Algebraic Modeling Past, Present and Future

Michael Bussieck mbussieck@gams.com

Alex Meeraus ameeraus@gams.com

Franz Nelissen fnelissen@gams.com

GAMS Software GmbH

www.gams.com

Model Structure

4 (c) Regional farmer employment accounting rows:

$$-RESr + 3 \sum_{d \in r} \sum_{q} dFLq + \sum_{d \in r} \sum_{t} dFLt = 0, \qquad \text{each } r$$

$$-\begin{bmatrix}\text{Regional farmer}\\ \text{employment}\\ \text{activity}\end{bmatrix} + 3\begin{bmatrix}\text{Sum over districts}\\ \text{and quarters of}\\ \text{quarterly farmer}\\ \text{employment}\end{bmatrix}^{37} + \begin{bmatrix}\text{Sum over districts}\\ \text{and months of}\\ \text{monthly farmer employment}\end{bmatrix}^{37} = 0$$

1 (d) Total employment accounting row in man-years:

$$-12LMAN + \sum_{t} LMANt = 0$$

$$-12\begin{bmatrix}\text{Total employment}\\ \text{in man-years}\end{bmatrix} + \begin{bmatrix}\text{Sum over months of}\\ \text{total employment}\\ \text{in man-months}\end{bmatrix} = 0$$

12 (e) Total monthly employment accounting rows in man-months:

$$-2.2LMANt + \sum_{d} dDLt + \sum_{d} dFLq + \sum_{d} dFLt = 0,$$

each t and q such that $t \in q$

$$-2.2\begin{bmatrix}\text{Total}\\ \text{employment}\\ \text{in month } t\end{bmatrix}^{38} + \begin{bmatrix}\text{Sum over districts of}\\ \text{day labor employment}\\ \text{in month } t\end{bmatrix}$$

$$+\begin{bmatrix}\text{Sum over districts of}\\ \text{quarterly farmer}\\ \text{employment in the}\\ \text{quarter containing}\\ \text{month } t\end{bmatrix} + \begin{bmatrix}\text{Sum over districts}\\ \text{of monthly farmer}\\ \text{employment}\end{bmatrix} = 0$$

[37] In irrigation districts the quarterly contract device is used for farmers, but in non-irrigated districts farmers are assumed to be available on a monthly basis, so that seasonal migration to irrigated areas may occur.

[38] The activities for hiring farmers and day laborers are stated in units of tens of man-days per month (or quarter), and there are 22 working days per month; hence the conversion factor of 2.2 is required in the first term of this equation.

Model Data

Table 3

Sequence of standard operations for cotton cultivation (days of unskilled labor, machinery services, and draft animal services required per hectare by month)

Cultivation month and operation		Mechanized		Partially mechanized			Non-mechanized	
		Unskilled labor	Machinery	Unskilled labor	Machinery	Animals	Unskilled labor	Animals
1st	Preparatory tasks		0.12		0.12		1.0	2.0
	Fallow		0.5		0.5		3.0	6.0
	Cross-plowing						2.5	5.0
	Harrowing		0.2		0.2		0.5	1.0
	Land levelling		0.25		0.25		1.0	2.0
	Canal cleaning	1.0		1.0			1.0	
2nd	Irrigation ditches	1.0	0.2	1.0	0.2		2.0	2.0
	Forming borders [a]		0.2		0.2		2.0	
	Linking borders [b]	1.0		1.0				
	Water application	2.0		2.0			2.0	
	Harrowing		0.2		0.2		2.0	4.0
	Seeding and fertilization	0.2	0.2	0.2	0.2		4.0	
	Maintenance of field works		0.2	0.2			2.0	
3rd	Thinning plants	4.0		4.0			4.0	
	Cultivation		0.2	2.0		4.0	2.0	4.0
	Weeding	6.0		6.0			6.0	
	Applications of insecticides (2) [c]							

Matrix Generator

```
Y(248)'X(248)                                                              CUMPPB
  IF (X(248).LT.0.5.AND.X(248).GT..00) Y(248)'Z(248,1)*(1+X(248))
Y(249)'X(249)                                                              COMPIB
  IF (X(249).LT.0.5.AND.X(249).GT..00) Y(249)'Z(249,1)*(1+X(249))
Y(250)'X(250)                                                              COMNEI
  IF (X(250).LT.0.5.AND.X(250).GT..00) Y(250)'Z(250,1)*(1+X(250))
Y(251)'X(251)                                                              CUMONE
  IF (X(251).LT.0.5.AND.X(251).GT..00) Y(251)'Z(251,1)*(1+X(251))
Y(252)'X(252)                                                              CUMTWO
  IF (X(252).LT.0.5.AND.X(252).GT..00) Y(252)'Z(252,1)*(1+X(252))
Y(253)'X(253)                                                              CUMTHR
  IF (X(253).LT.0.5.AND.X(253).GT..00) Y(253)'Z(253,1)*(1+X(253))
Y(254)'X(254)                                                              COMFOU
  IF (X(254).LT.0.5.AND.X(254).GT..00) Y(254)'Z(254,1)*(1+X(254))
Y(255)'Y(266)+Y(267)                                                       CUMFIV
Y(256)'X(256)                                                              CUMLCT
  IF (X(256).LT.0.5.AND.X(256).GT..00) Y(256)'Z(256,1)*(1+X(256))
Y(257)'X(257)                                                              CUMLCG
  IF (X(257).LT.0.5.AND.X(257).GT..00) Y(257)'Z(257,1)*(1+X(257))
Y(258)'X(258)                                                              CUMDLS
  IF (X(258).LT.0.5.AND.X(258).GT..00) Y(258)'Z(258,1)*(1+X(258))
Y(259)'X(259)                                                              CU 6-
  IF (X(259).LT.0.5.AND.X(259).GT..00) Y(259)'Z(259,1)*(1+X(259))
Y(260)'X(260)                                                              C-  -
  IF (X(260).LT.0.5.AND.X(260).GT..00) Y(260)'Z(260,1)*(1+X(260))
Y(261)'Y(63)                                                               EXPORT
Y(262)'X(262)                                                              NETDII
  IF (X(262).LT.0.5.AND.X(262).GT..00) Y(262)'Z(262,1)*(1+X(262))
Y(263)'X(263)                                                              NETDFI
  IF (X(263).LT.0.5.AND.X(263).GT..00) Y(263)'Z(263,1)*(1+X(263))
Y(264)'X(264)                                                              WRKRMT
  IF (X(264).LT.0.5.AND.X(264).GT..00) Y(264)'Z(264,1)*(1-X(264))
Y(265)'X(265)                                                              NETTRN
  IF (X(265).LT.0.5.AND.X(265).GT..00) Y(265)'Z(265,1)*(1-X(265))
Y(266)'X(266)                                                              OFFCUR
  IF (X(266).LT.0.5.AND.X(266).GT..00) Y(266)'Z(266,1)*(1-X(266))
Y(267)'X(267)                                                              OFFCAP
```

Matrix Generator Input

```
   25    1    8    0    0    0    1     AGGREGAT
      0.12                0.0165
ALA ALG ALV ARO AZU CAR CEG CHV FRI GAR JIT JON MAI MAT MEL P
PLU SAL SAN SOR SOT SOY TRI
    0.0286
     99999
AZU AZU    -0.25      1.0        0.0070     2627020.
JIT JIT    -0.4       1.0        0.1150     174752.
PEP PEP    -0.6       1.0        0.0590     19.
PLU PLU    -1800.     1.0        0.5770     85209.
CCC
CHI        1     -0.2
CHV         0.1500    14.459     1.0
FOR        6     -0.3
SOR         0.0630    285.818    1.0
CEG         0.0930    0.665      1.0
ALV         0.0100    226.109    1.0
ALA         0.0400    179.019    1.0
GAR         0.0990    1.427      1.0
MAI         0.0860    77.997     1.0
FEC        4     -0.3
FRI         0.1830    33.001     1.0
ARO         0.1220    126.197    1.0
PAP         0.0930    27.138     1.0
GAR         0.0990    0.158      1.0
GRA        2     -0.1
MAI         0.0860    132.804    1.0
TRI         0.0800    343.979    1.0
FRU        2     -2.0
SAN         0.0780    10.850     1.0
MEL         0.0680    6.9350      1.0
OLE        4     -1.2
SAL         0.0830    193.910    1.0
JON         0.2410    9.224      1.0
CAR         0.1550    72.490     1.0
SOY         0.1600    57.220     1.0
END
ALA         .02       0.0
```

