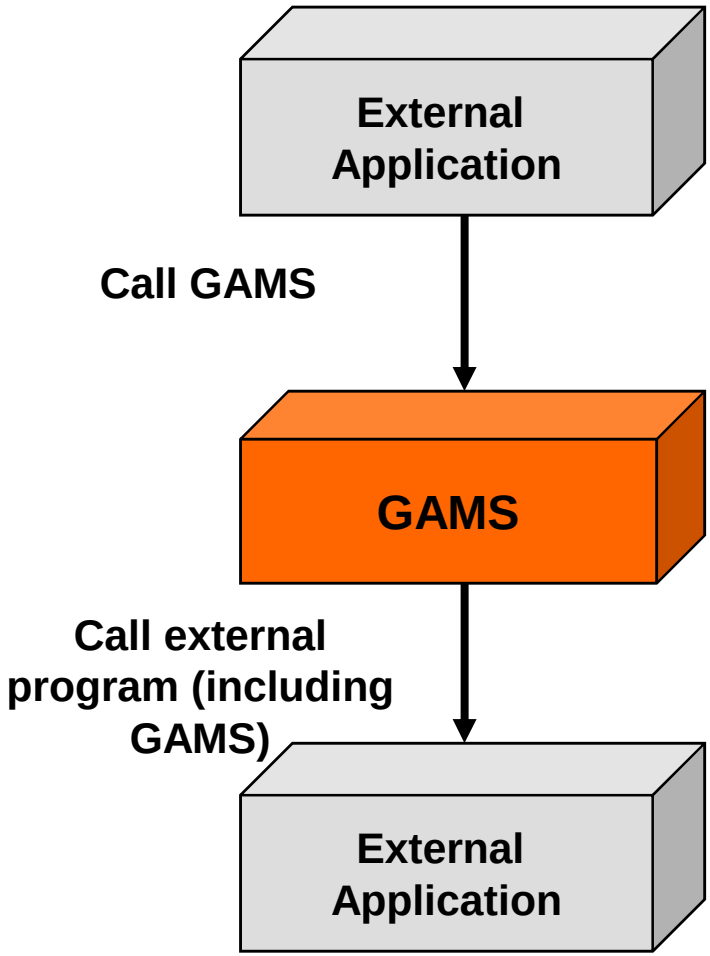
GDX Tools



GAMS in Control



Application in Control

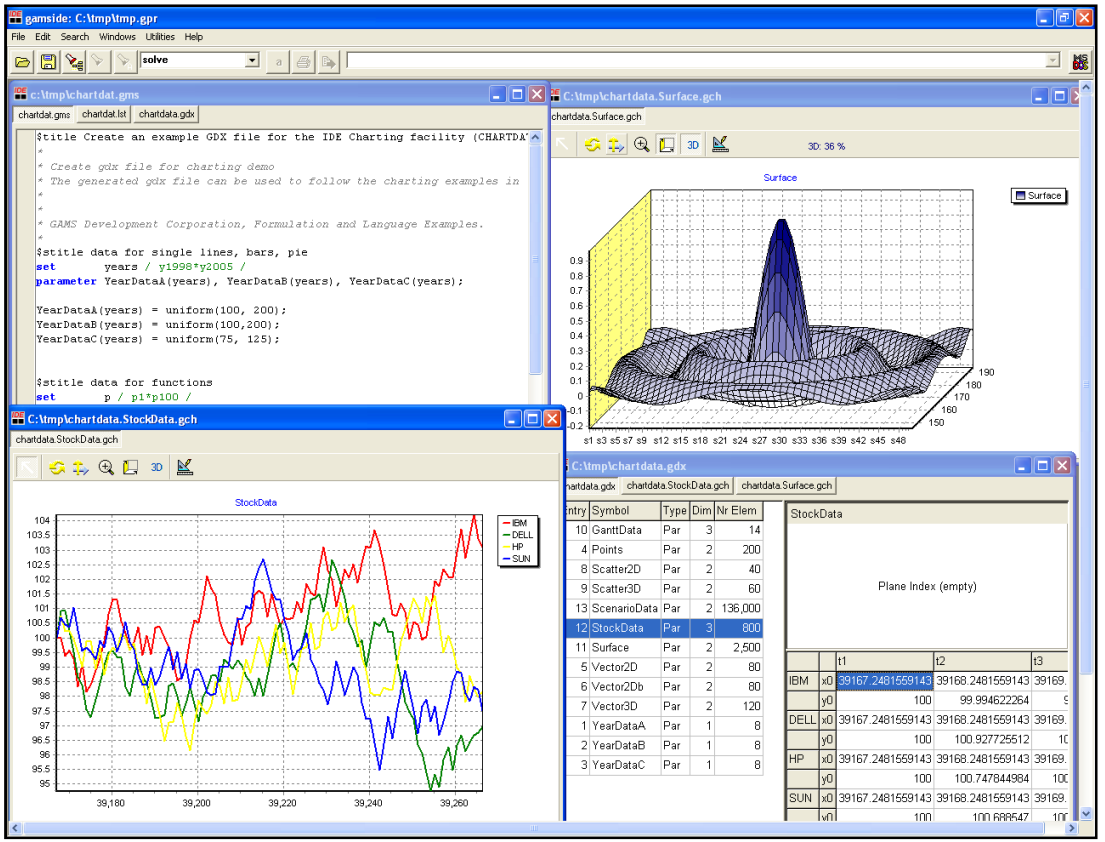


Programming Language or other Application

Application

Hands-on! GDX and Tools

- Create GDX file
  - execute_unload
  - Gdx=filename
- GDX Viewer
  - Data cube
  - Export to Excel
- GDXdiff
- Charting Engine



Agenda

- GAMS Development / GAMS Software
- Working with GAMS – A Guided Tour
  - **Maintenance**
- GAMS Grid Computing
- Compressed and Encrypted Input Files
- Summary

Model Support & Maintenance

Implementation

- It will be incorrect
- It will be inefficient
- It will be confusing (at least for others)
- …

Optimization

- Takes Longer than one is willing to wait
- It will eventually fail
- …

Application

- Real Time
- Always need a *Solution* to Problem
- …

Keys for Support & Maintenance

- Implement Data **Error checks**
- Use reference files: **rf=filename a=c**
- Get hold of Instance: **dumpopt=11/21**
- Use Profiler: **profile / profiletol**
- Get scalar Model using solver: **Convert**
- Use **Deployment** System

Hands-on! Reference file

gamside: C:\tmp\tmp.gpr

File Edit Search Windows Utilities Help

nn | rf=trnsport a=c

C:\tmp\trnsport.gms

trnsport.gms

```
$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 Extensions.
