Pre-Conference Workshop

Steve Dirkse SDirkse@gams.com

GAMS Development Corporation www.gams.com

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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 lasest features, solvers, etc.
- **COIN-OR Cup celebration**
  - **Monday night, 8:30-??**
  - **The Loon (500 N. 1st 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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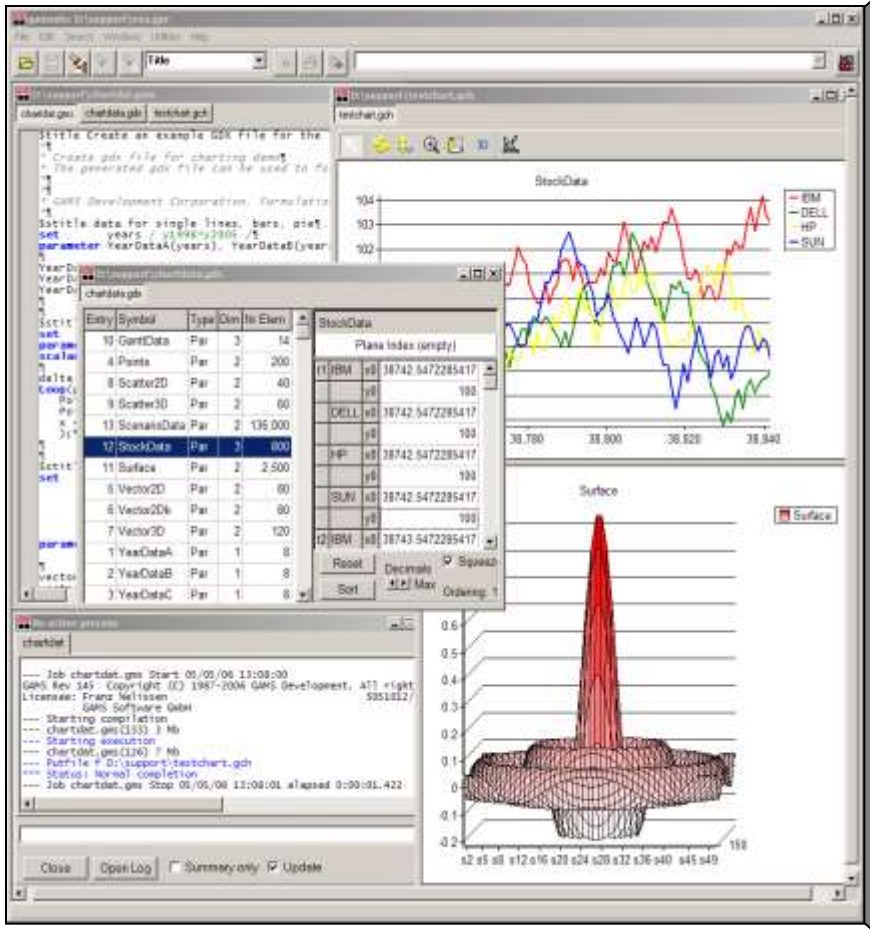
GAMS at a Glance



Algebraic Modeling System

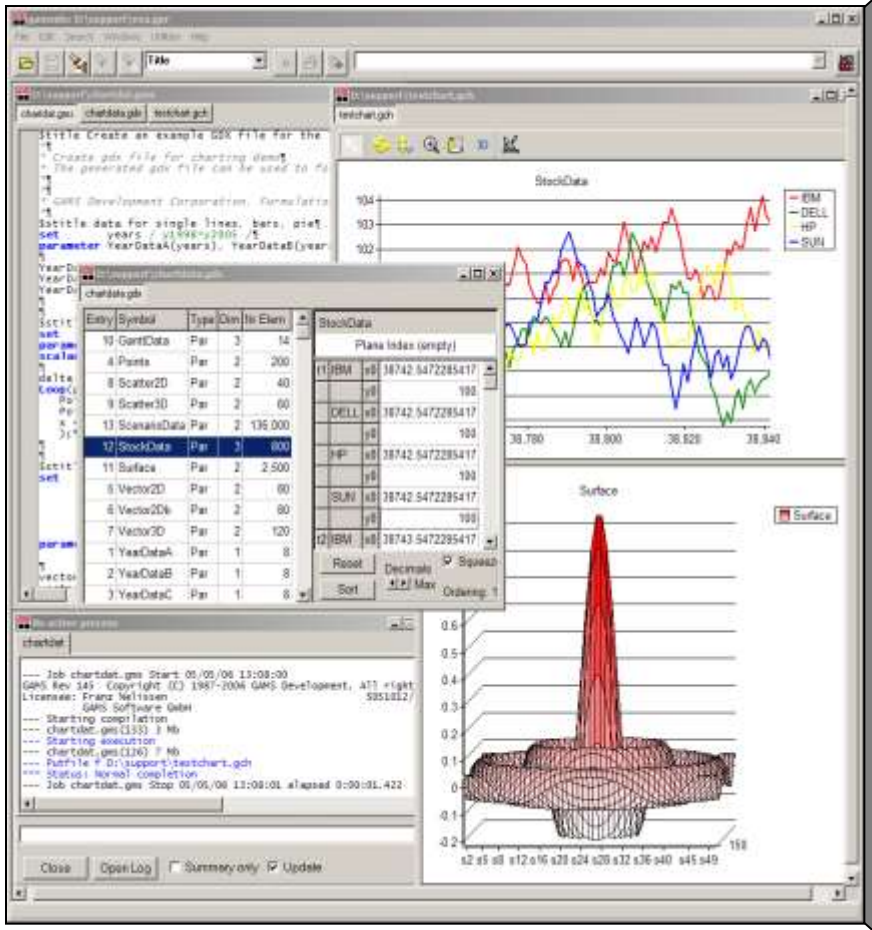
- Facilitates formulation of mathematical optimization problems expressed in an algebraic notation

