



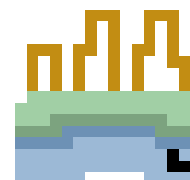
# Pre-Conference Workshop

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[www.gams.com](http://www.gams.com)



Minneapolis, 5 Oct 2013



# Introduction

- **Workshop is aimed at novice users**
  - What are the core features and strengths of GAMS?
  - What does effective GAMS use look like?
- **Visit us at the GAMS booth**
  - Bring your questions, comments, etc.
  - Learn about the latest features, solvers, etc.
- **COIN-OR Cup celebration**
  - **Monday night, 8:30-??**
  - **The Loon (500 N. 1<sup>st</sup> St)**



# Outline

- GAMS
  - GAMS at a Glance
  - Simple Example
  - GAMS/Base
  - Using GAMS Effectively
- Advanced features
  - Data Import/Export
  - Advanced Use of GAMS Solver Links
  - Extending the GAMS Syntax



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# GAMS at a Glance

The screenshot displays the GAMS software interface with several components:

- Code Editor:** Contains GAMS code for creating a GDX file and defining data for 'GantData', 'Scatter2D', 'Scatter3D', 'ScanData', 'StockData', 'Surface', and 'YearDataA/B/C'.
- Data Table:** A table listing variables and their properties.
 

Entry	Symbol	Type	Dim	Is Eten
10	GantData	Par	3	14
4	Points	Par	2	200
8	Scatter2D	Par	2	40
9	Scatter3D	Par	2	60
13	ScanData	Par	2	135 000
12	StockData	Par	3	600
11	Surface	Par	2	2 500
6	Vector2D	Par	2	60
6	Vector2Dk	Par	2	60
7	Vector3D	Par	2	120
1	YearDataA	Par	1	8
2	YearDataB	Par	1	8
3	YearDataC	Par	1	8
- StockData Graph:** A line graph showing multiple data series (EM, DELL, HP, SUN) over time. The x-axis ranges from 38,780 to 38,940, and the y-axis ranges from 902 to 904.
- Surface Plot:** A 3D surface plot showing a sharp peak. The x-axis is labeled with values s2, s5, s8, s12, s16, s28, s24, s28, s32, s36, s40, s45, s49. The y-axis ranges from -0.2 to 0.6.
- Log Window:** Shows the execution status of the job 'chartdat.gms', including start and stop times and a successful completion message.

## Algebraic Modeling System

- Facilitates formulation of mathematical optimization problems expressed in an algebraic notation
  - ➔ Simplified model building
- Provides links to appropriate state-of-the-art external algorithms
  - ➔ Efficient solution process