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 these
comments.

$Offtext


  Sets
```

C:\tmp\trnsport.ref

trnsport.ref

Symbols | Files used | Sets | Parameters | Variables | Equations | Models | Unused

	Id	Type	Domain	Text
1	a	Parameter	(i)	capacity of plant i in cases
2	b	Parameter	(j)	demand at market j in cases
3	c	Parameter	(i, j)	transport cost in thousands of dollars per case
4	cost	Equation		define objective function
5	d	Parameter	(i, j)	distance in thousands of miles
6	demand	Equation	(j)	satisfy demand at market j
7	f	Parameter		freight in dollars per case per thousand miles
8	i	Set	(*)	canning plants
9	j	Set	(*)	markets
10	supply	Equation	(i)	observe supply limit at plant i
11	transport	Model		
12	x	Variable	(i, j)	shipment quantities in cases
13	z	Variable		total transportation costs in thousands of dollars

C:\tmp\bchoil_d.inc

bchoil.gms | bchoil_d.inc | oilbase.inc

```
$Title  Data for Oil Pipeline Design Problem

Set n nodes in the oil pipeline network /
    1   H87
    2   ECHIRA
    3   SIMBA-CONOCO-C
    4   AGIP-TASSI
    5   SIMBA-CONOCO-B
    6   J87
    7   CONNO7
    8   MBASSI-CONOCO
    9   WELLO9
    10  NAMBA-TENNECO
    11  ELF-B
    12  NDOGO-C-ELF
    13  PANGA-AGIP
    14  BIGORNEAU
    15  CONN15
    16  AGIP-PANGA-B
    17  CONN17
    18  MASSANGA-TENNECO-A
```