  ➔ Simplified model building

- Provides links to appropriate state-of-the-art external algorithms

  ➔ Efficient solution process

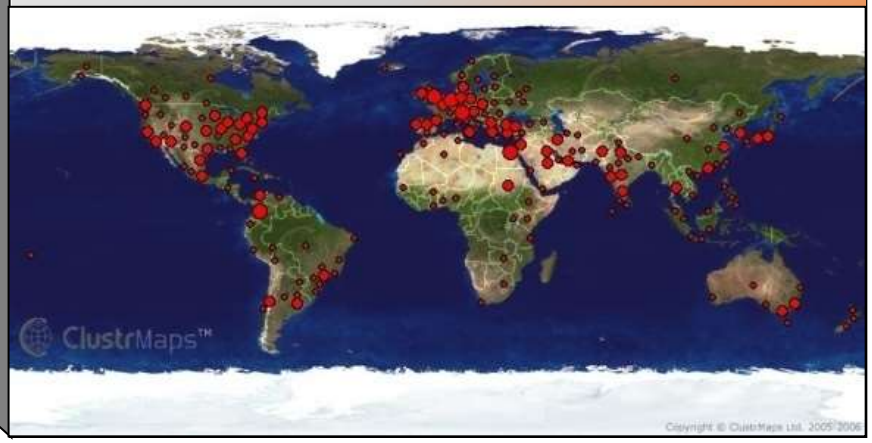
GAMS at a Glance



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

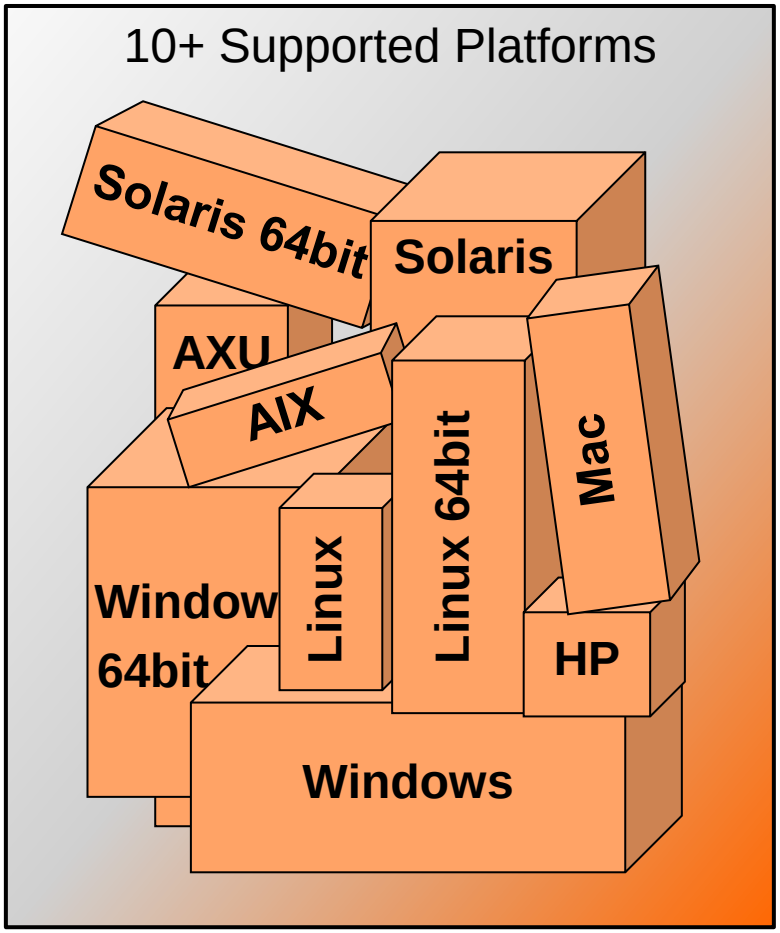
- Roots: World Bank, 1976
- Went commercial in 1987
- GAMS Development Corp.
- GAMS Software GmbH

- Broad academic & commercial user community and network



GAMS' Fundamental concepts

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



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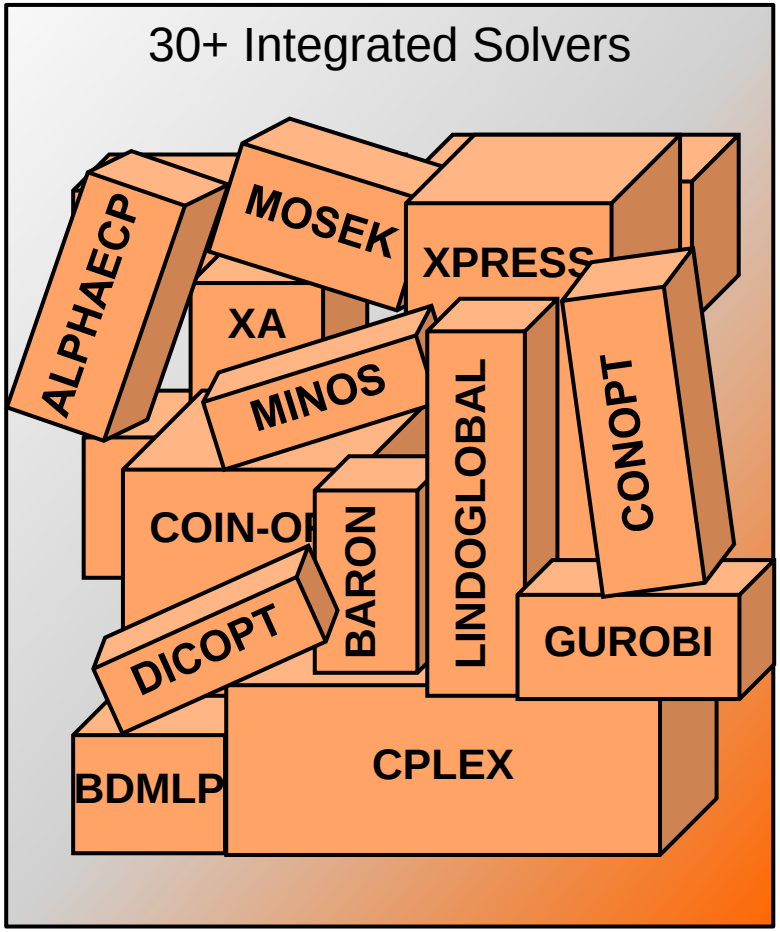

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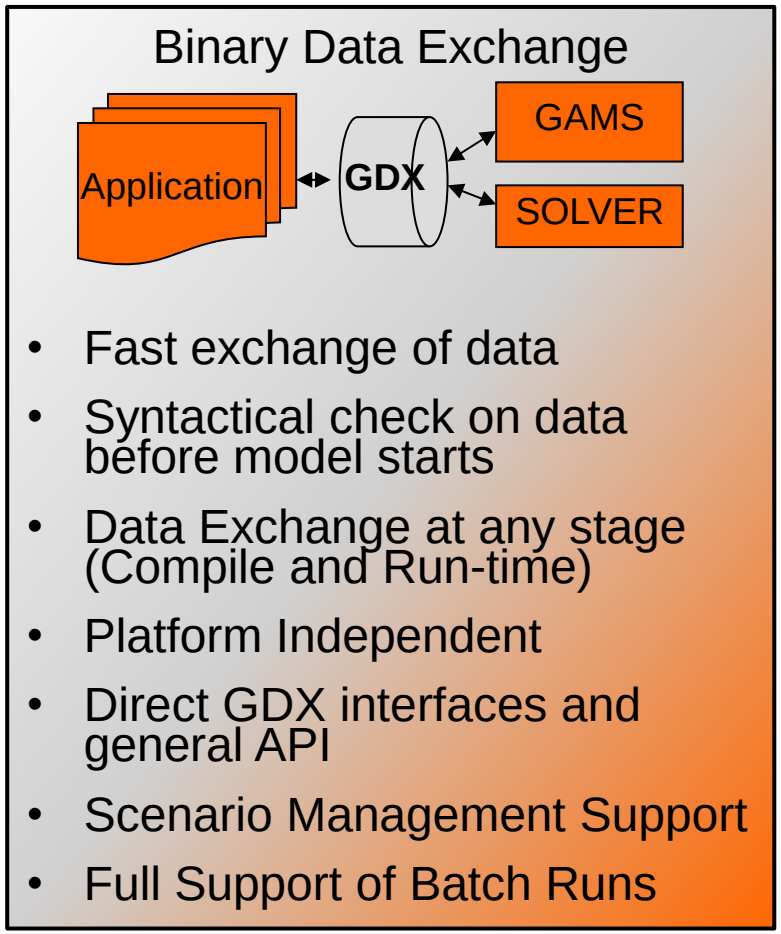

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- Platform independence
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- **Balanced mix of declarative and procedural elements**

Declaration of..