MPS File – Column Section

```
X,ASGHC2   B,AS,,C2       -1,00000
X,ASGHC2   A,TRA           6,98400
X,ASGHC3   D,,,GH,N        0,33500
X,ASGHC3   R,,,GHC3        1,00000
X,ASGHC3   B,AS,,C3       -1,00000
X,ASGHC3   A,TRA           6,98400
X,ASGHAS   D,,,GH,N        0,20600
X,ASGHAS   R,,,GHAS        1,00000
X,ASGHAS   B,AS,,AS       -1,00000
X,ASGHAS   A,TRA           6,98400
X,ASGHS1   D,,,GH,P        0,15000
X,ASGHS1   R,,,GHS1        1,00000
X,ASGHS1   B,AS,,S1       -1,00000
X,ASGHS1   A,TRA           6,98400
X,ASGHCN   R,,,GHCN        1,00000
X,ASGHCN   B,AS,,CN       -1,00000
X,ASGHCN   A,TRA           6,98400
X,ASKSC1   D,,,KS,N        0,26000
X,ASKSC1   R,,,KSC1        1,00000
X,ASKSC1   B,AS,,C1       -1,00000
X,ASKSC1   A,TRA           7,56000
X,ASKSC2   D,,,KS,N        0,31000
X,ASKSC2   R,,,KSC2        1,00000
X,ASKSC2   B,AS,,C2       -1,00000
X,ASKSC2   A,TRA           7,56000
X,ASKSC3   D,,,KS,N        0,33500
X,ASKSC3   R,,,KSC3        1,00000
X,ASKSC3   B,AS,,C3       -1,00000
X,ASKSC3   A,TRA           7,56000
X,ASKSAS   D,,,KS,N        0,20600
X,ASKSAS   R,,,KSAS        1,00000
X,ASKSAS   B,AS,,AS       -1,00000
X,ASKSAS   A,TRA           7,56000
X,ASKSS1   D,,,KS,P        0,15000
X,ASKSS1   R,,,KSS1        1,00000
X,ASKSS1   B,AS,,S1       -1,00000
X,ASKSS1   A,TRA           7,56000
X,ASKSCN   R,,,KSCN        1,00000
X,ASKSCN   B,AS,,CN       -1,00000
```

MPS Revision File

```
BRANCH     *          MAJERR

NEXT

REVISE     REV5       TAPE14

                                 ***** CARD READ SUMMARY ****

HEADER, CARD NO.     1     ØNAME          REVA
HEADER, CARD NO.     2     ØCOLUMNS
HEADER, CARD NO.     3     Ø  MODIFY
HEADER, CARD NO.     6     ØRHS
HEADER, CARD NO.     7     Ø  MODIFY
HEADER, CARD NO.    18     ØENDATA
HEADER, CARD NO.    19     ØNAME          REV1
HEADER, CARD NO.    20     ØCOLUMNS
HEADER, CARD NO.    21     Ø  MODIFY
HEADER, CARD NO.    42     ØENDATA
HEADER, CARD NO.    43     ØNAME          REV2
HEADER, CARD NO.    44     ØCOLUMNS
HEADER, CARD NO.    45     Ø  MODIFY
HEADER, CARD NO.    51     ØENDATA
HEADER, CARD NO.    52     ØNAME          REV4
HEADER, CARD NO.    53     ØRHS
HEADER, CARD NO.    54     Ø  MODIFY
HEADER, CARD NO.    68     ØENDATA
HEADER, CARD NO.    69     ØNAME          REV5
HEADER, CARD NO.    70     ØRHS
HEADER, CARD NO.    71     Ø  MODIFY
        CARD NO.    72     Ø     RHS1     CLA,V,01      5,03328
        CARD NO.    73     Ø     RHS1     CLA,V,02      5,03328
        CARD NO.    74     Ø     RHS1     CLA,V,03      5,03328
        CARD NO.    75     Ø     RHS1     CLA,V,04      5,03328
        CARD NO.    76     Ø     RHS1     CLA,V,05      5,03328
        CARD NO.    77     Ø     RHS1     CLA,V,06      5,03328
        CARD NO.    78     Ø     RHS1     CLA,V,07      5,03328
        CARD NO.    79     Ø     RHS1     CLA,V,08      5,03328
        CARD NO.    80     Ø     RHS1     CLA,V,09      5,03328
        CARD NO.    81     Ø     RHS1     CLA,V,10      5,03328
        CARD NO.    82     Ø     RHS1     CLA,V,11      5,03328
        CARD NO.    83     Ø     RHS1     CLA,V,12      5,03328
        CARD NO.    84     Ø     RHS1     CLA,V,TO     60,39936
HEADER, CARD NO.    85     ØENDATA
```

MPS Output

DATE 07/30/76 TIME 22.12.21   C O L U M N S   APEX-III 1.000 PAGE

PRINT OPTION = COMPLETE OUTPUT W/SPECIAL

NAME = CENTRAL   OBJ = OBJ   RHS = RHS1   BND = LIMITS   TIVE = 28.18489

DIR = MAXIMIZE   COBJ =   CRHS =   RNG =

1.0000 RPSRHS = 1.0000

0.0000 RPCHRMS = 0.0000

NUMBER	NAME	TYPE	STATUS	COL ACTIVITY	OBJ COEF	D UPPER	MARGINAL
101	CBE1V..	PL	LOWER	.	-47.80000	+INF	-6.46851
102	CBE2F..	PL	ACTIVE	.00087	-701.00000	+INF	.
103	CBE3C..	PL	ACTIVE	.	-10330.60000	+INF	.
104	CBE4F..	PL	LOWER	.	-2429.70000	+INF	-912.25118
105	CBE5C..	PL	LOWER	.	-9418.00000	+INF	-2342.38642
106	CBE6C..	PL	ACTIVE	.	-5118.00000	+INF	.
107	CBE7C..	PL	ACTIVE	.06067	-13.20000	+INF	.
108	CSG.V..	PL	ACTIVE	.	-231.57000	+INF	.
109	CSG.F..	PL	ACTIVE	.00226	-231.57000	+INF	.
110	CPO.V..	PL	ACTIVE	.	-139.67000	+INF	.
111	CPO.F..	PL	ACTIVE	.00002	-139.67000	+INF	.
112	CPO.C..	PL	ACTIVE	.00045	-139.67000	+INF	.
113	CEG.V..	PL	ACTIVE	.	-76.71000	+INF	.
114	CEG.F..	PL	ACTIVE	.00025	-76.71000	+INF	.
115	CEG.C..	PL	ACTIVE	.00128	-76.71000	+INF	.
116	CDA.CX.	PL	ACTIVE	.07685	12.91000	+INF	.
117	COF.CX.	PL	LOWER	.	180.74000	+INF	-87.19134
118	CDC.CX.	PL	LOWER	.	167.83000	+INF	-256.39963
119	COS.CX.	PL	ACTIVE	.06968	121.35000	+INF	.
120	COL.CX.	PL	ACTIVE	.00225	91.66000	+INF	.
121	CWS.CX.	PL	ACTIVE	.00606	109.74000	+INF	.
122	CWL.CX.	PL	ACTIVE	.00748	77.46000	+INF	.