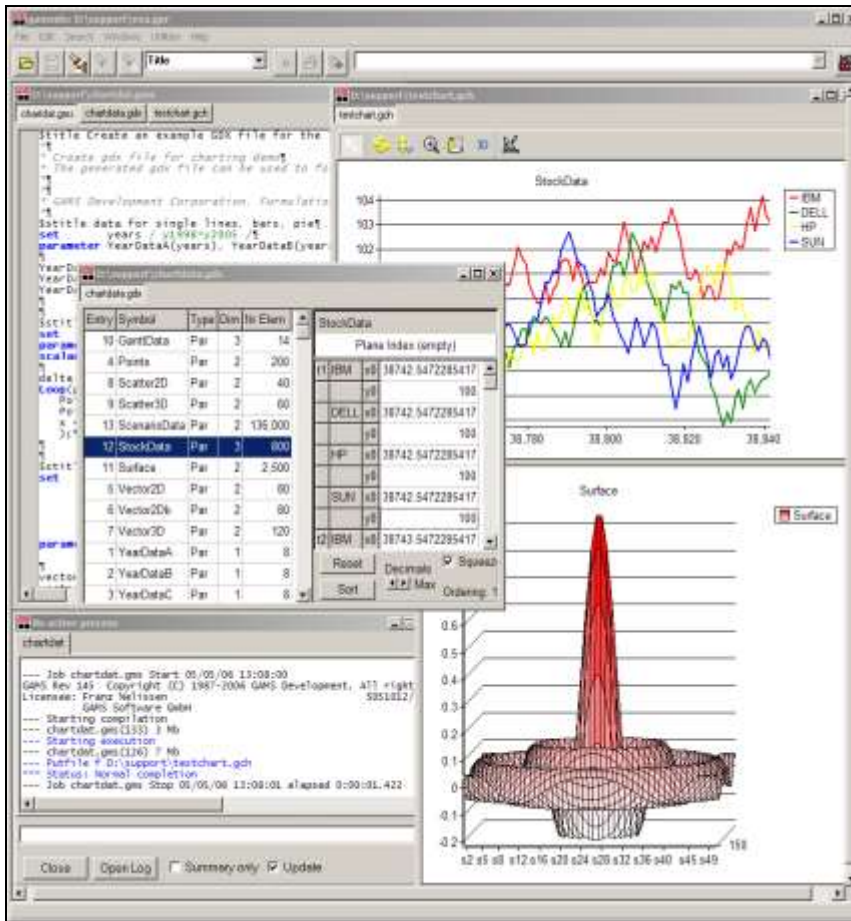




# GAMS at a Glance

## General Algebraic Modeling System

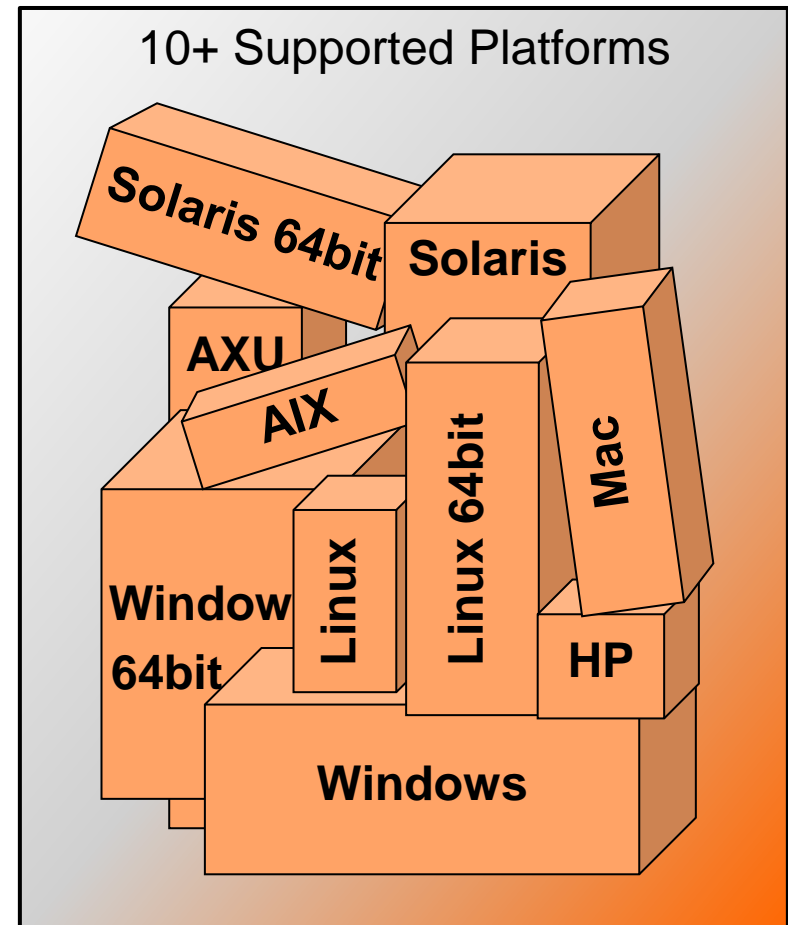
- Roots: World Bank, 1976
- Went commercial in 1987
- GAMS Development Corp.
- GAMS Software GmbH
- Broad academic & commercial user community and network





# GAMS' Fundamental concepts

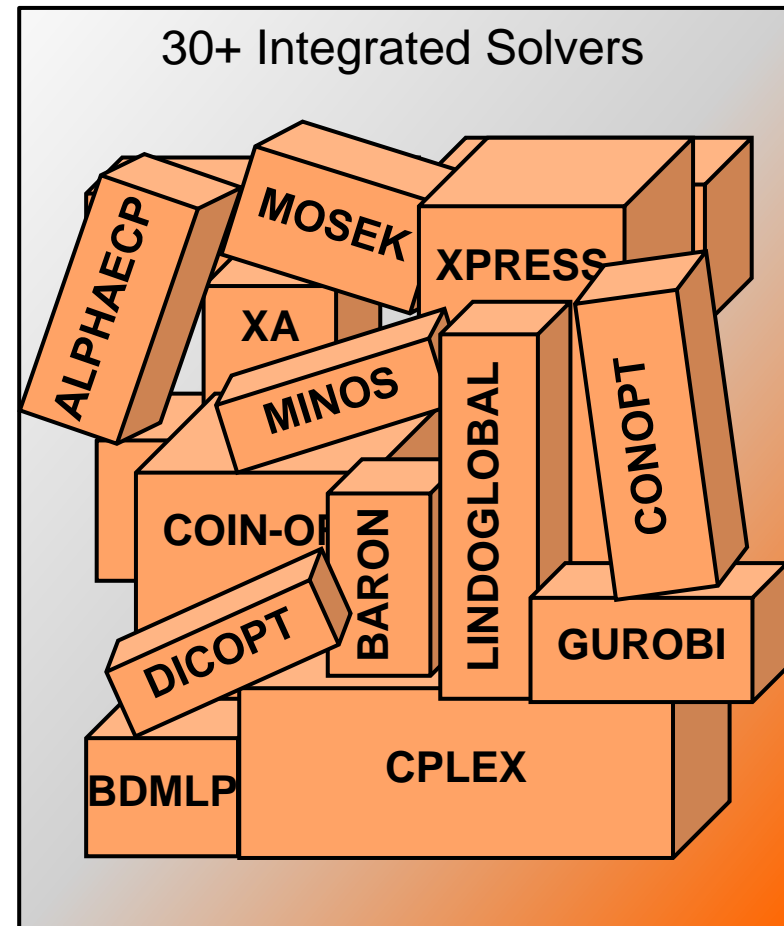
- **Platform independence**
- Hassle-free switch of solution methods
- Open architecture and interfaces to other systems
- Balanced mix of declarative and procedural elements





# GAMS' Fundamental concepts

- Platform independence
- **Hassle-free switch of solution methods**
- Open architecture and interfaces to other systems
- Balanced mix of declarative and procedural elements

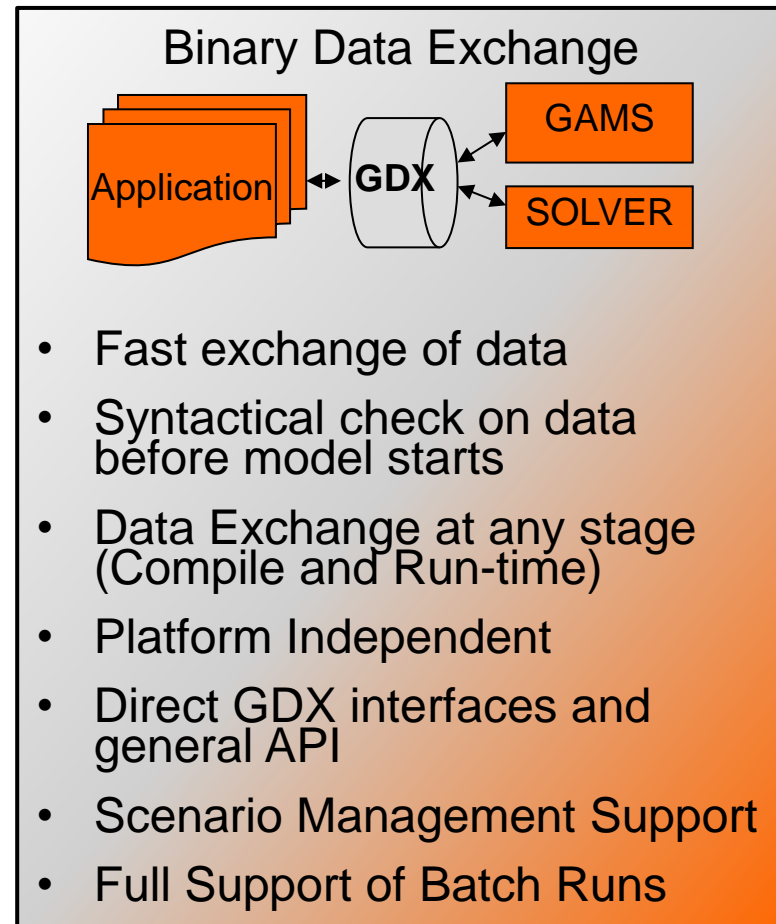






# GAMS' Fundamental concepts

- Platform independence
- Hassle-free switch of solution methods
- **Open architecture and interfaces to other systems**
- **Balanced mix of declarative and procedural elements**





# GAMS' Fundamental concepts

- Platform independence
- Hassle-free switch of solution methods
- Open architecture and interfaces to other systems
- **Balanced mix of declarative and procedural elements**

## Declaration of..

- Sets
- Parameters
- Variables
- Equations
- Models
- ...