- **Sets**
- **Parameters**
- **Variables**
- **Equations**
- **Models**
- **…**

Procedural Elements like…

- **loops**
- **if-then-else**
- **…**

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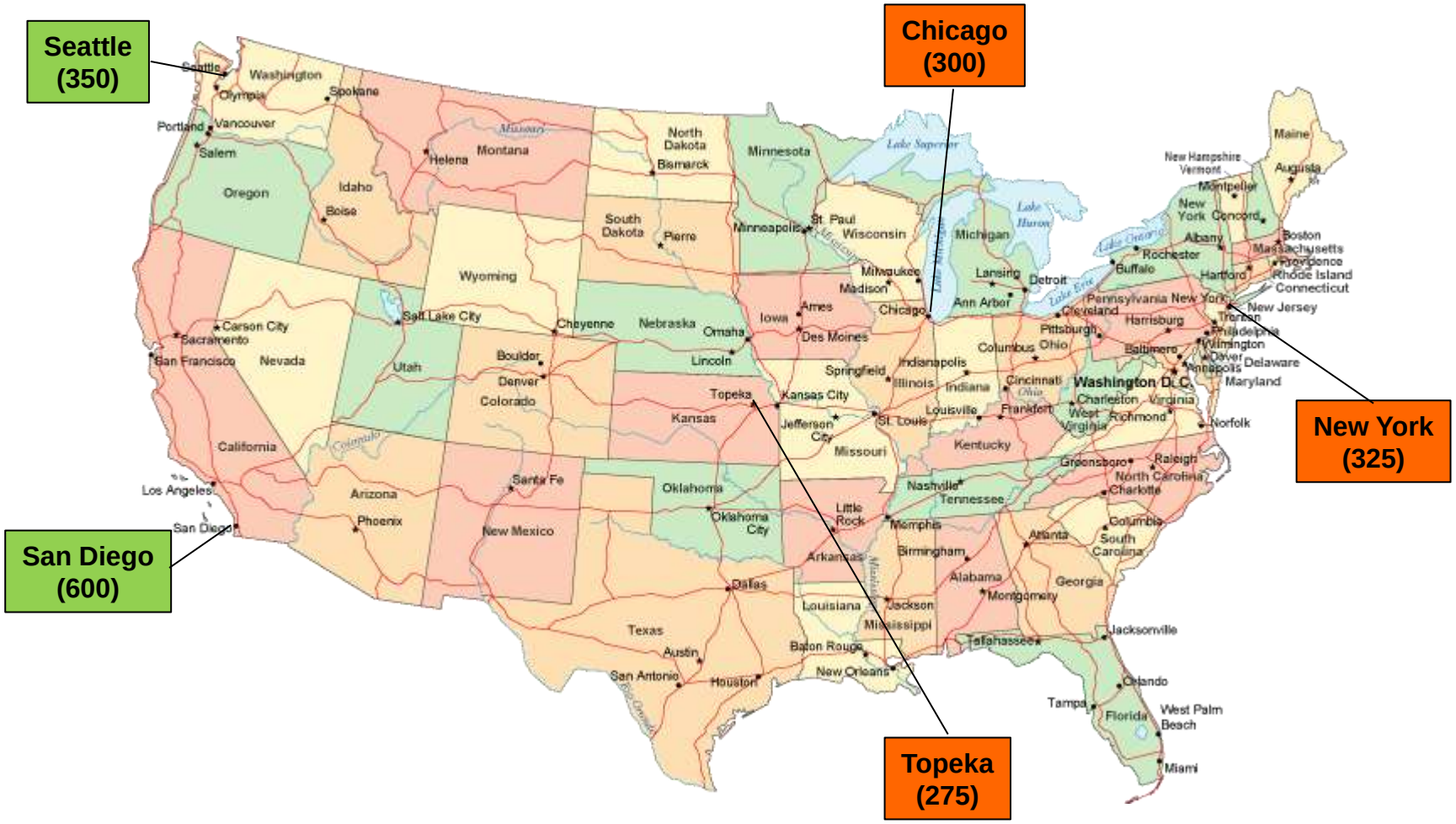
A Transportation Model



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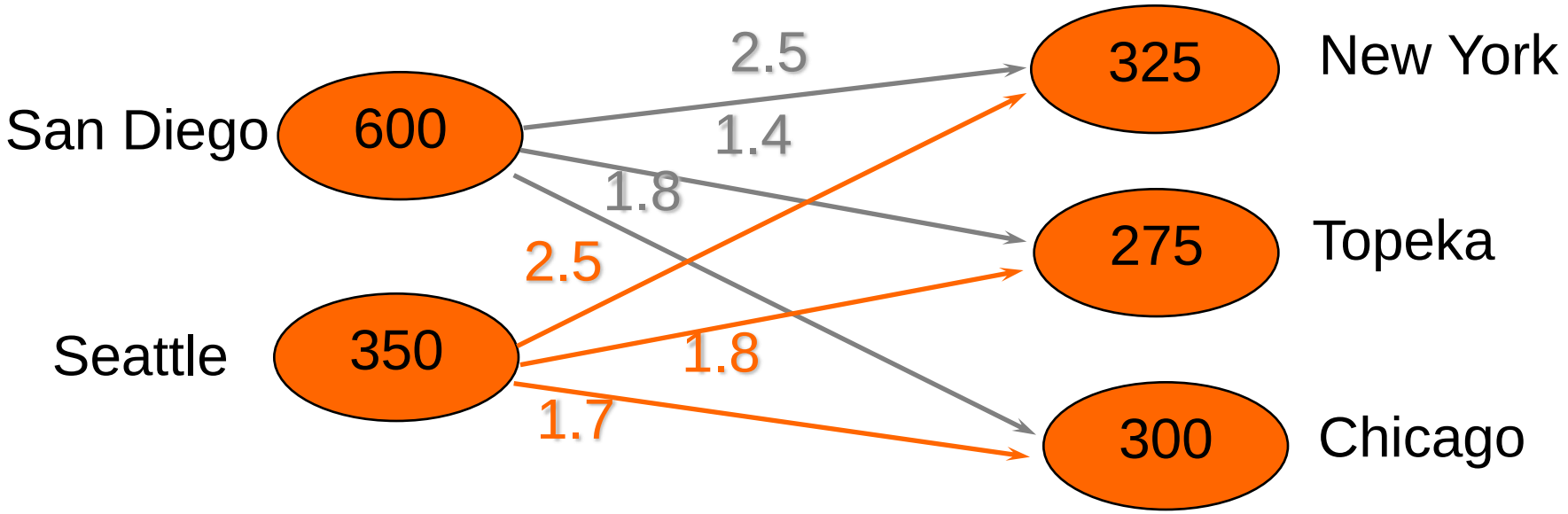