WB Old Slide 1

PLANNING PROBLEM AND OBJECTIVES INITIALLY OFTEN

UNSTRUCTURED

ILL-DEFINED

CONFLICTING

UNCERTAIN

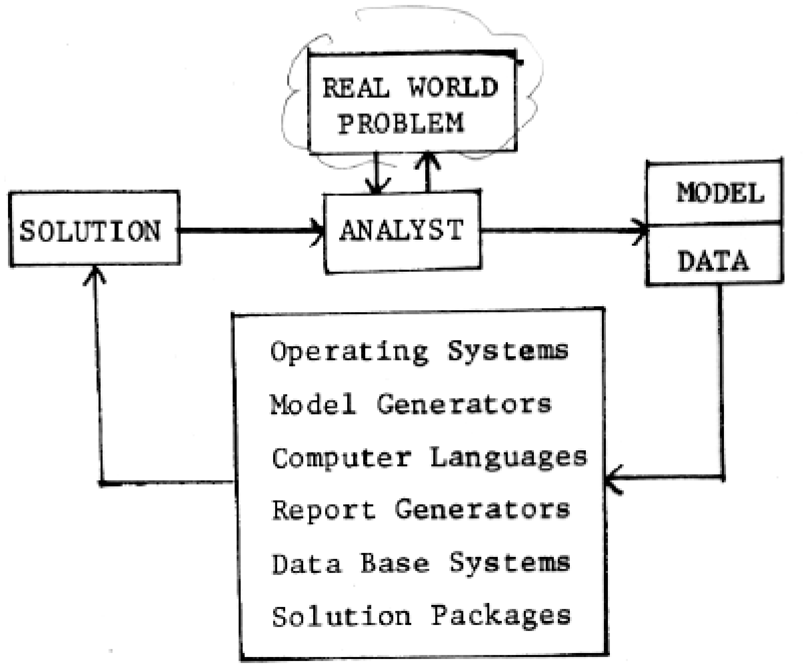
CHANGING

EMOTIONAL

MATHEMATICAL MODEL USED TO RECOGNIZE AND FORMULATE PROBLEMS, DEFINE ISSUES AND EXPLORE SOLUTION SPACE

WB Old Slide 2

PRESENT TECHNOLOGY



RESULT: - Drain of resources (technical, time, money)

- Essentially no documentation

WB Old Slide 3

MAJOR CONSTRAINTS : COST

SKILLS

TIME

TOOLS

DOCUMENTATION

TRUST

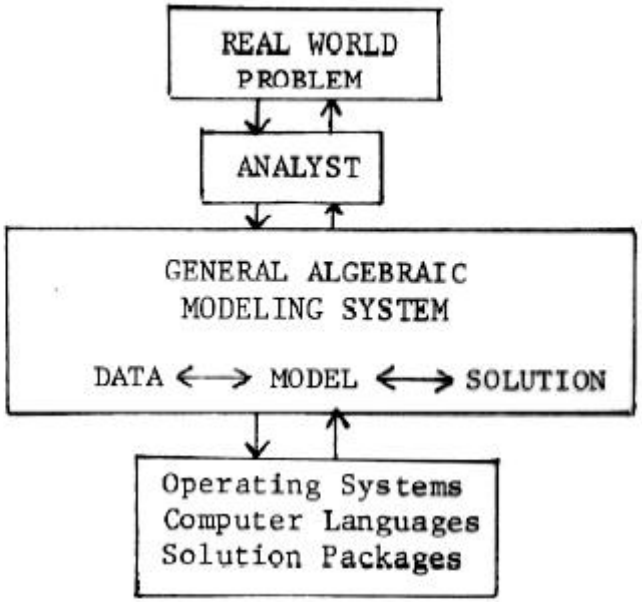
.

.

.

WB Old Slide 4

IDEAL TECHNOLOGY



RESULT: - Limited drain of resources

- Same representation of models for humans and machines
- Model representation is also model documentation

WB Old Slide 5

DEVELOPMENT OF GAMS

Phase 1 (1978)

- The system can be used to represent and analyze any algebraic model (be it linear or nonlinear)

- The system can perform algebraic manipulations on all data

- The system can generate and solve linear programs automatically

- The system can generate reports on data and solutions via simple 'display' statements

WB Old Slide 6

DEVELOPMENT OF GAMS

Phase 2 (1979)

- The system can generate and solve nonlinear programs
- The system will provide links to special-purpose algorithms for econometric problems, network problems, etc.
- Appropriate extensions to the language will be made as the need arises

WB Old Slide 7

DEVELOPMENT OF GAMS

Phase 3 (?)

- Automatic structure recognition
- Internal generation of *exact* point-derivatives
- Improved data-base design with e.g. unit analysis, and links to existing data bases
- Availability of GAMS on different machines
- World-wide availability of the system so that it can be used as a market for testing models and algorithms

Change in Focus

Computation
Past

- Algorithm limits applications
- Problem representation is low priority
- Large costly projects
- Long development times
- Centralized expert groups
- High computational cost, mainframes
- Users left out

Model
Present

- Modeling skill limits applications
- Algebraic model representation
- Smaller projects
- Rapid development
- Decentralized modeling teams
- Low computational cost, workstations
- Machine independence
- Users involved

Application
Future

- Domain expertise limits application
- Off-the-shelf graphical user interfaces
- Links to other types of models
- Models embedded in business applications
- New computing environments
- Internet/web
- Users hardly aware of model

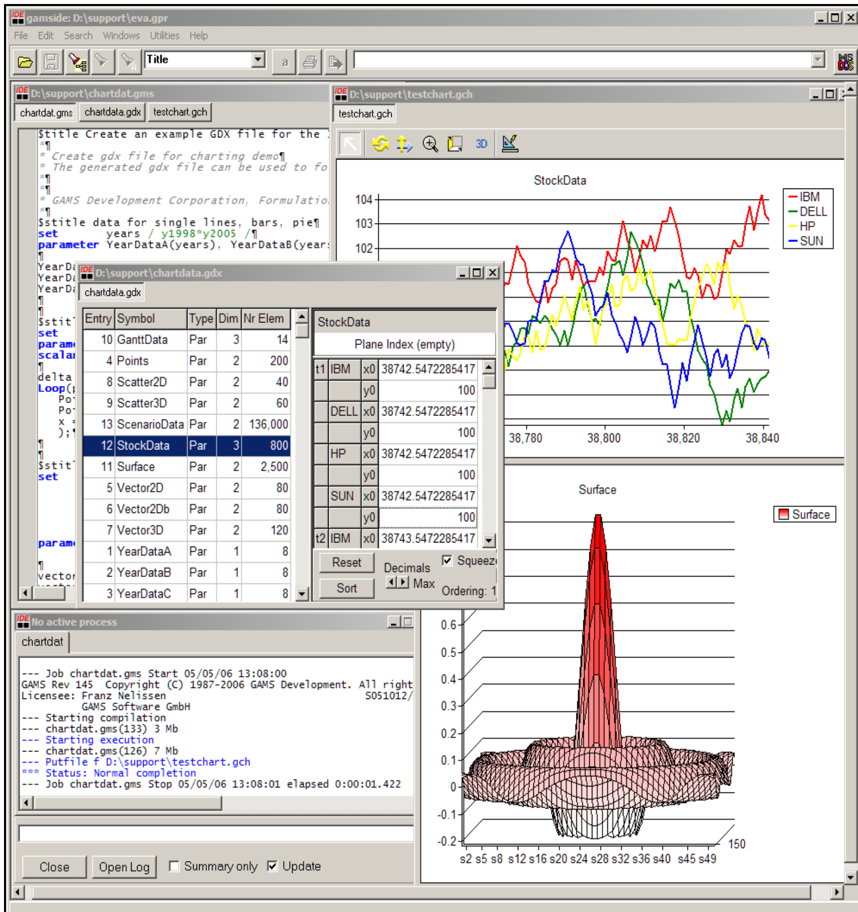
Typical GAMS User

- Successful PhD level professional in any field often outside of traditional OR
- 10 years of experience
- Wants to add value to his work by using Optimization

Who is the *User* of a Model?