## Procedural Elements like...

- loops
- if-then-else
- ...



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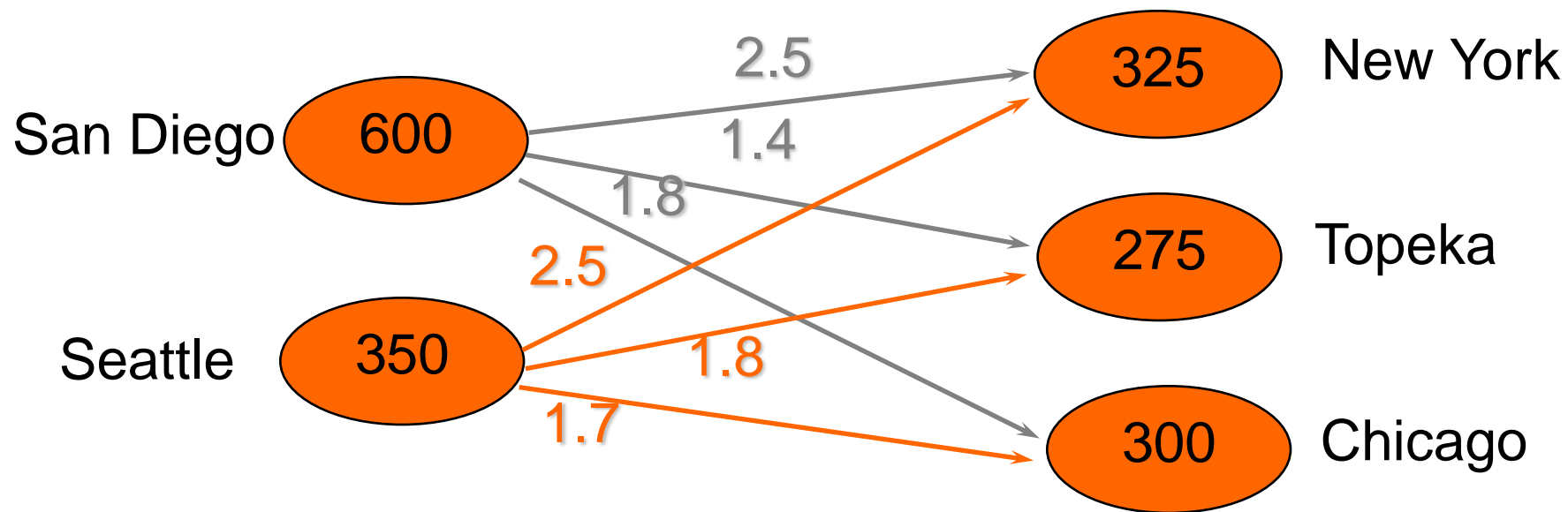
# A Transportation Model







# A Transportation Model



**Minimize** Transportation cost  
**subject to** Demand satisfaction at markets  
Supply constraints



# Model Formulation

Indices:  $i$  (Canning plants)

$j$  (Markets)

Decision variables:  $x_{ij}$  (Number of cases to ship)

Parameter:  $c_{ij}$  (Transport cost per case)

$\min \sum_i \sum_j c_{ij} \cdot x_{ij}$  (Minimize total transportation cost)

subject to

$\sum_j x_{ij} \leq sup_i \quad \forall i$  (Shipments from each plant  $\leq$  supply capacity)

$\sum_i x_{ij} \geq dem_j \quad \forall j$  (Shipments to each market  $\geq$  demand)

$x_{ij} \geq 0 \quad \forall i, j$

$i, j \in \mathbb{N}$



# GAMS Algebra

```
IDE gamside: C:\Documents and Settings\bussieck\My Documents\gamsdir\project.gpr - [c:\documents an...
IDE File Edit Search Windows Utilities Help
call {a}
transport.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/ ;
```



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# GAMS at a Glance

The screenshot displays the GAMS/IDE interface. The main window shows a code editor with the following code:

```

* Create an example GDX File for the
* Create gdx file for charting demo
* The generated gdx file can be used to do
* GAMS Development Corporation. Formulate
* instance data for single lines, bars, pie,
set years / 2000-2005 /
parameter YearDataA(years), YearDataB(year
YearData
YearData
YearData
chartdat.gdx
scrit
set
scrit
set
param
vector

```

Below the code editor is a table with the following data:

Entry	Symbol	Type	Dim	No Elem
10	GantData	Par	3	14
4	Points	Par	2	200
8	Scatter2D	Par	2	40
9	Scatter3D	Par	2	60
13	ScanalsData	Par	2	135 000
12	StockData	Par	3	600
11	Surface	Par	2	2 500
6	Vector2D	Par	2	80
6	Vector2Dk	Par	2	80
7	Vector3D	Par	2	120
1	YearDataA	Par	1	8
2	YearDataB	Par	1	8
3	YearDataC	Par	1	8

Two plots are visible: 'StockData' showing multiple time series and 'Surface' showing a 3D surface plot.