Minimize	Transportation cost
subject to	Demand satisfaction at markets
	Supply constraints

Model Formulation

Indices: i (Canning plants)

j (Markets)

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

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

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

subject to

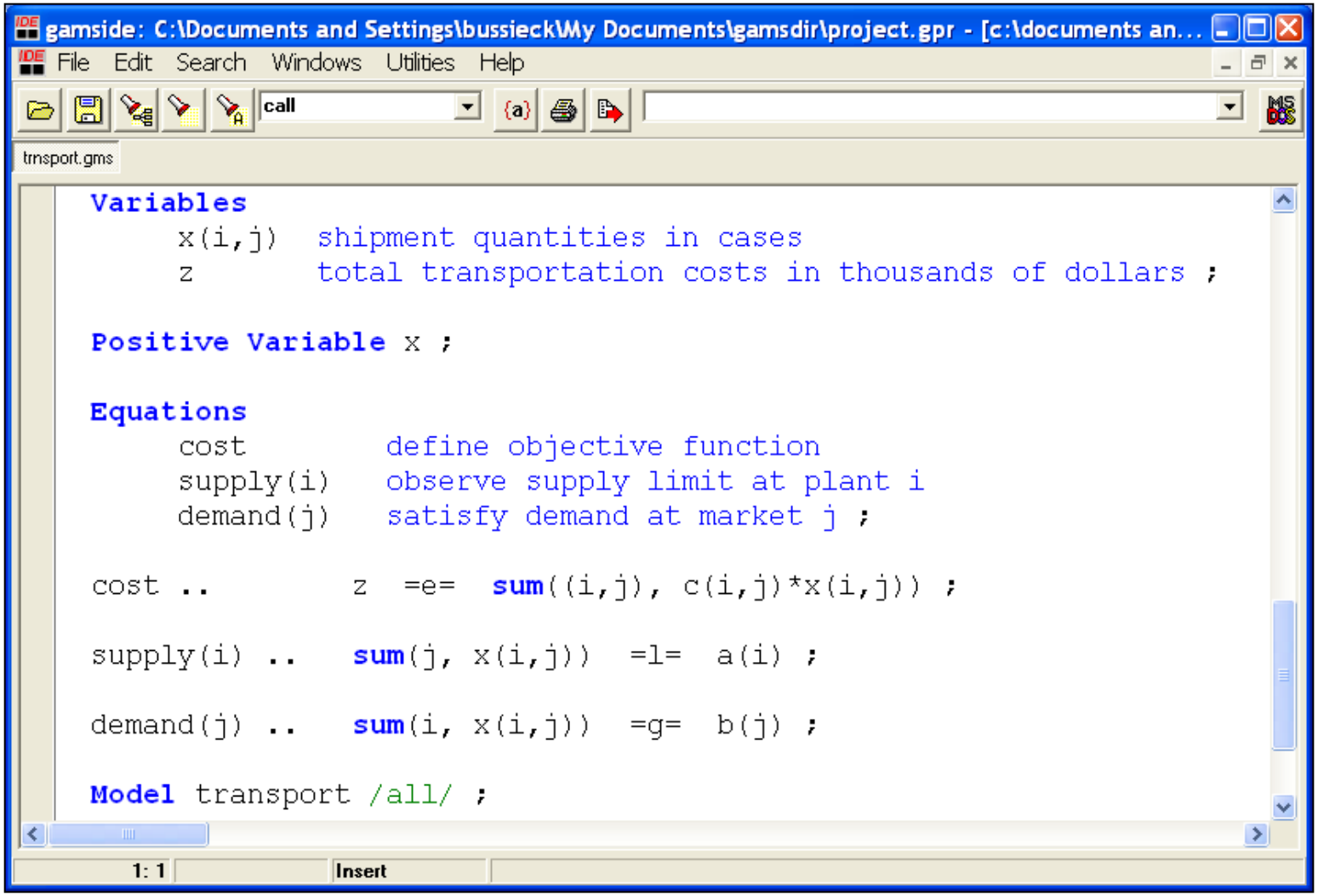
$\sum_j x_{ij} \leq sup_i \quad \forall\, i$ (Shipments from each plant $\leq$ supply capacity)

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

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

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

GAMS Algebra



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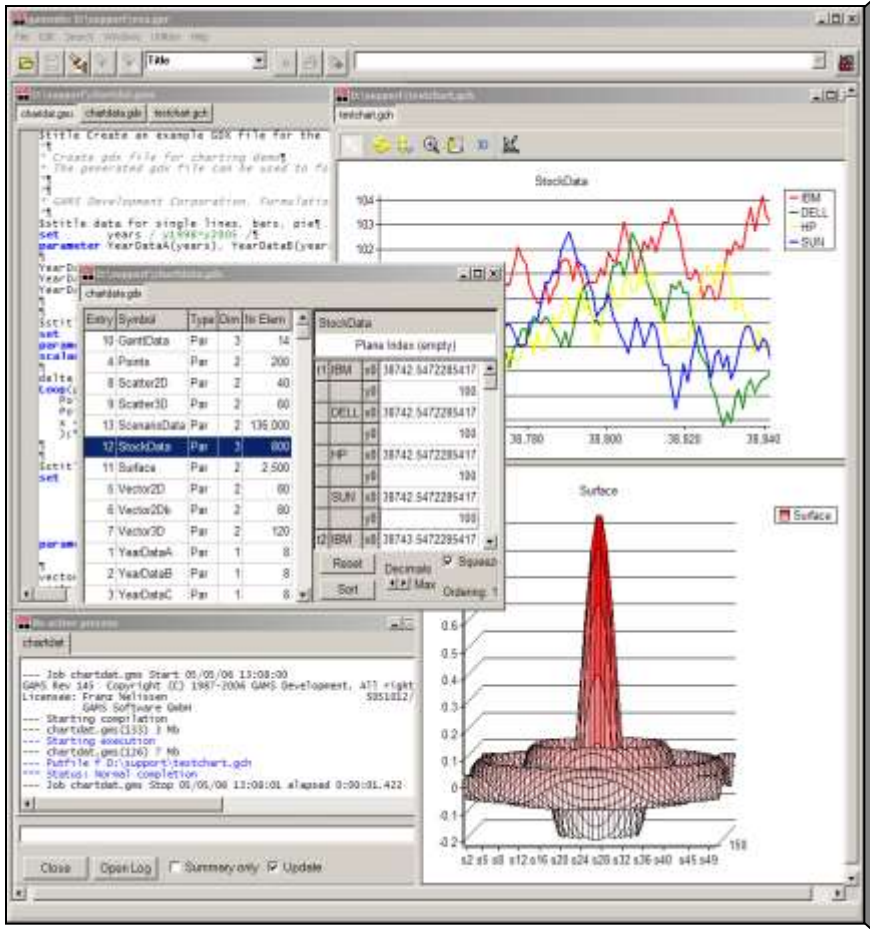
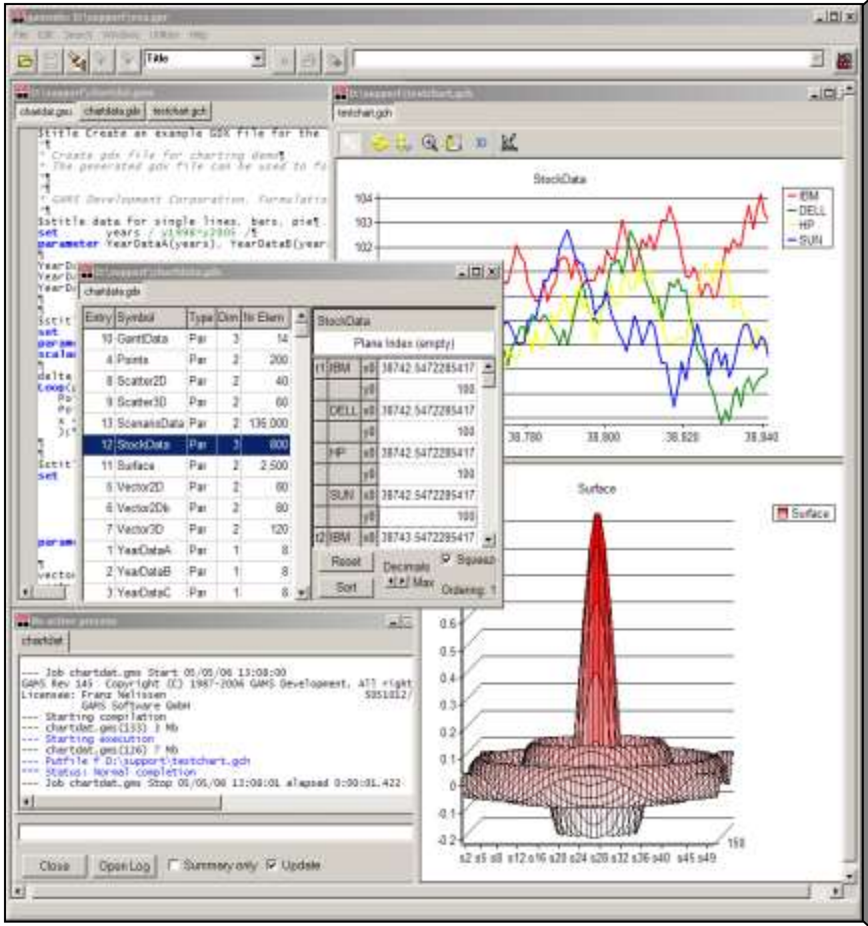