- (Academic) Researcher
  - One time use (Research Paper)
- Domain&Model Expert
  - Model Results used for Consulting
- Black Box User
  - Model integrated in (Optimization) Application
- Each Category has its own needs
  - Development & Deployment

GAMS at a Glance



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

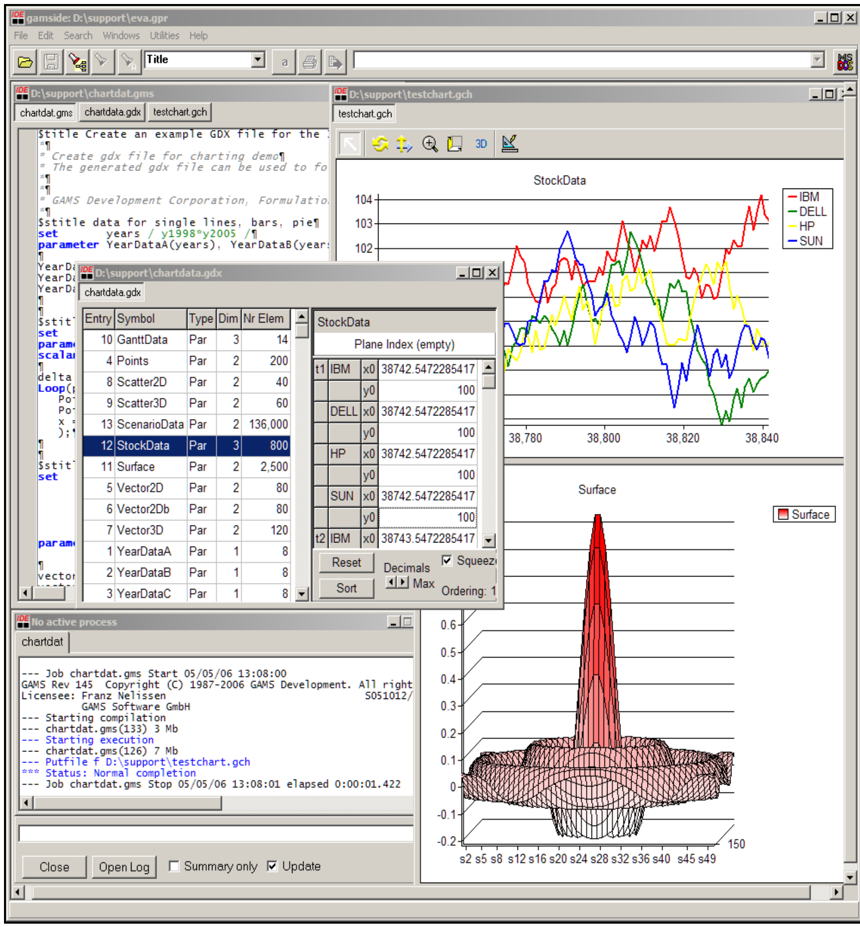
- Roots: World Bank, 1976
- Went commercial in 1987
- GAMS Development Corp.
- GAMS Software GmbH

- Broad academic & commercial user community and network

GAMS Software GmbH

- Founded 1995
- Tool Provider: Software Sales, Support, and Development, Research, Technical Consulting
- Offices at Cologne and Braunschweig
- GAMS used in 41 European Countries
- Transnational Organizations: EC, FAO, NATO, OECD, UN, WTO
- Germany:
  - More than 50% of the DAX 30 enterprises
  - The top five consulting companies
  - More than 300 academic institutes
  - 100 different universities and research institutes