At the bottom, a log window shows the following execution details:

```

--- Job chartdat.gms Start 05/05/06 13:08:00
Gdx Rev 145 Copyright (C) 1987-2004 GAMS Development, All right
License: Franz Wotzian, 5351212
GAMS Software Data
--- Starting compilation
chartdat.gms (133) 1 Mb
--- Starting execution
chartdat.gms (126) 7 Mb
Pathfile # D:\support\chartdat.gdx
--- Status: Normal completion
Job chartdat.gms Stop 05/05/06 13:08:01 elapsed 0:00:01.422

```

## The GAMS/BASE Module

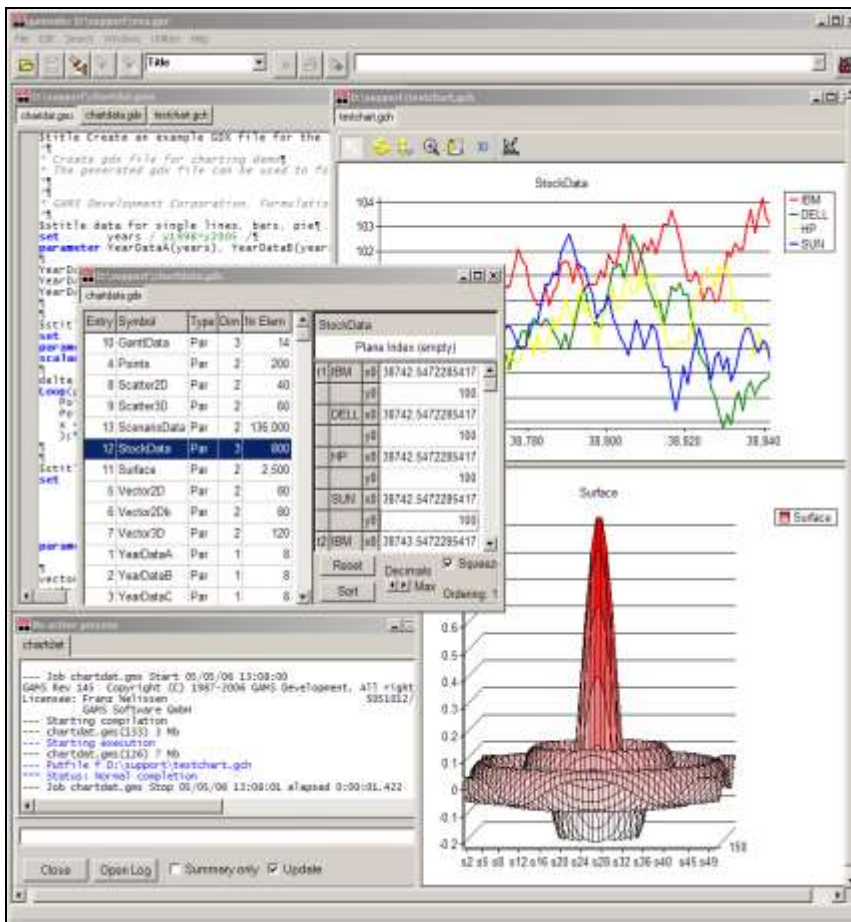
- Compiler and Execution System
- GAMS IDE (Windows)
- Documentation + Model libraries
- GDX Utilities
- Free Solvers/Solver Links







# GAMS at a Glance



## The GAMS/BASE Module

- Compiler and Execution System
- GAMS IDE (Windows)
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# 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>



# Documentation

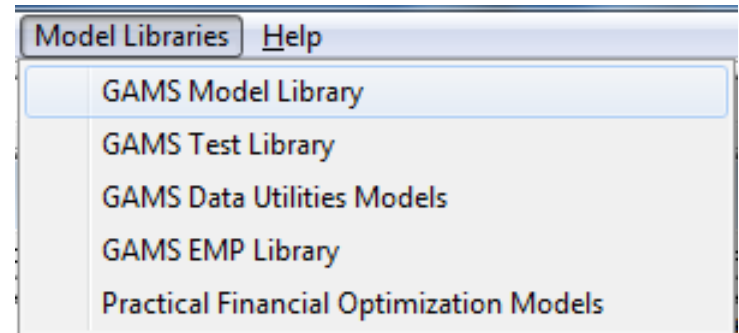
- **Groups**
  - User Group [http://www.gams.com/maillist/gams\\_l.htm](http://www.gams.com/maillist/gams_l.htm)
  - Google Group <http://groups.google.de/group/gamsworld>
- **Newsletter**
  - McCarl's News  
<http://www.gams.com/maillist/newsletter.htm>
  - Release List
- **Search all GAMS Websites**  
<http://www.gams.com/search.htm>



# Distributed Model Libraries

- **GAMS Model Library**

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



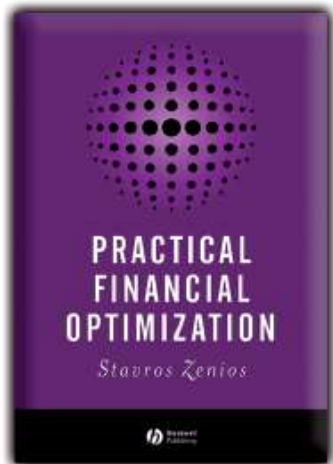
- **GAMS Test Library**

- 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. gdxxrw, mdb2gms, sql2gms
- **GAMS EMP Library**
  - Examples for the use of Extended Mathematical Programming



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

*“PRACTICAL FINANCIAL OPTIMIZATION –  
A Library of GAMS Models”*

by Consiglio, Nielsen and Zenios





# GAMS at a Glance

The screenshot displays the GAMS/IDE interface. On the left is a code editor with the following code:

```

title Create an example GDX File for the
+ Create.gdx file for charting demo
+ The generated gov file can be used to fu
+ CARE Development Corporation. Formula to
+ estimate data for single lines, bars, pief.
set years / 2000*2005 /
parameter YearDataA(years), YearDataB(year
YearData
YearData
YearData
chartdata.gdx
+-----+
| Entry | Symbol | Type | Dim | No Elem |
+-----+-----+-----+-----+-----+
| 10 | GantData | Par | 3 | 14 |
| 4 | Points | Par | 2 | 200 |
| 8 | Scatter2D | Par | 2 | 40 |
| 9 | Scatter3D | Par | 2 | 60 |
| 13 | ScanlineData | Par | 2 | 135 000 |
| 12 | StockData | Par | 3 | 600 |
+-----+-----+-----+-----+-----+
| 11 | Surface | Par | 2 | 2 500 |
| 6 | Vector2D | Par | 2 | 60 |
| 6 | Vector2Di | Par | 2 | 60 |
| 7 | Vector3D | Par | 2 | 120 |
+-----+-----+-----+-----+-----+
| 1 | YearDataA | Par | 1 | 8 |
+-----+-----+-----+-----+-----+
| 2 | YearDataB | Par | 1 | 8 |
+-----+-----+-----+-----+-----+
| 3 | YearDataC | Par | 1 | 8 |
+-----+-----+-----+-----+-----+

```

In the center, a table titled 'StockData' is displayed:

Plan	Index (empty)
(1) IBM	vB 18742.5472285417
	yB 100
DELL	vB 18742.5472285417
	yB 100
HP	vB 18742.5472285417
	yB 100
SUN	vB 18742.5472285417
	yB 100
(2) IBM	vB 18743.5472295417
	yB 100

At the top right, a 'StockData' line chart shows four data series: IBM (red), DELL (blue), HP (green), and SUN (yellow) from 2000 to 2005. At the bottom right, a 'Surface' plot shows a 3D surface with a prominent peak.