The GAMS/BASE Module

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

GAMS at a Glance



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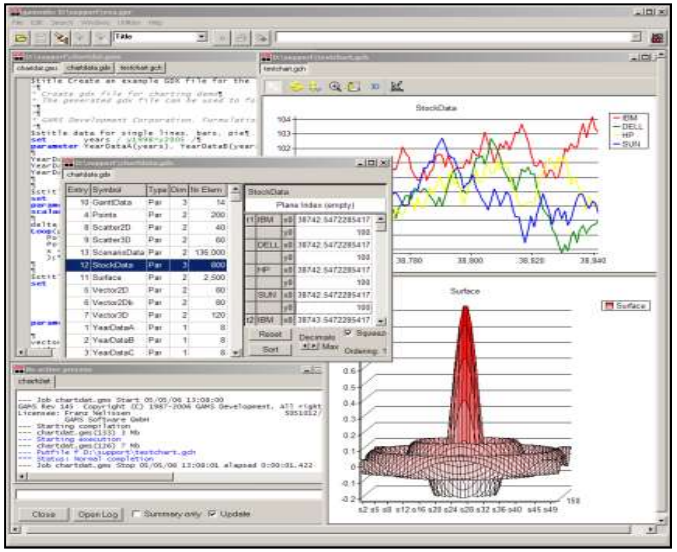
Integrated Development Environment

- 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
- Model libraries
- Documentation
- Diff for GDX and Text

Hands-On



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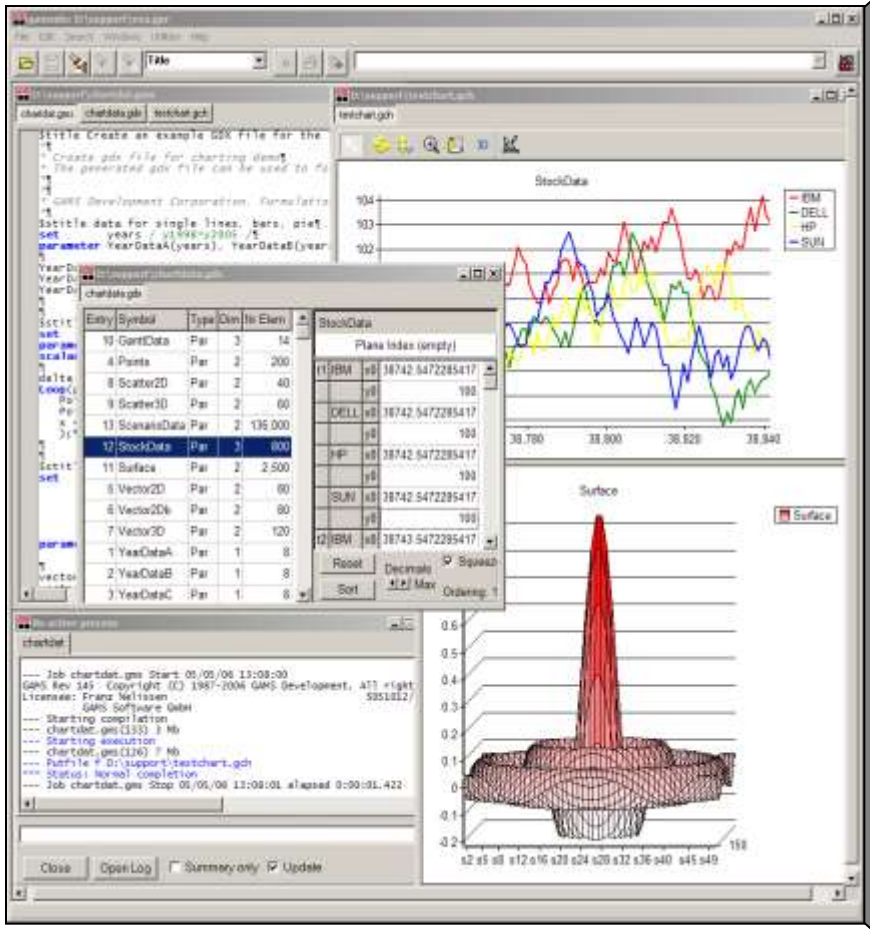