C:\tmp\bchoil.ref

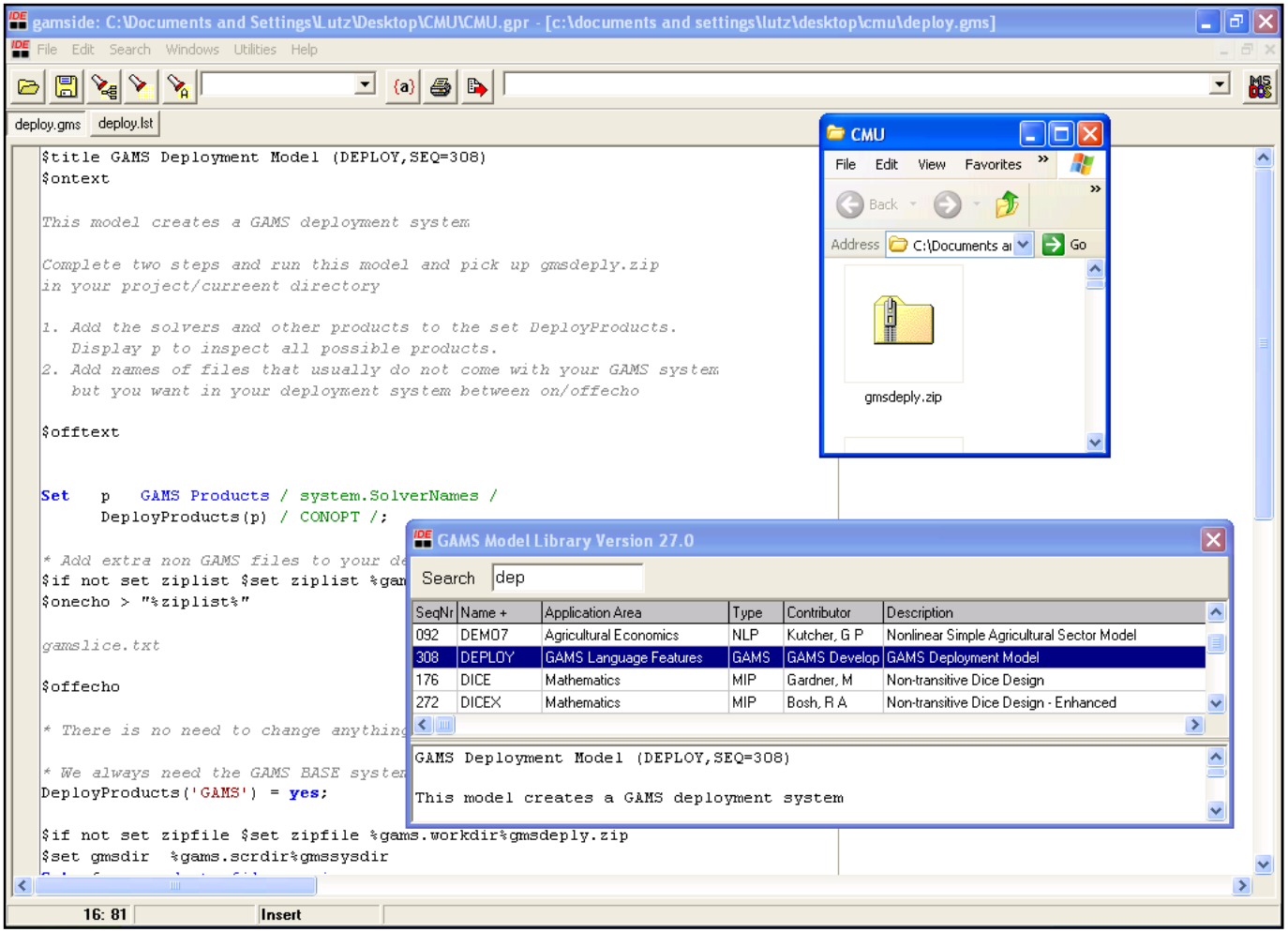
bchoil.ref

Symbols | Files used | Sets | Parameters | Variables | Equations | Models | Unused