At the bottom left, a console window shows the execution log:

```

--- Job chartdat.gms Start 05/05/06 13:08:00
Gdx Rev 145 Copyright (C) 1987-2004 GAMS Development, All right
License: Franz Wotzian, 5351212/
GAMS Software Data
--- Starting compilation
chartdat.gms (133) 1 Mb
--- Starting execution
chartdat.gms (126) 7 Mb
Pathfile # D:\support\testchart.gdx
--- Status: Normal completion
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```

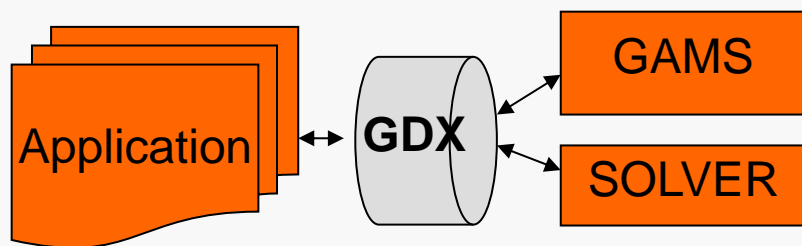
## The GAMS/BASE Module

- Compiler and Execution System
- GAMS IDE (Windows)
- Documentation + Model libraries
- GDX Utilities
- Free Solvers/Solver Links



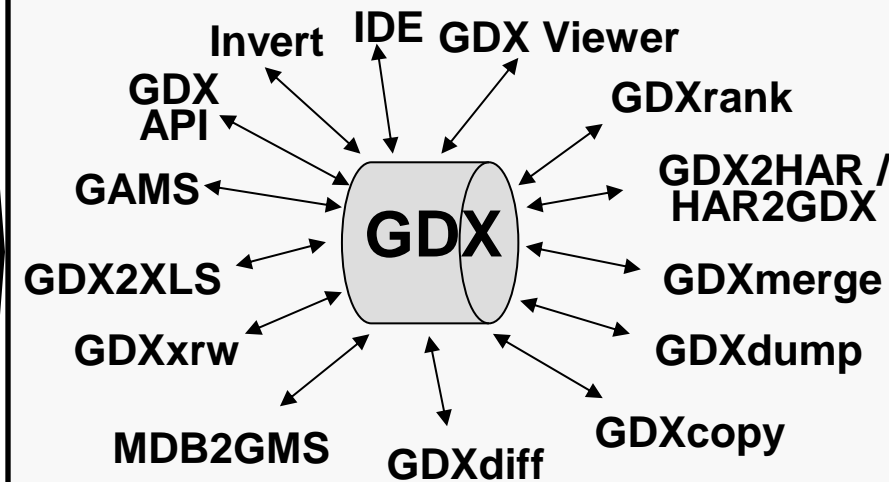
# Gams Data eXchange

## Binary Data Exchange



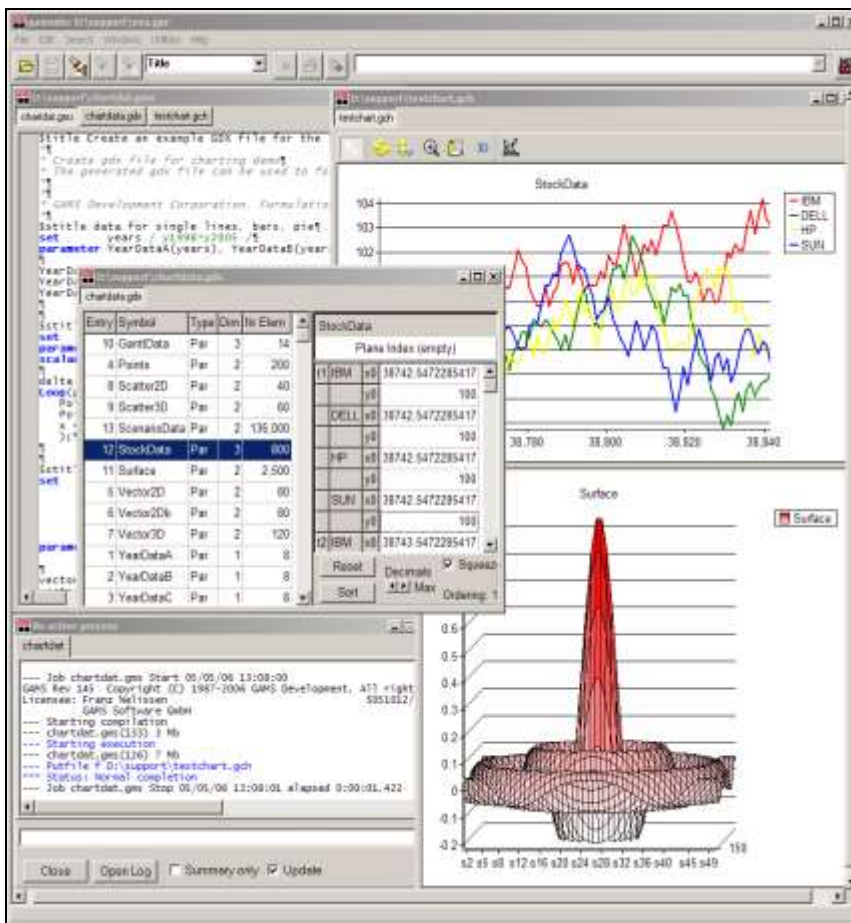
- Fast exchange of data
- Syntactical check on data before model starts
- Data Exchange at any stage (Compile and Run-time)
- Platform Independent
- Direct GDX interfaces and general API
- Scenario Management Support
- Full Support of Batch Runs

## GDX Tools





# GAMS at a Glance



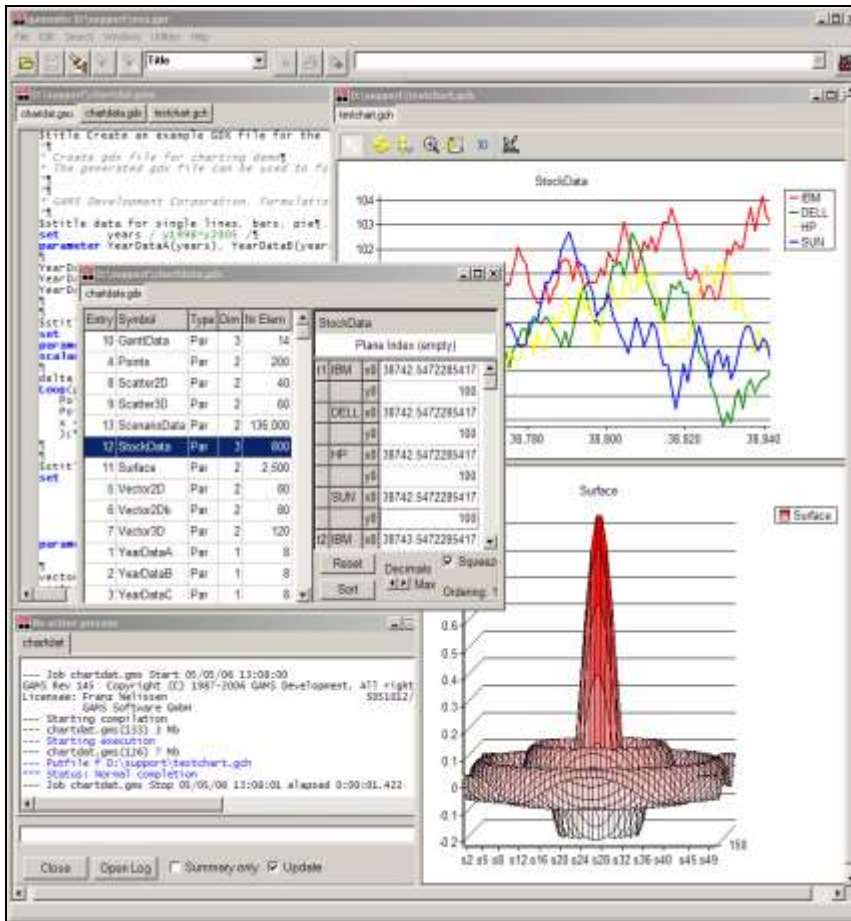
## The GAMS/BASE Module

- Compiler and Execution System
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# GAMS at a Glance



## The GAMS/BASE Module

### Free Solvers:

- Convert
- EMP/JAMS, DE, NLPEC
- BENCH, EXAMINER, GAMSCHK
- BDMLP, LS, and MILES
- KESTREL (Remote Solver Execution on NEOS Servers)