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Documentation

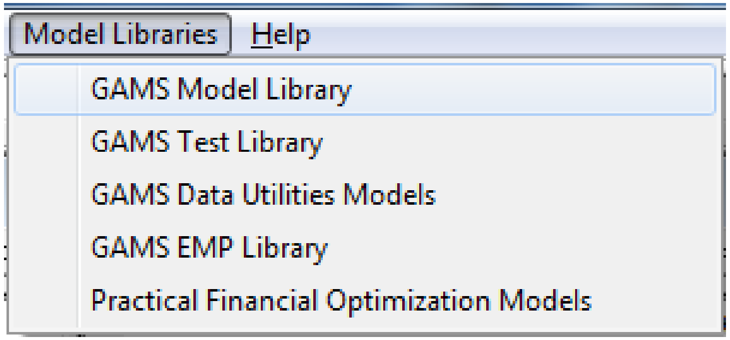
- **Distributed Documentation**
  - GAMS Users Guide
  - Expanded GAMS Users Guide (McCarl)
  - Solver Manuals
  - GAMS Utility Manuals

- **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
  - 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



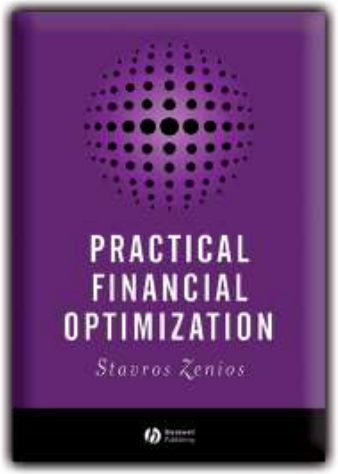
- **GAMS Model Library**
  - Example and user-contributed models
  - Very often used as templates
  - Tests for
    - Solver robustness and correctness
    - Backward compatibility

- **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



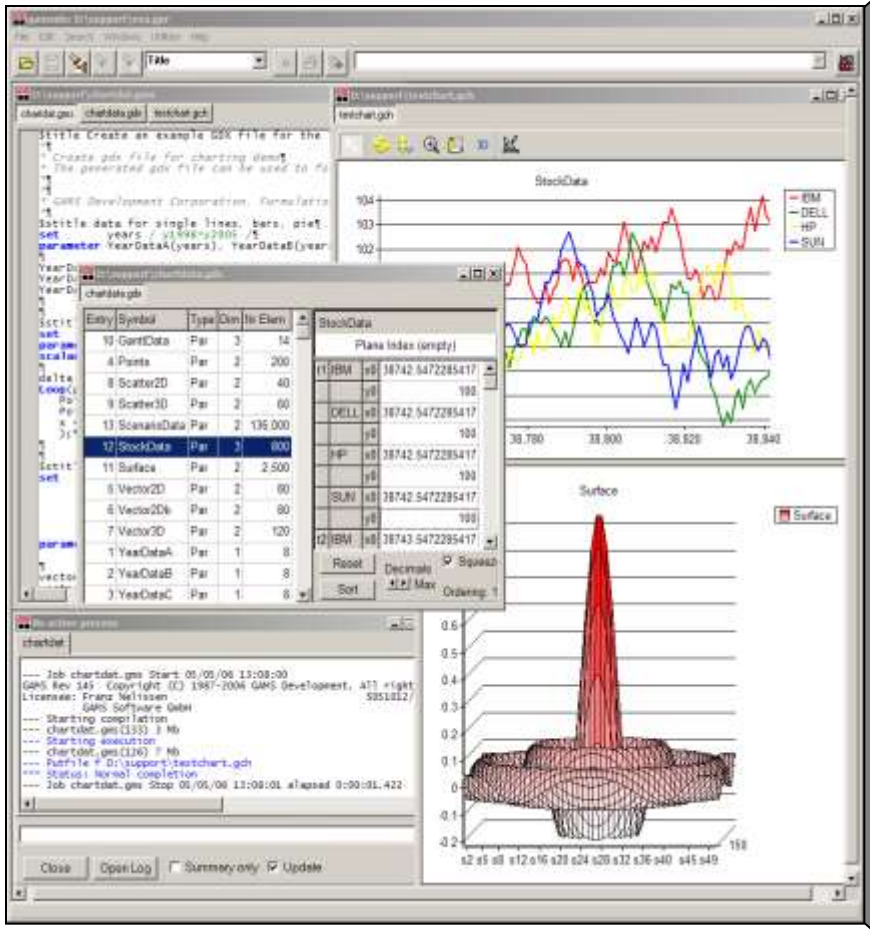
- **Practical Financial Optimization Models**

  Models of the book

  "PRACTICAL FINANCIAL OPTIMIZATION – A Library of GAMS Models"

  by Consiglio, Nielsen and Zenios

GAMS at a Glance



The GAMS/BASE Module

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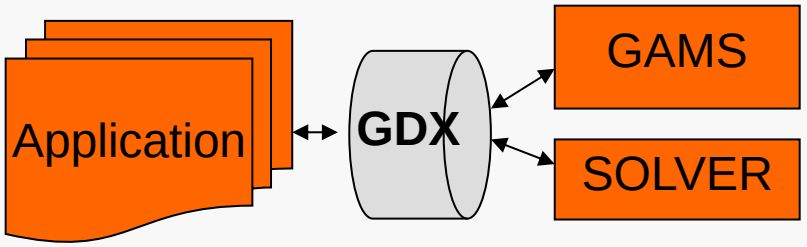
- GDX Utilities
- Free Solvers/Solver Links