	Id	Type	Domain	Text
1	arc	Set	(n, n)	arcs in the network
2	b	Variable	(n, n)	build variable for some pipe on the arc
3	bal	Equation	(n)	flow conservation constraints
4	bigM	Equation	(n, n)	the flow capacity constraints
5	bk	Variable	(n, n, k)	build variable for type k pipe on the arc
6	cap	Parameter	(k)	capacity of type k oil pipe
7	cap1	Parameter		capacity of type 1 oil pipe
8	cost	Variable		the cost for installing pipes in the network
9	defb	Equation	(n, n)	Additional pipe constraint
10	dist	Parameter	(n, n)	the distance of the arcs
11	dsh	Set	(ss, n, n)	the descendant structure of previous integer solutions
12	edgedist	Parameter	(n, n)	one way distance
13	f	Variable	(n, n)	flow variable on the arc

1: 1 | Insert

Hands-on! Deployment



Agenda

- GAMS Development / GAMS Software
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- **GAMS Grid Computing**
- Compressed and Encrypted Input Files
- Summary

Release Notes

New Solvers

- **COIN-OR Solvers** (http://www.coin-or.org/)
  - MINLP solver: CoinBonmin
- **AlphaECP**
  - MINLP solver
  - Extended Cutting Plane method by T. Westerlund and T. Lastusilta (Abo Akademi University, Finland)
- **LINDOGlobal**
  - finds proven optimal solutions to non-convex MINLP
  - Global Optimization Solver from LINDO Systems,Inc

Improvements

- **BARON, CONOPT, CPLEX, MOSEK, XPRESS,…**

Solver Technology

è Tremendous algorithmic and computational progress

- **LP** in fact only restricted by available memory
- **MIP**
  - Some small (academic) problems still unsolvable
  - Commercial problems in most case docile
- **NLP/MINLP**
  - Predictions are problem and data specific, global vs. local solutions

à L.Westermann: “Global Optimization with GAMS”
Wednesday 2-2.30pm, Room B3 1 3.18

è Further progress using Multiple Threads / Grid Computing

Multiple Threads / SMP

- **CPLEX**
  - **parallel extension** for B&B and interior point solver
  - **concurrent optimizer**
  - academic license includes 4 threads
- **MOSEK**
  - **parallel extension** for the interior solver comes free of charge
  - **concurrent optimizer**
- **XPRESS**
  - **parallel extension** for B&B and interior point solver
  - academic license includes 4 threads
- **XA (XAPAR)**

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

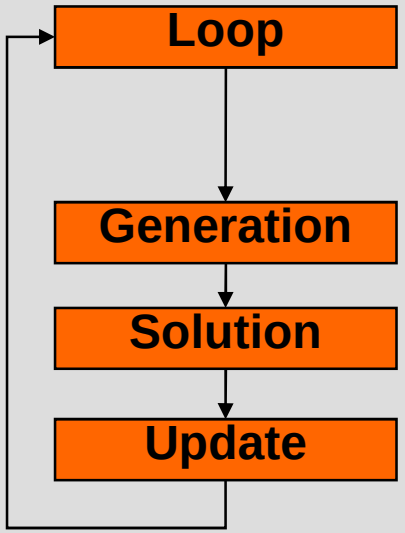
What is Grid Computing?

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

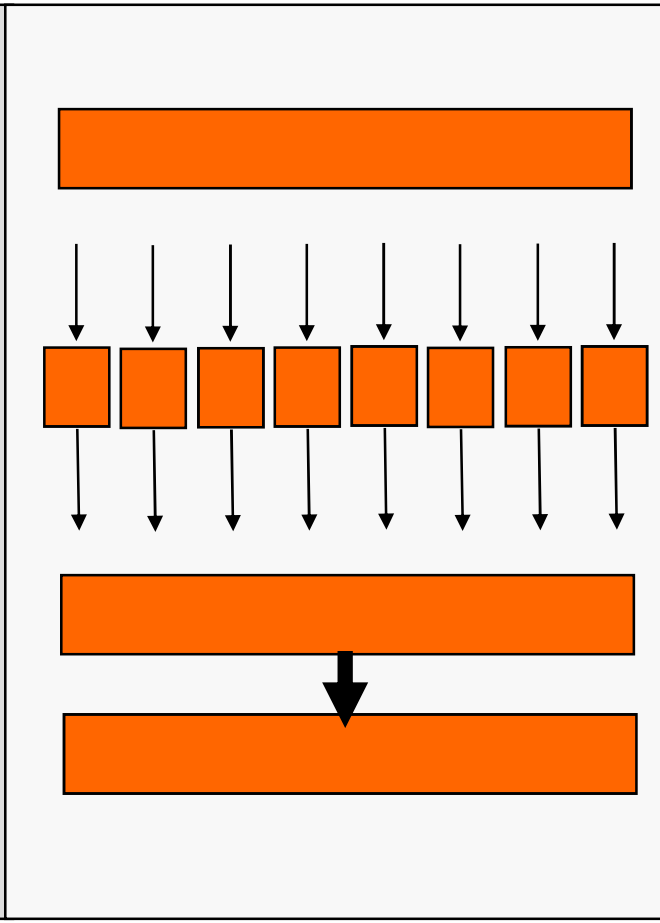
```
Loop(p(pp),
   v.fx = vmin + (vmax-vmin)
    /(card(pp)+1)*ord(pp) ;
   Solve var1 maximizing m using nlp ;
   xres(i,p)         = x.l(i);
   xres('mean',p)    = m.l;
   xres('var',p)     = v.l;
   xres('status',p) = var1.modelstat;
);
```