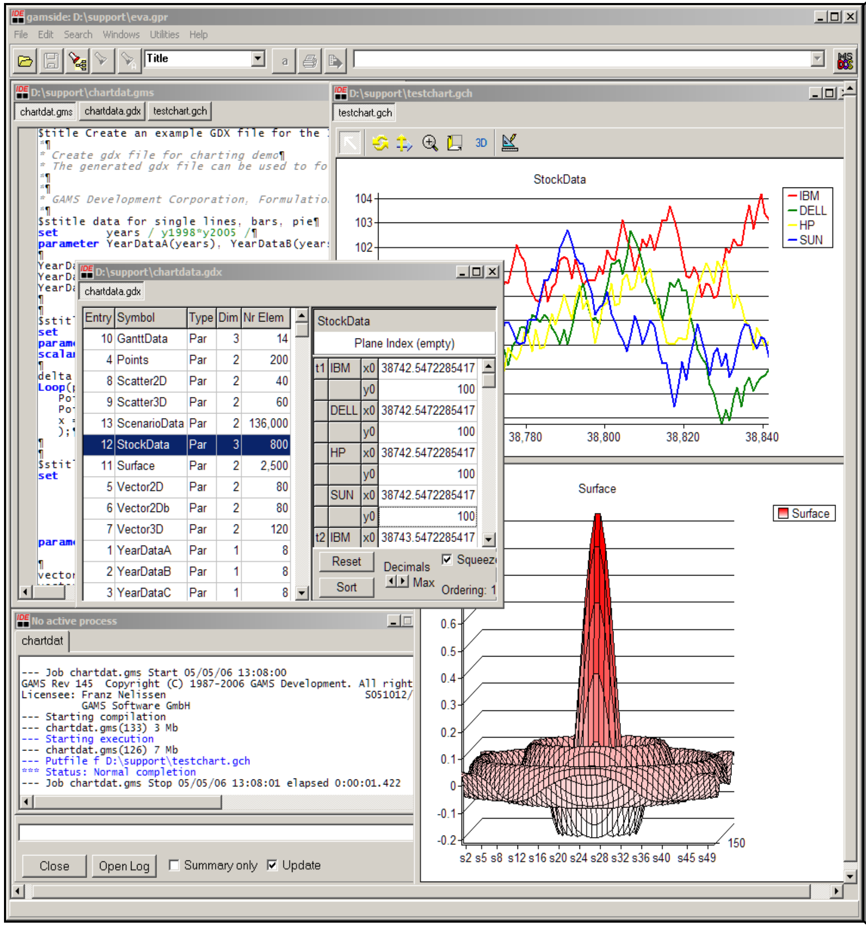
GAMS at a Glance

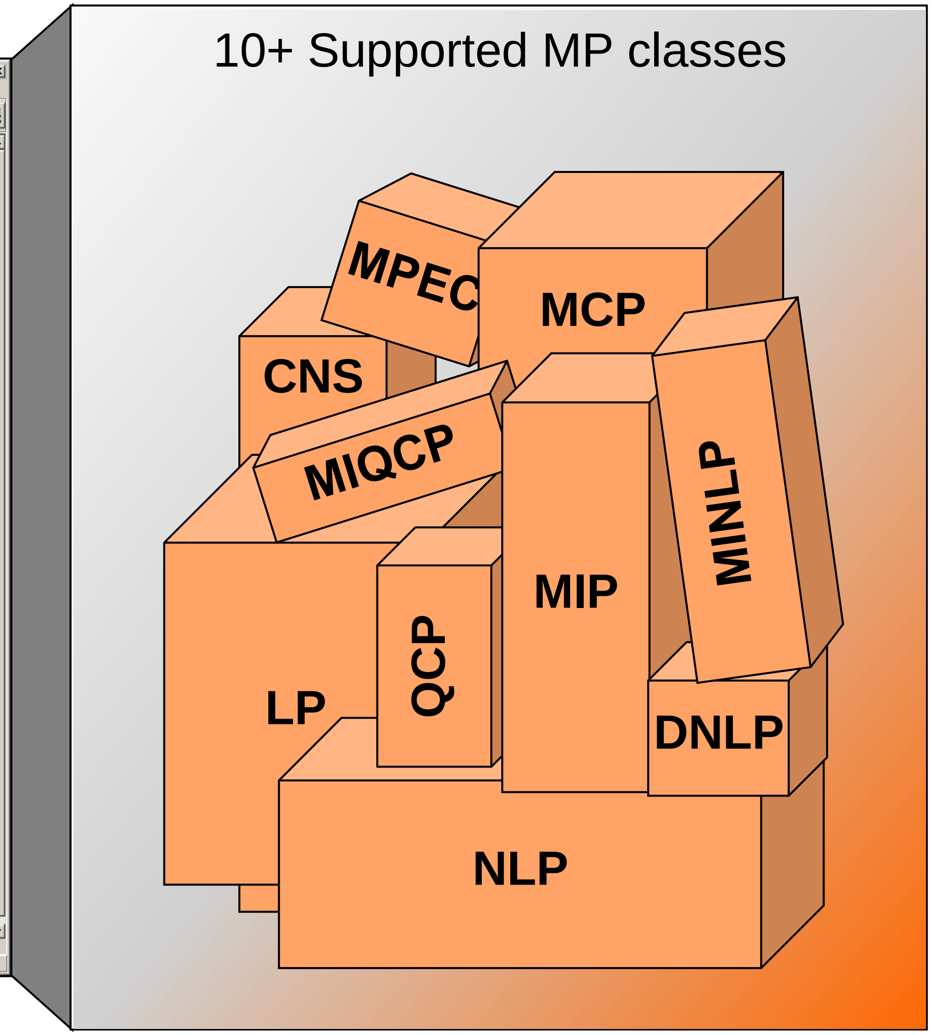


General **A**lgebraic **M**odeling **S**ystem

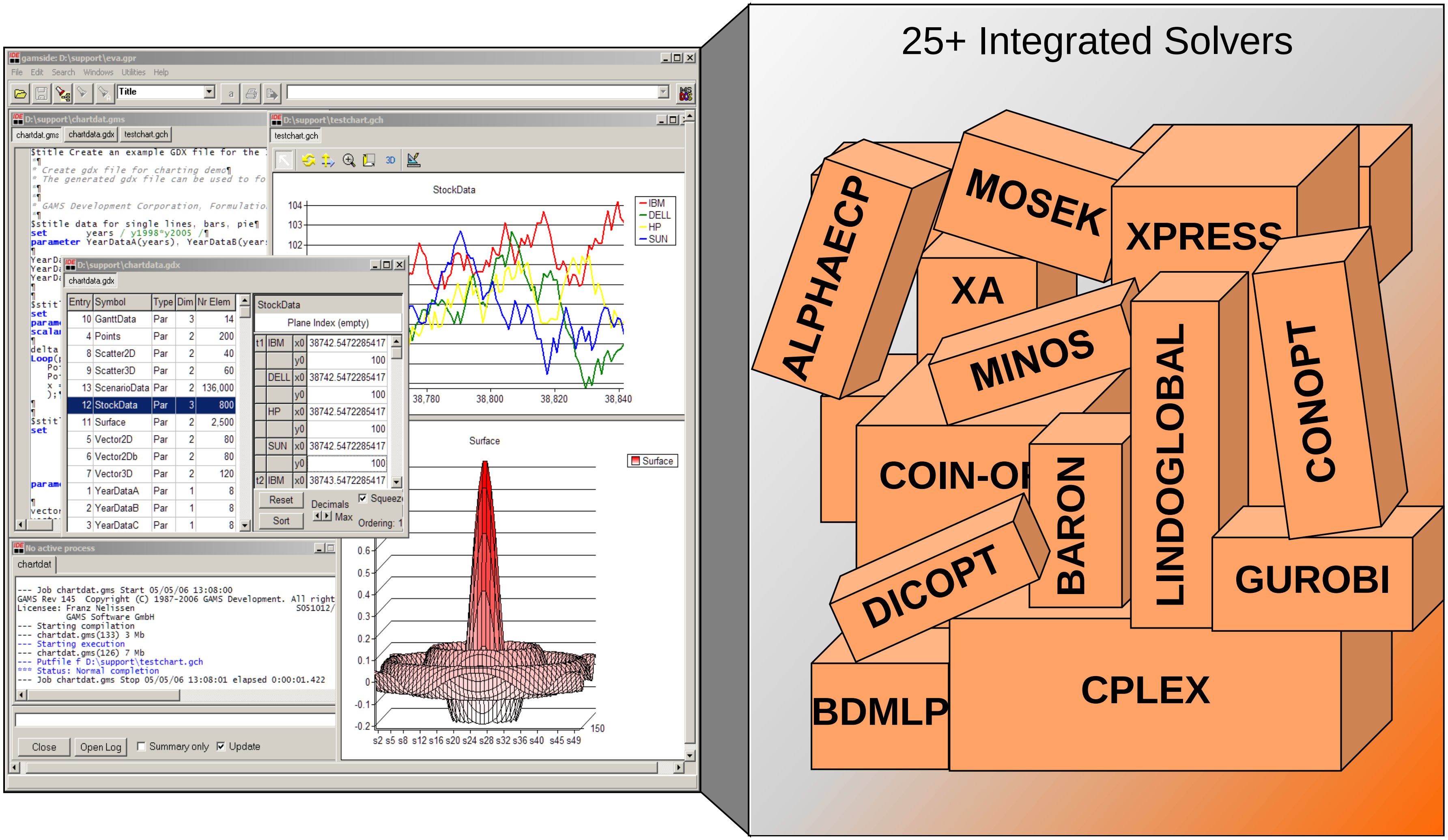
- Algebraic Modeling Language
- 25+ Integrated Solvers
- 10+ Supported MP classes
- 10+ Supported Platforms
- Connectivity- & Productivity Tools
  - IDE
  - Model Libraries
  - GDX, Interfaces & Tools
  - Grid Computing
  - Benchmarking
  - Compression & Encryption
  - Deployment System
  - …

GAMS at a Glance





GAMS at a Glance



GAMS' Fundamental concepts

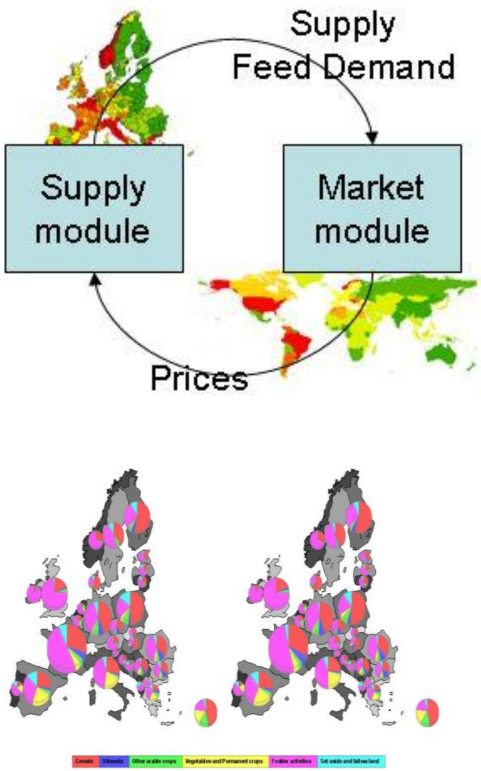
- Platform independence
- Open architecture and interfaces to other systems
- Different layers with separation of
  - model and data
  - model and solution methods
  - model and operating system
  - model and interface

Market Demands

- **Minimize Risks** for new Clients / Management:
  - Deliver (expected) Results
  - Support Rapid Prototyping
  - Increase Productivity
  - Do not lock user into a certain environment
- **Provide cutting edge technology:** Models and users must benefit from:
  - Changing environments (Hardware, OS, GUI)
  - Enhanced / new modeling & solver technology
  - Improved / new interfaces to other systems
- **Protect user investments**: Deployed models often have 15+ years lifecycle