- COIN-OR:  
Cbc, IpOpt, BonMin, Couenne, ...
- Soplex, Scip (academic only)
- All other solvers in limited versions





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- Data Import/Export

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- Extending the GAMS Syntax

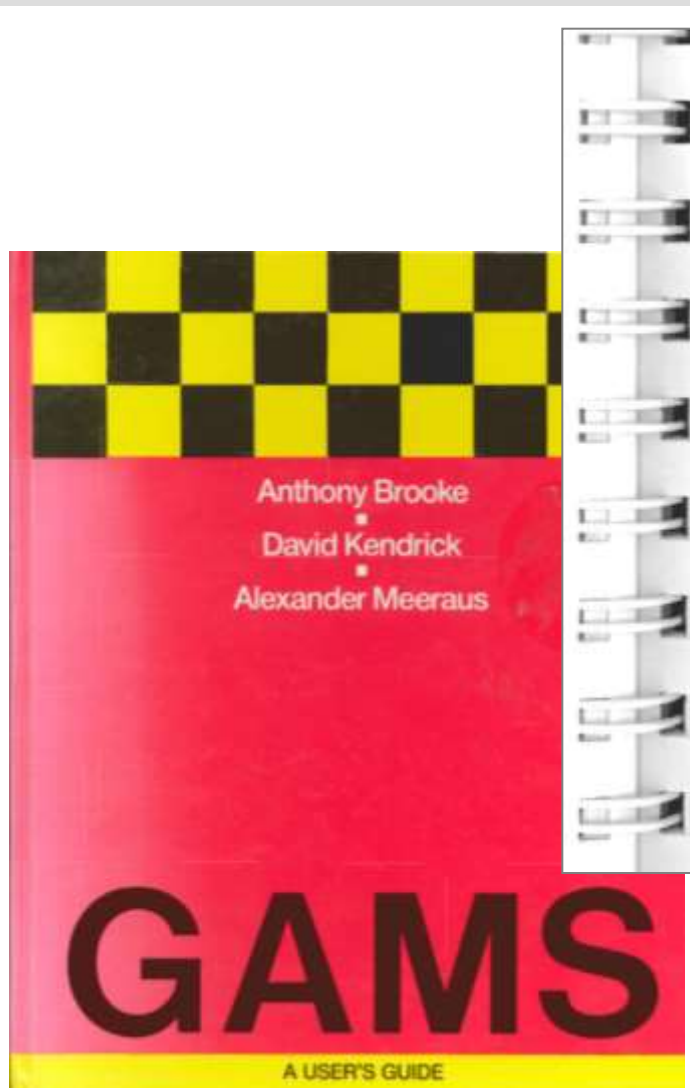


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# Then ...



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

<sup>a</sup>Measured in **minutes**.

<sup>b</sup>The problem is too big for MINOS. ZOOM was used instead.

<sup>c</sup>A nonlinear problem. 63% of the non-zeros are nonlinear.

<sup>d</sup>A nonlinear problem. 58% of the non-zeros are nonlinear.

<sup>e</sup>A mixed binary problem, with 55 binary variables (solved with a relative termination criterion of 10%).

<sup>f</sup>A linear problem, solved using XMP which is contained within ZOOM.

## GAMS Users Guide (1988)



## ... and now

	Type	s in 1988	s in 2013	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





# Improvements on all Frontiers

- **Solver Technology**
  - Updates for existing solver
  - New solvers
- **Productivity Tools**
  - Databases, spreadsheets
  - Specialized visualization tools
  - IDE improvements
  - Grid computing
- **Interfaces**
  - Gams Data eXchange
  - Using GAMS from other applications



# Outline

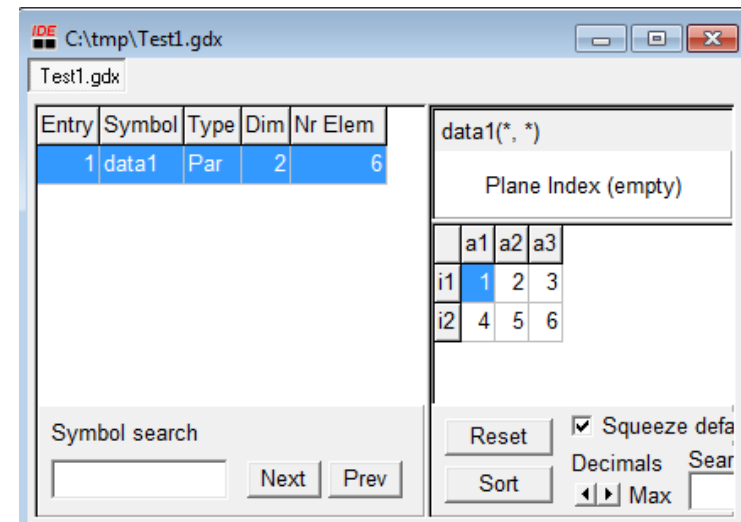
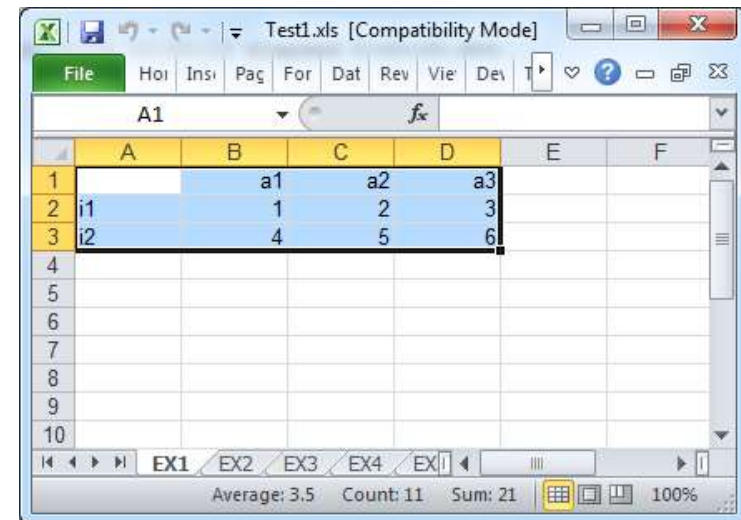