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



Hands-on! GAMS Grid Computing

gamside: C:\Documents and Settings\Jan\My Documents\presentation\2007-07-EURO-Prag\Workshop\meanvar_grid\meanvar.gpr

File Edit Search Windows Utilities Help

c:\documents and settings\jan\my documents\presentation\2007-07-euro-prag\wor...

meanvar.gms

```
   xres('var',p)      = v.l;
   xres('status',p)   = var1.modelstat;
   vmin = v.l; );

Loop(p(pp),
   v.fx = vmin + (vmax-vmin)/(card(pp)+1)*ord(pp) ;
   Solve var1 maximizing m using nlp ;
   xres(i,p)          = x.l(i);
   xres('mean',p)     = m.l;
   xres('var',p)      = v.l;
   xres('status',p)   = var1.modelstat; );

Display xres;
```

C:\Documents and Settings\Jan\My Documents\presentation\2007-07-EURO-Prag\Wo...

meanvar.gms | meanvar_edited.gms

```
   xres('var',p)      = v.l;
   xres('status',p)   = var1.modelstat;
   vmin = v.l; );

$if not set grid $set grid 0
parameter handle(p) Grid handle;

if(not %grid%,
   Loop(p(pp),
      v.fx = vmin + (vmax-vmin)/(card(pp)+1)*ord(pp)
      Solve var1 maximizing m using nlp ;
      xres(i,p)          = x.l(i);
      xres('mean',p)     = m.l;
      xres('var',p)      = v.l;
      xres('status',p)   = var1.modelstat; );
else
   var1.solvelink=3;
   Loop(p(pp),
      v.fx = vmin + (vmax-vmin)/(card(pp)+1)*ord(pp)
      Solve var1 maximizing m using nlp ;
      handle(p) = var1.handle );
   Repeat
      loop(p(pp)$handlecollect(handle(p)),
         xres(i,p)          = x.l(i);
         xres('mean',p)     = m.l;
         xres('var',p)      = v.l;
         xres('status',p)   = var1.modelstat;
         display$handledelete(handle(p)) 'trouble del
         handle(p) = 0 ) ;
      display$sleep(card(handle)*0.2) 'sleep some tim
   until card(handle) = 0 or timeelapsed > 100;
   xres(i,p(pp))$handle(p) = na;
);
Display xres;

execute_unload "portfolio.gdx" xres;
```

Hands-on! The Mean-Variance Model

Markowitz (1952), Nobel prize 1990

Given

Some investments x_i with historical data

– **Rewards = Expected returns** of investments: μ_i (**Mean** of historical returns)

– **Risk = Variance** of investments $Q_{i,j}$

Goal

Balance risk *r* of portfolio against expected returns of portfolio

Variance of Portfolio	$Min \sum_{i=1}^{I} \sum_{j=1}^{J} x_i Q_{i,j} x_j$
Target return	$s.t. \quad \sum_{i=1}^{I} \mu_i x_i \geq r$
Budget constraint	$\sum_{i=1}^{I} x_i = 1$
No short sales	$x_i \geq 0$

Minimize variance *v* for a given target return *r*

Job Submission Loop

```
* turn on grid option
var1.solvelink=3;
Loop(p(pp),
  v.fx = vmin + (vmax-vmin)/(card(pp)+1)*ord(pp);
  Solve var1 maximizing m using nlp ;
* save instance handle
  handle(p) = var1.handle );
```