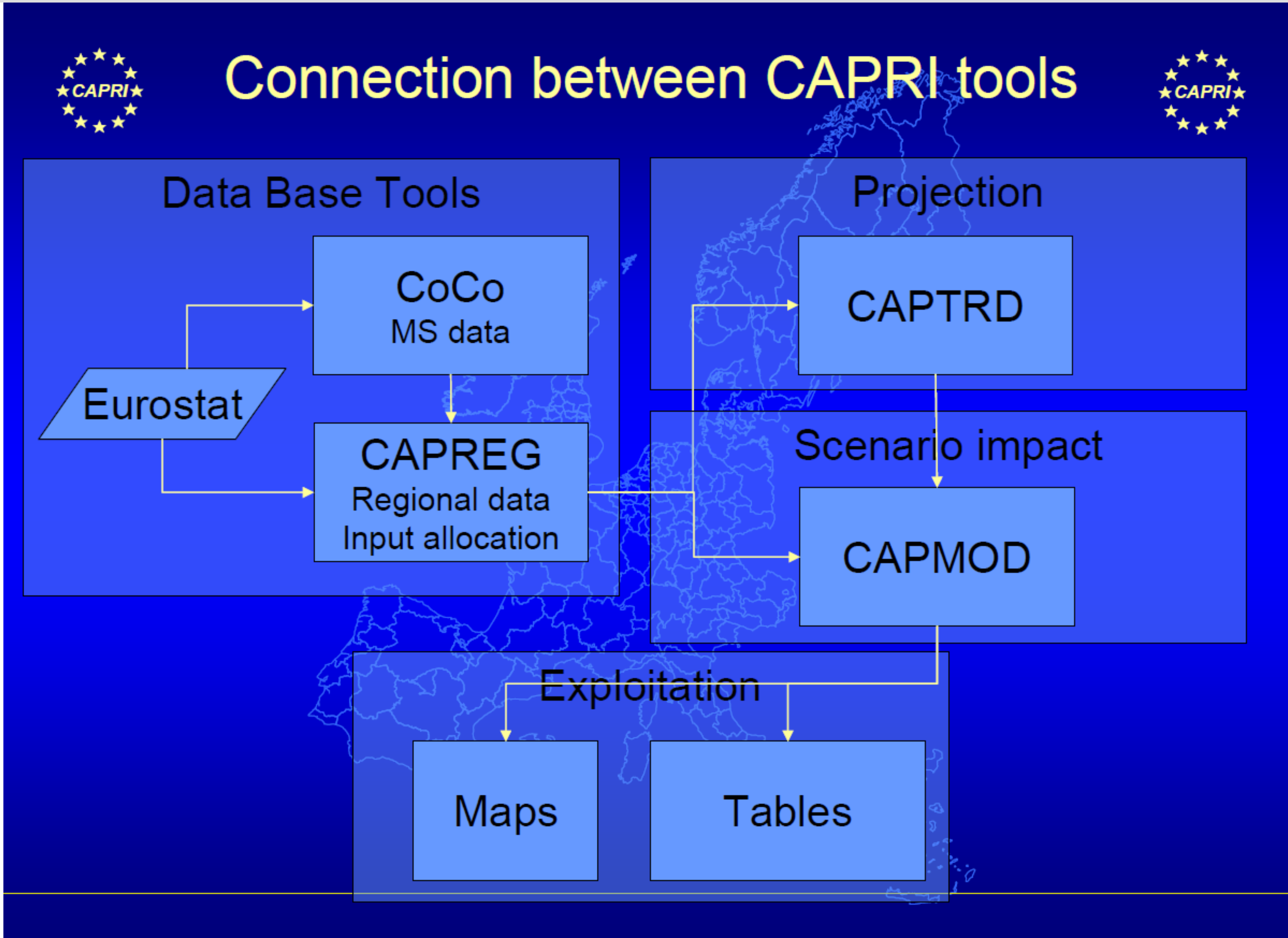
Dissemination of OR into other fields I

Common Agricultural Policy Regional Impact Analysis (CAPRI)



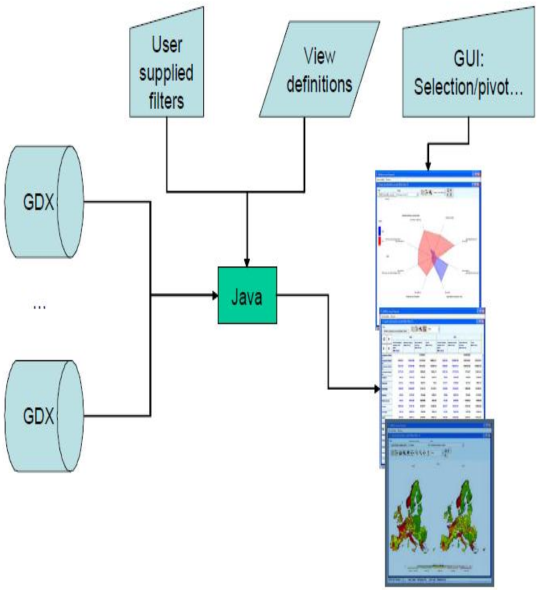
- A global agricultural sector model system with focus on 27 countries of the European Union and Norway
- Covers agricultural production in 18 trade blocks and about 250 regions
- Evaluates regional and aggregate impacts of trade policies on production, income, markets, trade and environment
- Used by network of ~ 37 research institutions and EU Commission services

CAPRI



CAPRI
Connection between CAPRI tools
CAPRI
Data Base Tools
CoCo
MS data
Eurostat
CAPREG
Regional data
Input allocation
Projection
CAPTRD
Scenario impact
CAPMOD
Exploitation
Maps
Tables

CAPRI – Some Technical Aspects



- System bridged several generations of GAMS, solvers, hardware, platforms, and GUIs.
- System includes both large scale
  - Non linear Problems
  - Mixed Complementarity Problems
- Distributed Model Code, Databases and User Communities
- Java based GUI (Reports / GIS)
- Coordinated by the Institute for Food and Resource Economics, University of Bonn (Wolfgang Britz)

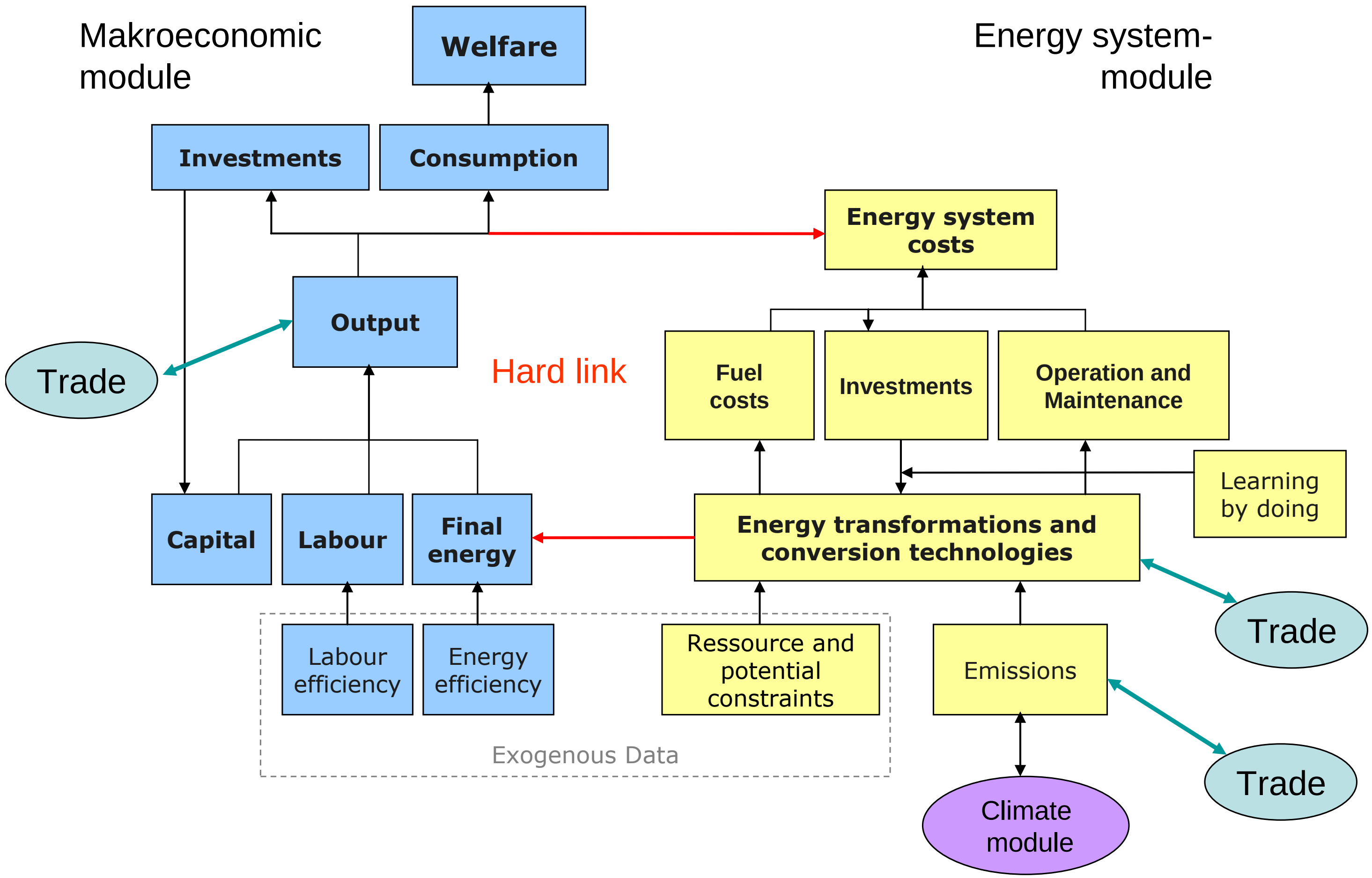
Dissemination of OR into other fields II