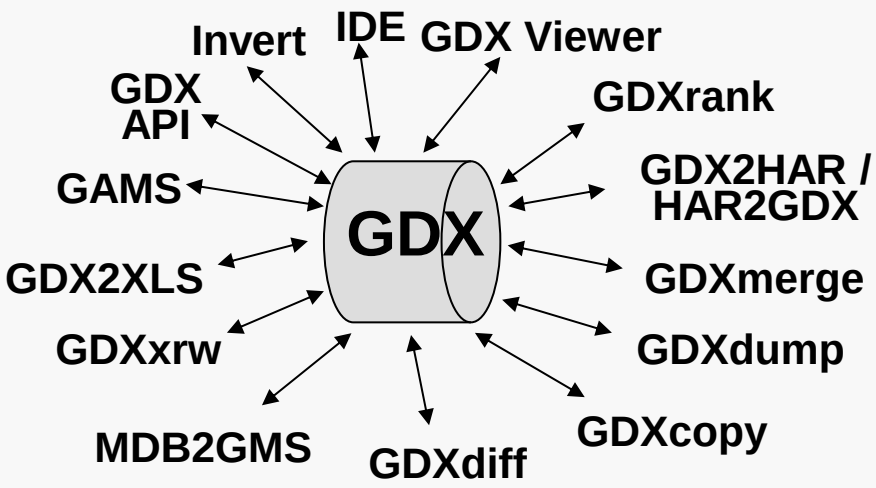
Gams Data eXchange

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



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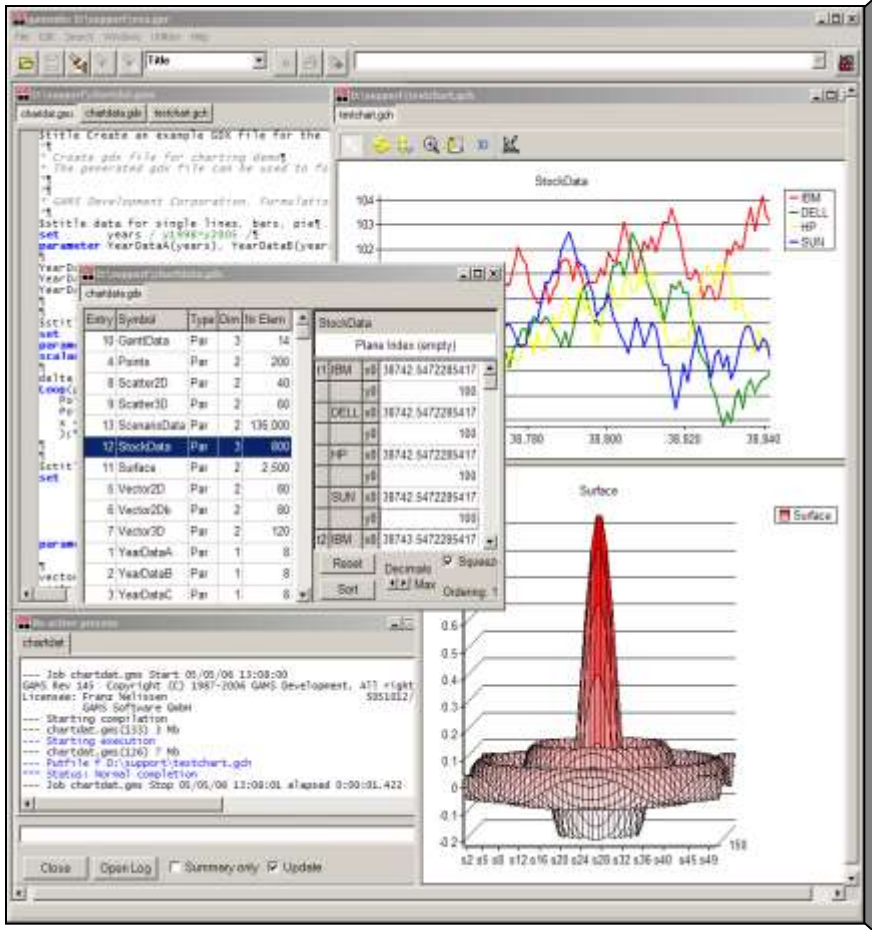

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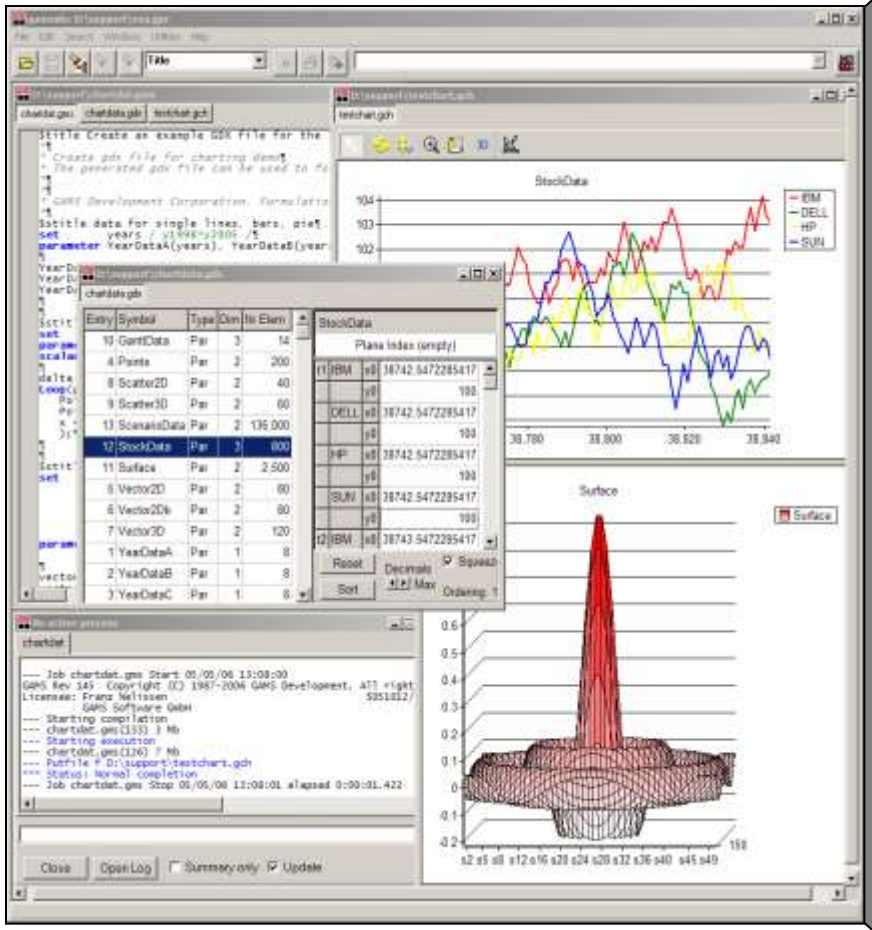

The GAMS/BASE Module

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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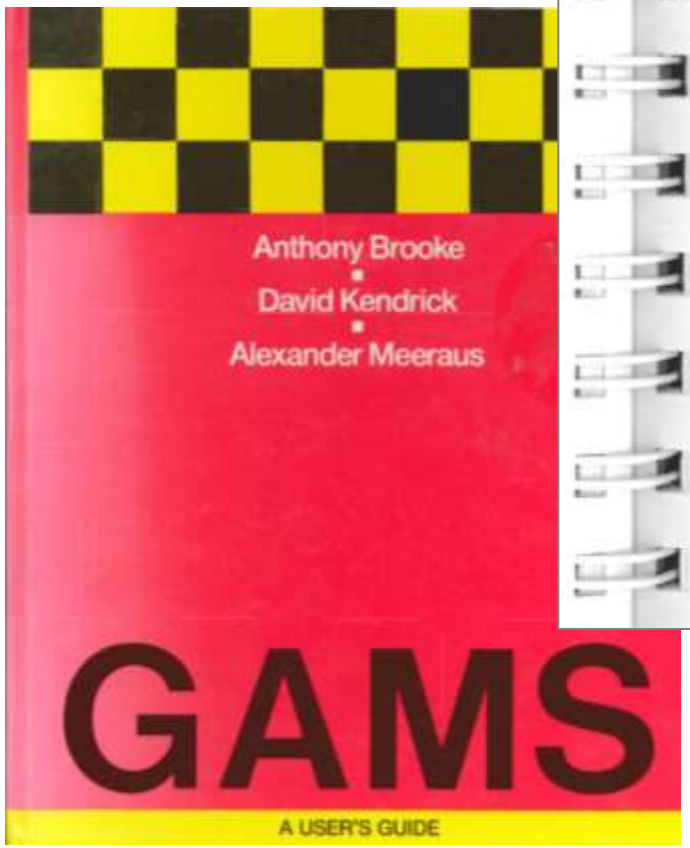
Then …



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 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