LOG

```
…
--- LOOPS pp = p1
---   3 rows  9 columns  23 non-zeroes
---   538 nl-code  7 nl-non-zeroes
--- meanvar_edited.gms(174) 3 Mb
--- Submitting model var1 with handle grid133000004
…
```

“Grid”- Middleware (PC)

```
@echo off
: gams grid submission script
: arg1 solver executable
:    2 control file
:    3 scratch directory
: gmscr_nx.exe processes the solution and produces 'gmsgrid.gdx‘
: note: %3 will be the short name, this is neeeded because
:       the START command cannot handle spaces or "...'
:       before we use %~3  will strip surrounding "..."
:       makes the name short
: gmsrerun.cmd will resubmit runit.cmd

echo @echo off              > %3runit.cmd
echo %1 %2                 >> %3runit.cmd
echo gmscr_nx.exe %2       >> %3runit.cmd
echo echo OK ^> %3finished >> %3runit.cmd
echo exit                  >> %3runit.cmd

echo @start /b %3runit.cmd ^> nul  > %3gmsrerun.cmd
start /b  %3runit.cmd > nul

exit
```

Solution Collection Loop

```
Repeat
    loop(p(pp)$handlecollect(handle(p)),
    xres(i,p)     = x.l(i); xres('mean',p)   = m.l;
    xres('var',p) = v.l;    xres('status',p) = var1.modelstat;
    display$handledelete(handle(p)) 'trouble deleting handles';
    handle(p) = 0 ) ;
    display$sleep(card(handle)*0.2) 'sleep some time';
until card(handle) = 0 or timeelapsed > 100;
xres(i,p(pp))$handle(p) = na;
```

LOG

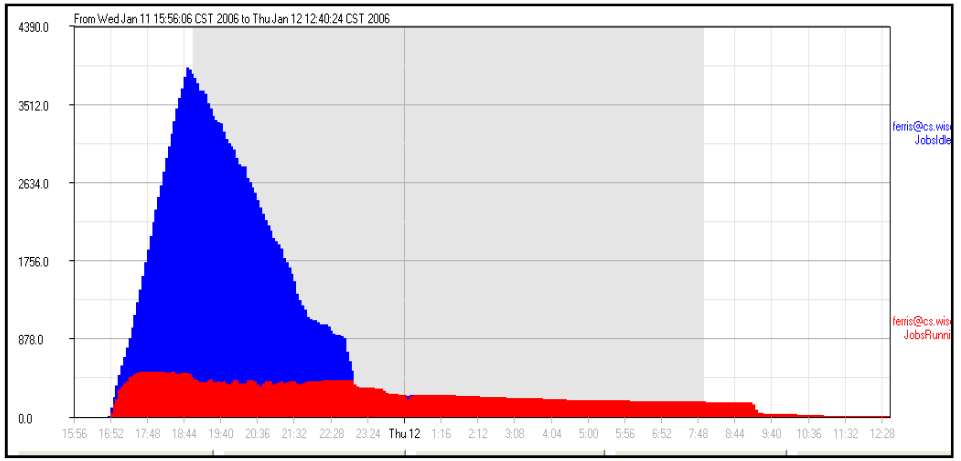
```
…
--- meanvar_edited.gms(161) 3 Mb
--- GDXin=C:\...\225a\grid133000004\gmsgrid.gdx
--- meanvar_edited.gms(161) 3 Mb
--- Removed handle grid133000004
…
```

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**

SUNgrid

www.network.com

- On-demand grid computing service operated by Sun Microsystems
- Access to enormous computing power over Internet
- Opteron-based servers with 4 GB of RAM per CPU
- Solaris 10 OS, and Sun Grid Engine 6 software.
- $1 per CPU-hour
- **GAMS Distribution 22.5 available**
- **250 free CPU hours to new users**

www.gams.com/sungrid

à F. Nelissen: “Grid Computing in Finance using an Algebraic Modeling System”, Thursday 2:30-3pm, Room A2 4 1.32

Agenda

- GAMS Development / GAMS Software
- Working with GAMS – A Guided Tour
- GAMS Grid Computing
- **Compressed and Encrypted Input Files**
- Summary