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# GDXRW

- Read and write Excel spreadsheet data
- Can read multiple ranges in a spreadsheet and write the data to a GDX file
- Can read from a GDX file and write the data to different ranges in a spreadsheet
- Examples in the GAMS Data Library

**Hands-On**

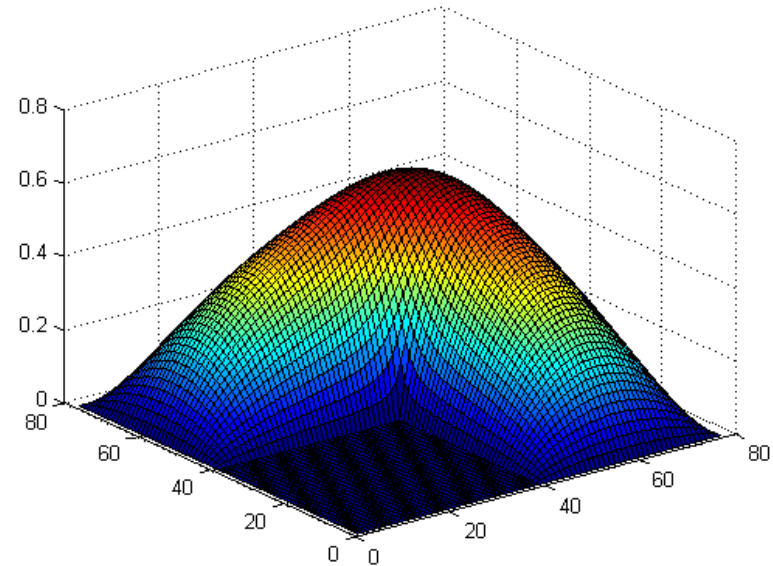




# GDXMRW

- Import/export data between GAMS and MATLAB
- Call GAMS models from MATLAB
- Get results back in MATLAB
- Gives MATLAB users the ability to use all the optimization capabilities of GAMS
- Allows visualization of GAMS models directly within MATLAB
- More Information:

[http://support.gams.com/doku.php?id=matlab\\_and\\_gams:interfacing\\_optimization\\_and\\_visualization\\_software\\_via\\_the\\_gdxmrw\\_utilities](http://support.gams.com/doku.php?id=matlab_and_gams:interfacing_optimization_and_visualization_software_via_the_gdxmrw_utilities)

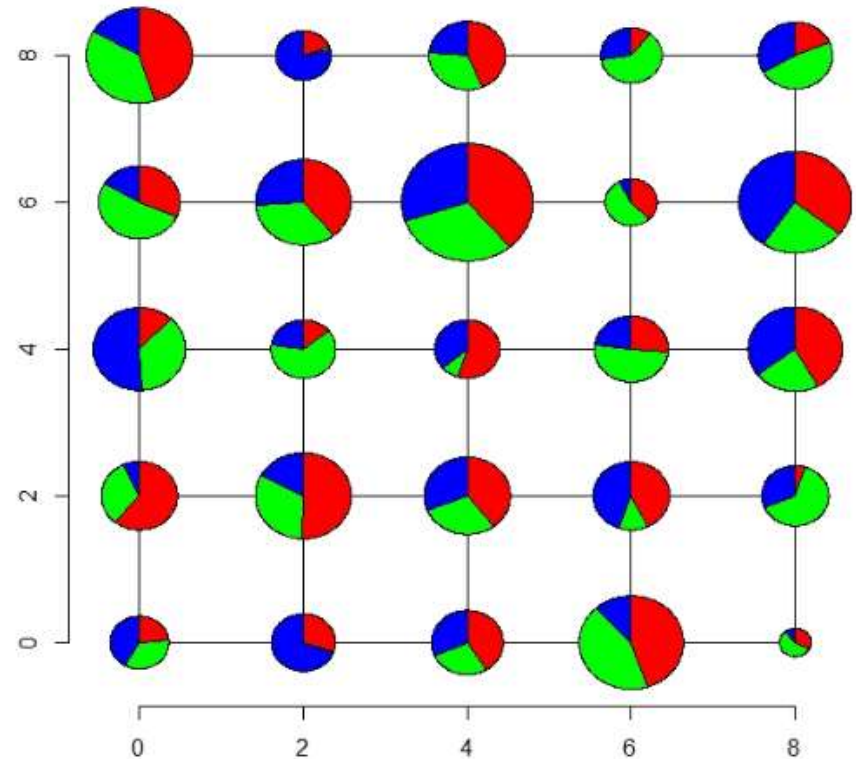






# GDXRRW

- GDXRRW bridges the gap between R and GAMS (import/export data between GAMS and R)
- Fits into the ecosystem of existing GDX utilities
- Presents data in a natural form for R users
- More information:  
[http://support.gams.com/doku.php?id=gdxrrw:interfacing\\_gams\\_and\\_r](http://support.gams.com/doku.php?id=gdxrrw:interfacing_gams_and_r)



Source: <http://blog.modelworks.ch>



# Load from GDX

## Compile Time:

```
$gdxIn transSol.gdx // open file for reading
$load                // list file content
$load      i         // load symbol i
$load      jj=j      // load symbol j as jj
$loadDC    a b       // load a & b domain controlled
$load[DC]M k        // load symbol k, merge content
$load[DC]R l        // load symbol l, replace content
$gdxIn              // close open file
```

## Execution Time:

```
execute_load 'transSol.gdx' a;

put_utility 'gdxin' / 'transSol.gdx';
execute_load b;
```

**Hands-On**



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# SolveLink Option

```
Model transport /all/ ;  
Option solveLink = {%SolveLink.ChainScript%,  
                    %SolveLink.CallScript%,  
                    %SolveLink.CallModule%,  
                    %SolveLink.AsyncGrid%,  
                    %SolveLink.AsyncSimulate%,  
                    %SolveLink.LoadLibrary%};  
solve transport using lp minimizing z;
```

- ChainScript [0]: Solver process, GAMS vacates memory
  - + Maximum memory available to solver
  - + protection against solver failure (*hostile* link)
  - swap to disk





## Solverlink Option – cont.

- Call{Script [1]/Module [2]}: Solver process, GAMS stays live
  - + protection against solver failure (*hostile link*)
  - + no swap of GAMS database
  - file based model communication
- LoadLibrary [5]: Solver DLL in GAMS process
  - + fast memory based model communication
  - + update of model object inside the solver (hot start)
  - not supported by all solvers

**Hands-On**



# Solving Scenarios

transport.gms (LP) solved 500 times with CPLEX:

```
Loop (s,  
      d(i,j) = dd(s,i,j);  
      f = ff(s);  
      solve transport using lp minimizing z;  
      rep(s) = transport.objval;  
);
```

Setting	Solve time (secs)
Sovelink=%Sovelink.ChainScript%	52.221
Sovelink=%Sovelink.CallModule%	37.366
Sovelink=%Sovelink.LoadLibrary%	03.252



# Gather-Update-Solve-Scatter (GUSS)

Setting	Solve time (secs)
Solverlink=%Solverlink.ChainScript%	52.221
Solverlink=%Solverlink.CallModule%	37.366
Solverlink=%Solverlink.LoadLibrary%	03.252
GUSS	01.046

- Update model data instead of matrix coefficients/rhs
- Hot start (keep the model hot inside the solver and use solver's best update mechanism)
- Save model generation and solver setup time
- Model rim unchanged from scenario to scenario
- Apriori knowledge of all scenario data

**Hands-On**



# Solution Pool

- Several solver links can write out alternative solutions to GDX: AlphaECP, ANTIGONE, BARON, CBC, CPLEX, GloMIQO, Gurobi, SCIP, Xpress
- BARON, CPLEX, and Xpress also offer functionality to explicitly search for alternative solutions
- See GAMS Model Library model `solnpool`

```
----      142 PARAMETER xcostX   cost structure by solution

           totcost           tcost           fcost

file1      499.000           219.000           280.000
file2      512.000           212.000           300.000
file3      985.000           355.000           630.000
```





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  - Extending the GAMS Syntax



# Function Libraries

- Allows users to import functions from an external library into a GAMS model
- Imported functions can be used in the same way as intrinsic GAMS functions
- Some function libraries are included in the GAMS distribution
- Users can create their own libraries using an open programming interface (simple examples written in C, Delphi and Fortran come with every GAMS system)
- To make a library available call

```
$FuncLibIn <IntLibName> <ExtLibName>
```

- Declare functions similar to sets, parameters, ..., :

```
Function <IntFuncName> /<IntLibName>.<FuncName>/;
```



# Function Libraries – Included Examples

- FITfclib
  - FITPACK from P. Dierckx
  - One and two dimensional spline interpolation
- LSAdclib
  - Use sampling routines from Lindo inside GAMS
  - Requires GAMS/Lindo license (or runs in limited demo mode)
- PWPcclib
  - Piecewise polynomial function evaluation
- STOdclib
  - Random deviates, probability density functions, cumulative density functions and inverse cumulative density functions
  - E.g., ChiSquare, Gumbel, Logistic, Rayleigh, ...
- TRlclib, TRldclib, TRlfclib
  - Simple examples compiled and as source code written in C, Delphi and Fortran respectively



# Function Libraries – Interface

- ```
int LibInit(  
    abcRec_t *abc,          // in  handle  
    const int version,     // in  library version  
    char *msg)             // out message
```
  
- ```
int <FUNCTIONNAME>(  
    abcRec_t *abc,          // in  handle  
    const int DR,          // in  derivative request  
    const int args,        // in  number of arguments  
    const double x[],      // in  arguments  
    double *f,             // out function value  
    double g[],            // out gradient  
    double h[],            // out hessian  
    void *cb,              // in  error callback  
    void *usermem)         // in  user memory for error callback
```





# Stochastic Programming in GAMS

- The Extended Mathematical Programming (EMP) framework is used to replace parameters in the model by random variables
- Support for Multi-stage recourse problems and chance constraint models
- Easy to add uncertainty to existing deterministic models, to either use specialized algorithms or create Deterministic Equivalent (new free solver DE)



## Excursus: EMP, what?

With new modeling and solution concepts do not:

- overload existing GAMS notation right away !
- attempt to build new solvers right away !

But:

- Use existing language features to specify additional model features, structure, and semantics
- Express extended model in symbolic (source) form and apply existing modeling/solution technology
- Package new tools with the production system

→ **Extended Mathematical Programming (EMP)**



# JAMS: a GAMS EMP Solver