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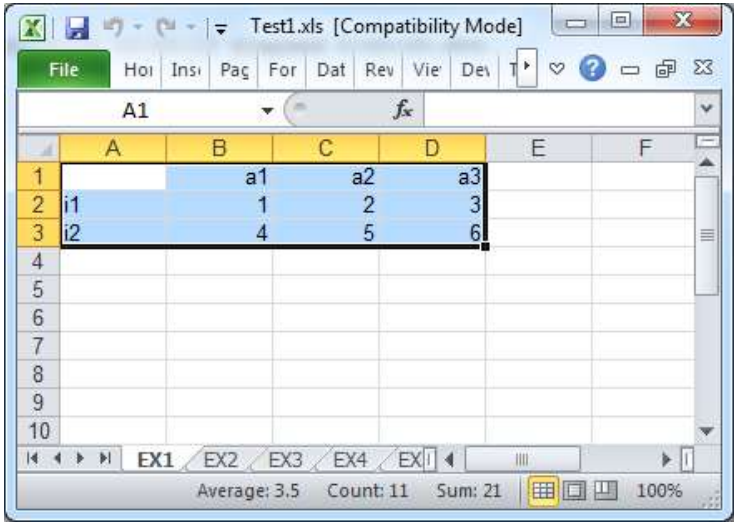
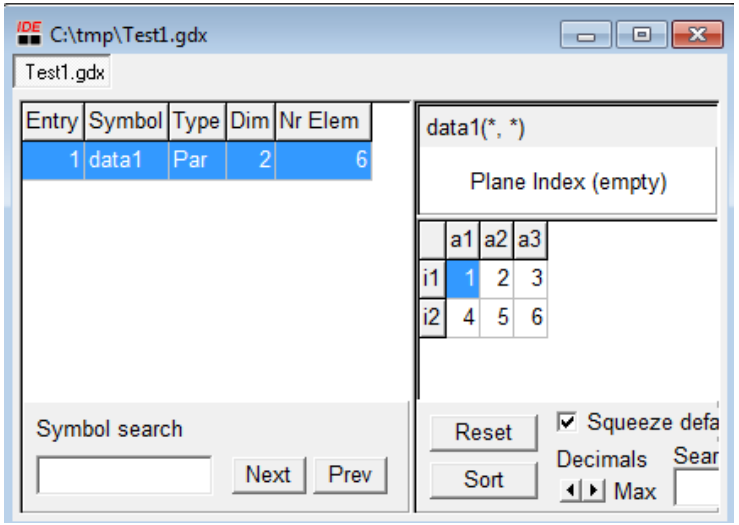
GDXXRW

- 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

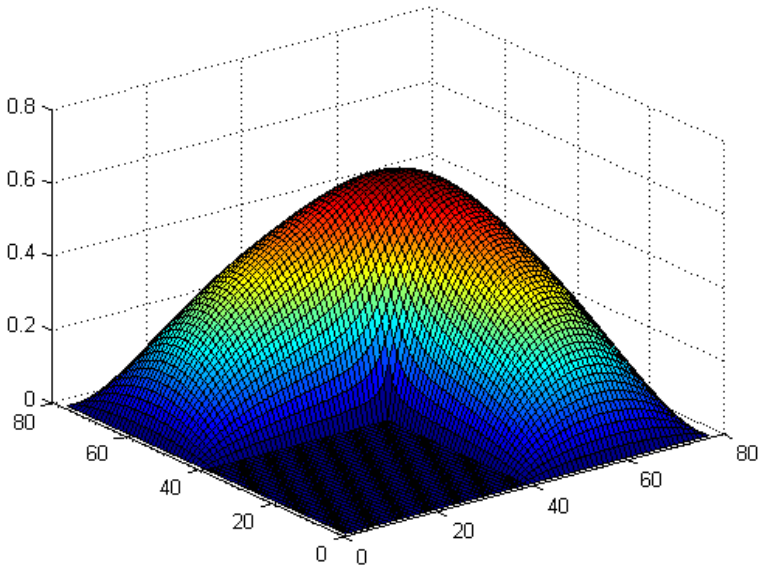
Hands-On





GDXMRW

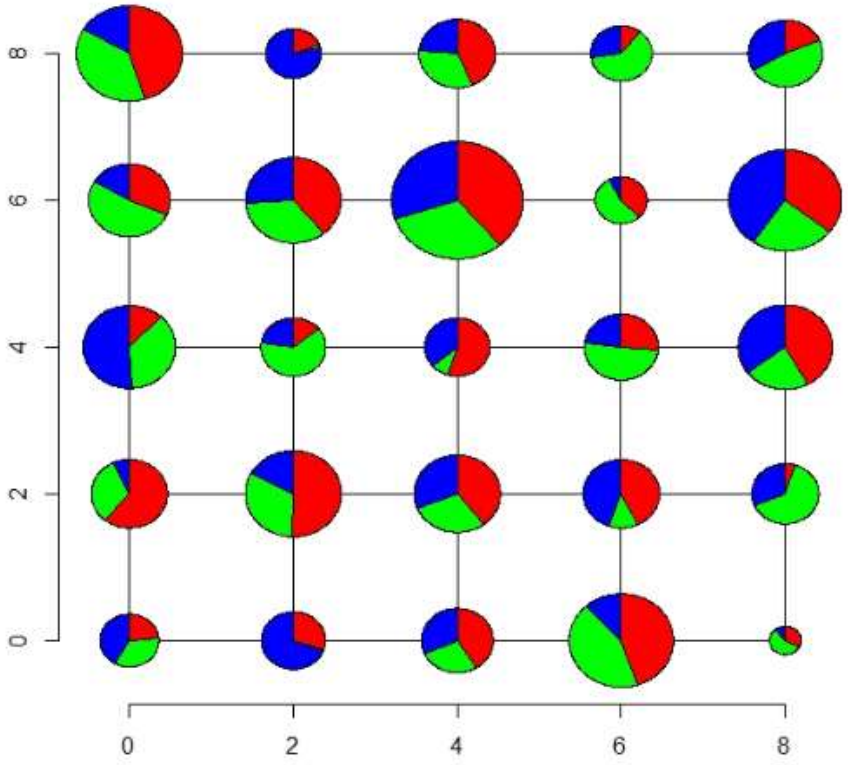
- Import/export data between GAMS and MATLAB
- Call GAMS models from MATLAB
- Get results back in MATLAB
- Gives MATLAB users the ability to use all the optimization capabilities of GAMS



- 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

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



Source: http://blog.modelworks.ch

- More information: http://support.gams.com/doku.php?id=gdxrrw:interfacing_gams_and_r

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;
```

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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

Solvelink 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

trnsport.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)
Solvelink=%Solvelink.ChainScript%	52.221
Solvelink=%Solvelink.CallModule%	37.366
Solvelink=%Solvelink.LoadLibrary%	03.252

Gather-Update-Solve-Scatter (GUSS)

Setting	Solve time (secs)
Solvelink=%Solvelink.ChainScript%	52.221
Solvelink=%Solvelink.CallModule%	37.366
Solvelink=%Solvelink.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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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, …
- TRIcclib, TRIdclib, TRIfclib
  - 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