Compressed and Encrypted Input Files

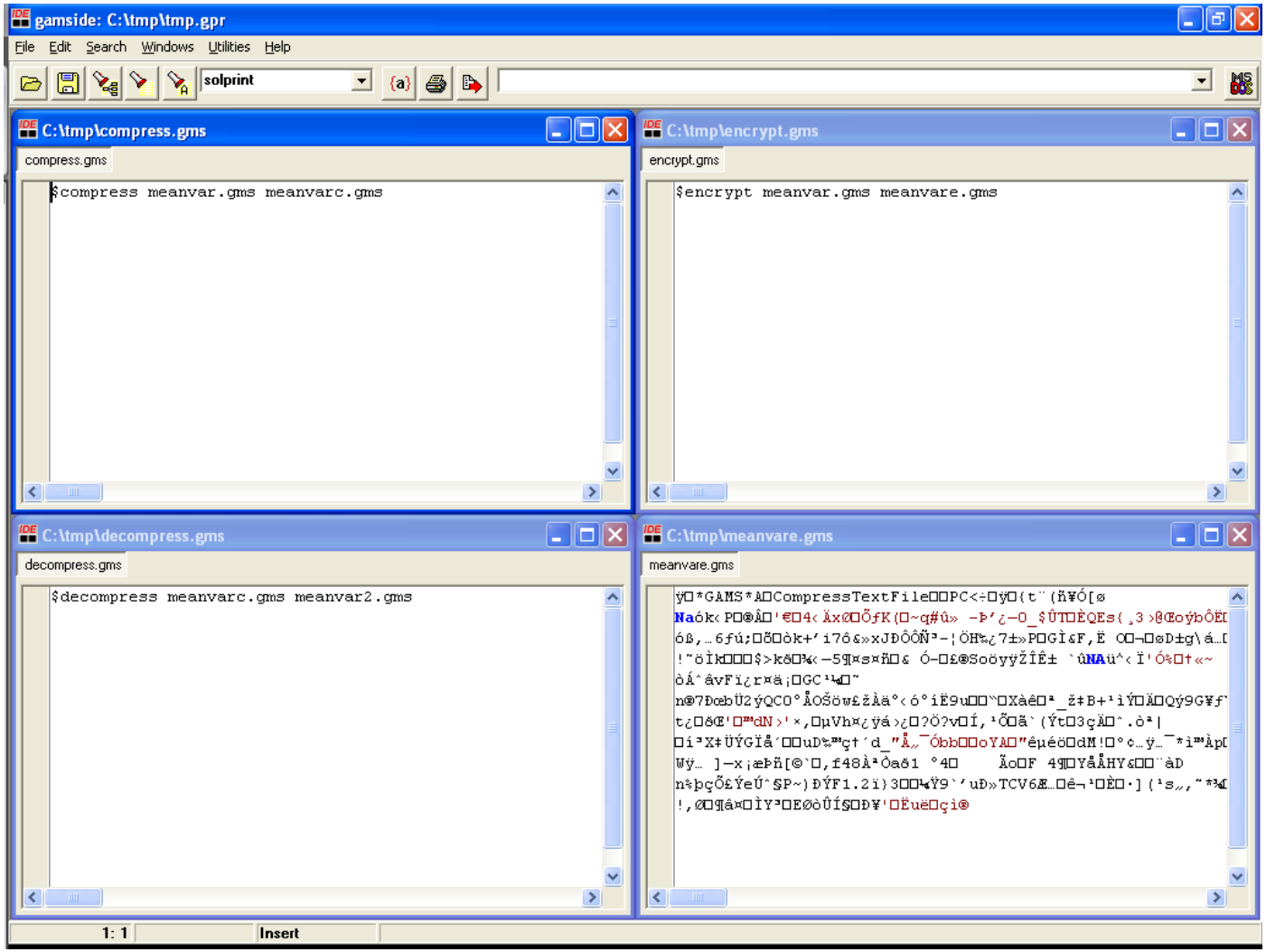
Distribution of models to users/customers

- $Compress
  - compresses into a GAMS system file
- $Decompress
  - decompresses a GAMS system file

Issues of privacy, security, data integrity and ownership

- $Encrypt
  - encrypts into a GAMS system file
  - requires special licensing

Hands-on! Compression & Encryption



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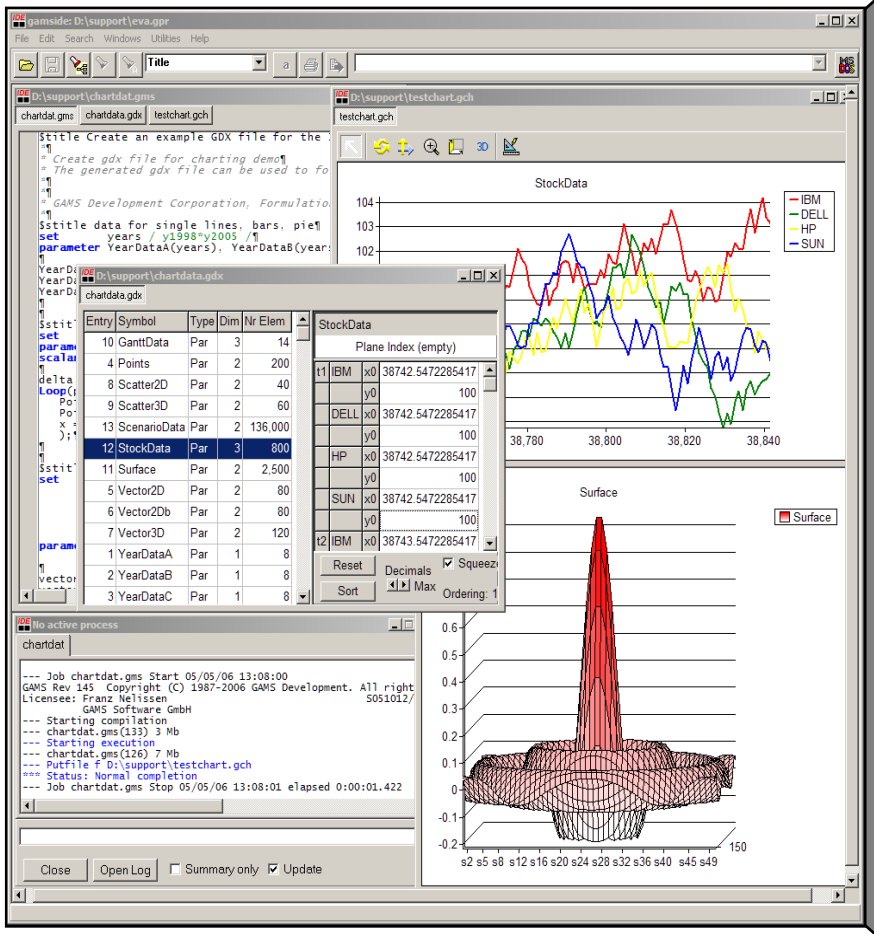
Benefits for Users



- Robust and scalable state-of-the-art modeling technology
- Tailored for complex, large-scale modeling applications. Less than 5% of modeling/optimization projects do not fit the GAMS way
- Productivity gains through rapid development environment
- Broad academic and commercial network
- Proven reliability (30+ years of experience)
- Protection of investments through platform and solver independency

Sources of GAMS Information

Download: http://download.gams-software.com/
Release Notes: http://www.gams.com/docs/release/release.htm
Contributed Documentation: http://www.gams.com/docs/contributed
Contributed Software: http://www.gams.com/contrib/contrib.htm
Presentations: http://www.gams.com/presentations
Workshops: http://www.gams.com/courses.htm

Bruce McCarl's Newsletter: http://www.gams.com/maillist/newsletter.htm
GAMS User Group: http://www.gams.com/maillist/gams_l.htm
GAMS Google Group: http://groups.google.de/group/gamsworld

Other relevant sites on the Web: http://www.gams.com/hotlinks.htm

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support@gams.com

Benefits for Different User Groups

Researcher	• Projects • Product maintenance	• Commercial network • Quality assurance
Model Developer	• Rapid prototyping • Higher productivity	• Robust & scalable solution • Academic network
Consultants & Solution Provider	• Rapid prototyping • Tailored solutions	• Benchmarking • Extended support
Innocent User	• Works in different environments • Lots of different interfaces	• Robust and reliable system
Management	• Protection of investments • Low cost • Maintainable applications	• Independence: - Solver - Platform - Interface