REMIND-R by Potsdam Institute for Climate Impact Research (PIK)

- A global energy-economy climate model in a multi-regional setting
- 11 world regions and 7 types of traded energy (incl. emission rights)
- Climate policy analysis:
  - Business as usual
  - Different climate policies
- Combines complex optimization and simulation models
- Developed by group of experts from different fields
- Model documentation, code and data available
- Coordinated by Marian Leimbach (PIK)

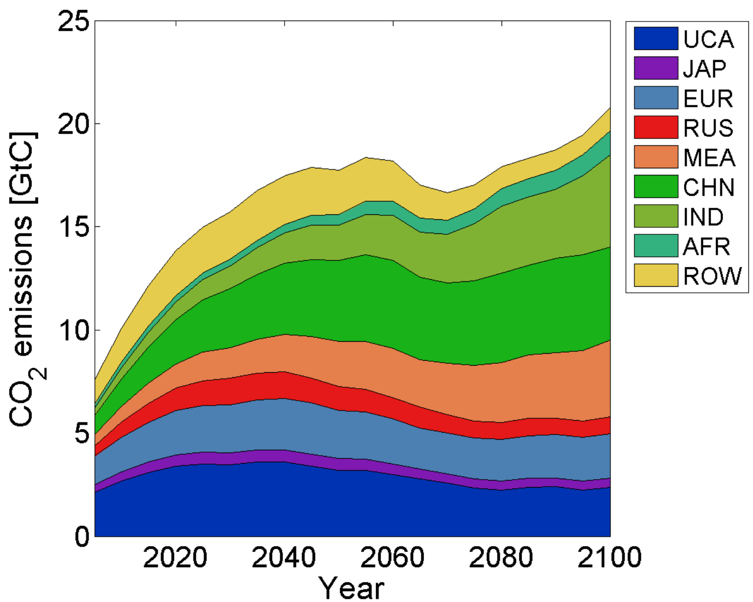
GAMS

REMIND-R

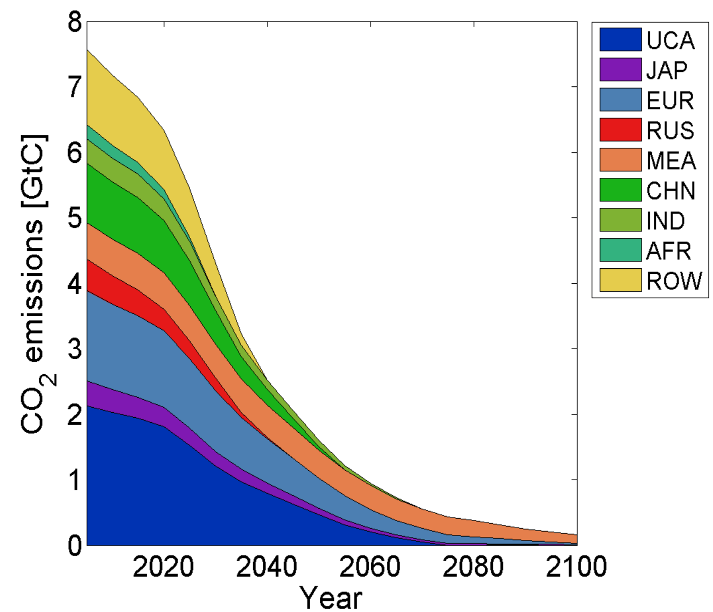


CO_2 - Emissions

Reference scenario



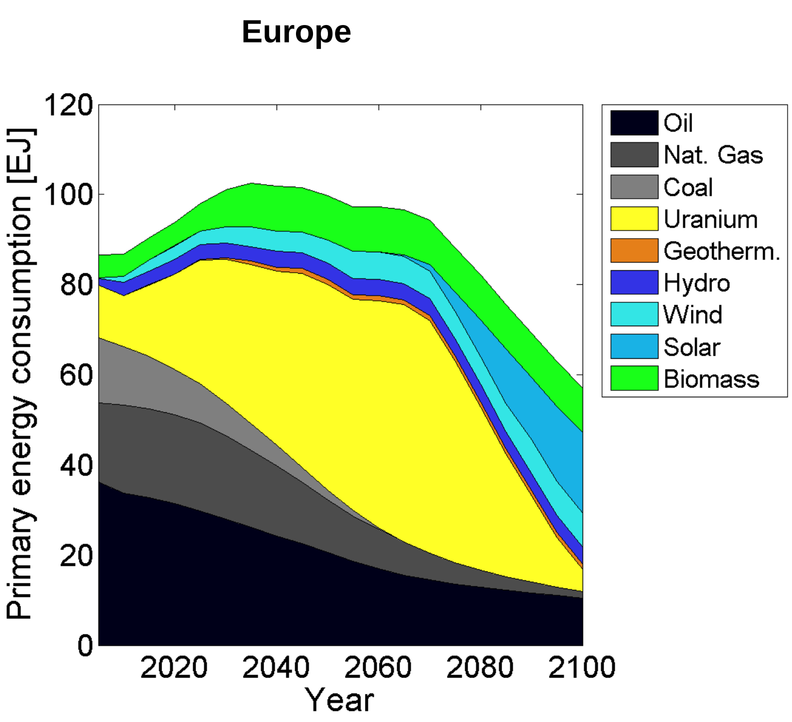
Policy scenario

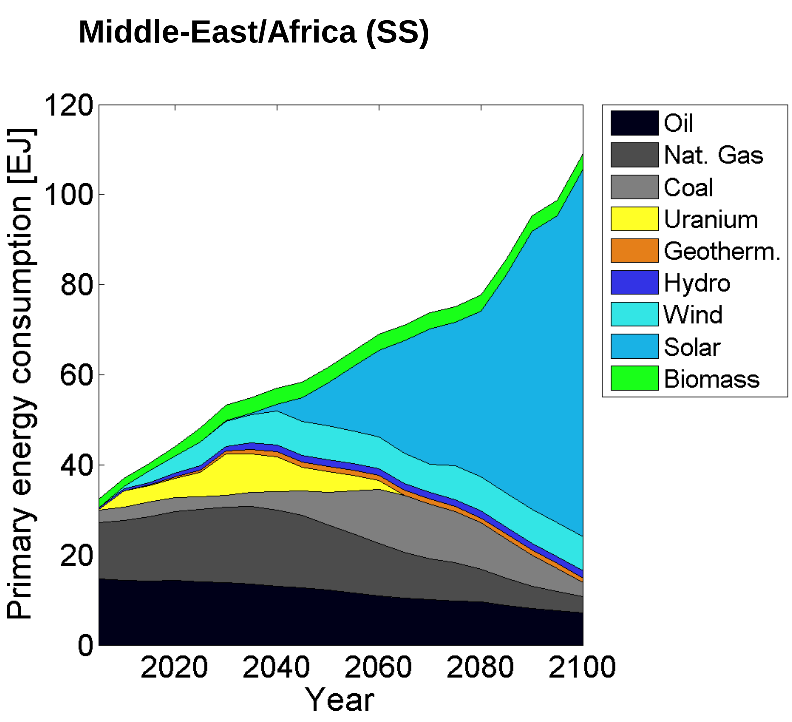


Reaching a 2°C target requires a fast and drastic decrease of emissions of all regions:

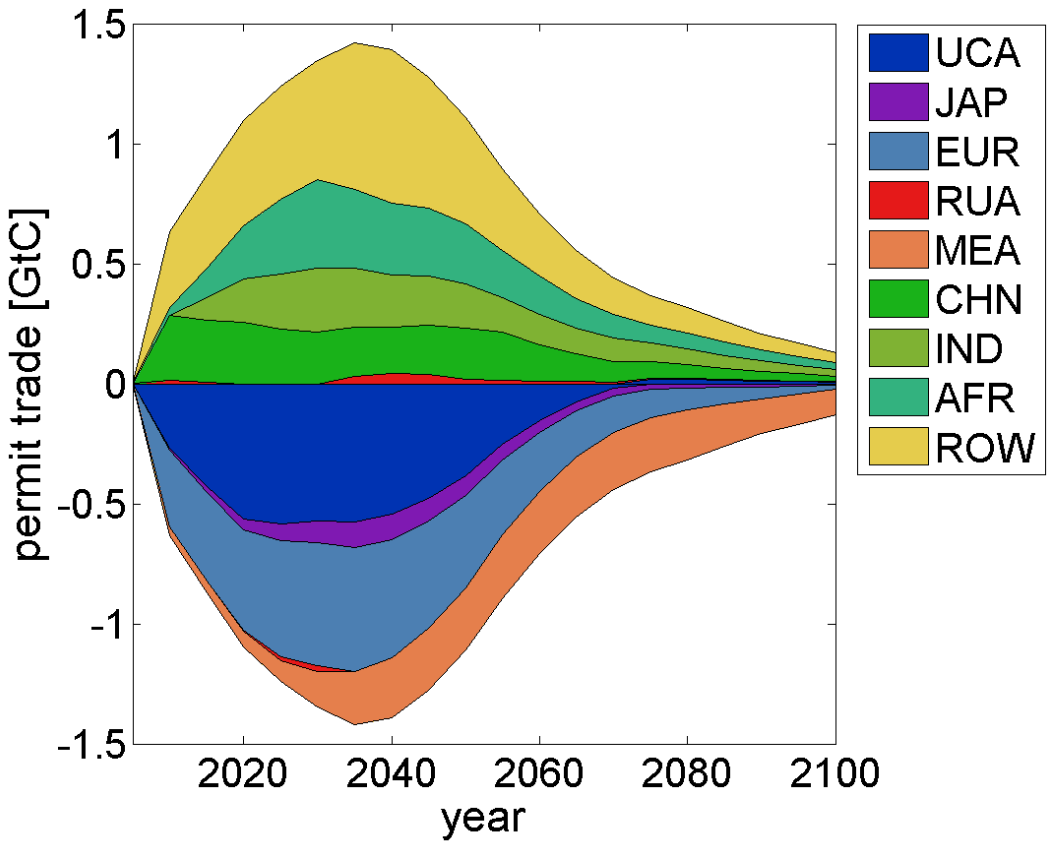
- 50% until 2035
- 78% until 2050

Primary energy production (regional)





Trading of Emission Rights



R&D at GAMS

- 30% of revenue invested in R&D
- Product Development
- Research with academic & commercial partners
  - Emerging technologies (5-15 years)
    - Computing (grid, cloud, parallel, …)
    - Mathematics/Algorithms
    - Modeling
  - Dissemination of technology from academia/research labs to clients

GAMS

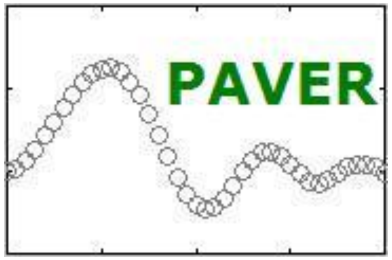
R&D at GAMS

- GAMS is a platform for
  - implementing research ideas quickly
  - assuring quality to achieve commercial strength software
  - deploying at minimal cost and risk to the user

Global Optimization

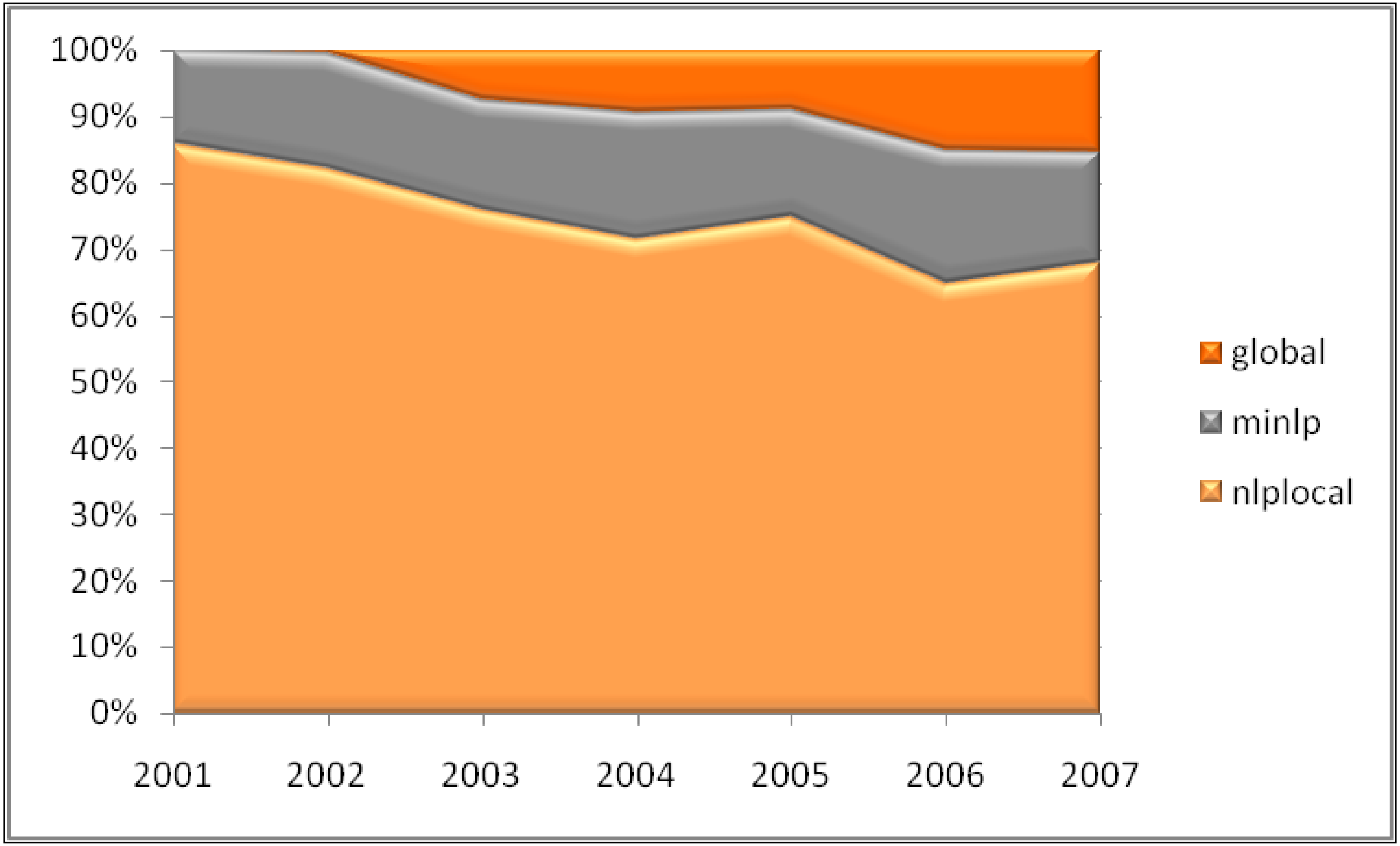
- Various research codes for Global Optimization: BARON, LGO, OQNLP, LindoGlobal
- Deterministic GO codes need more than function and gradient values (provide algebra to the solver)
- Establish quality assurance procedures and test model libraries

- Performance testing (set expectations right)



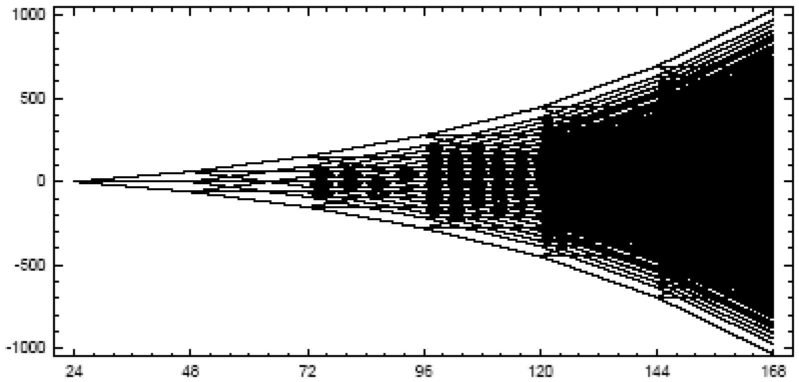
Performance **A**nalysis and **V**isualization for **E**ffortless **R**eproducibility

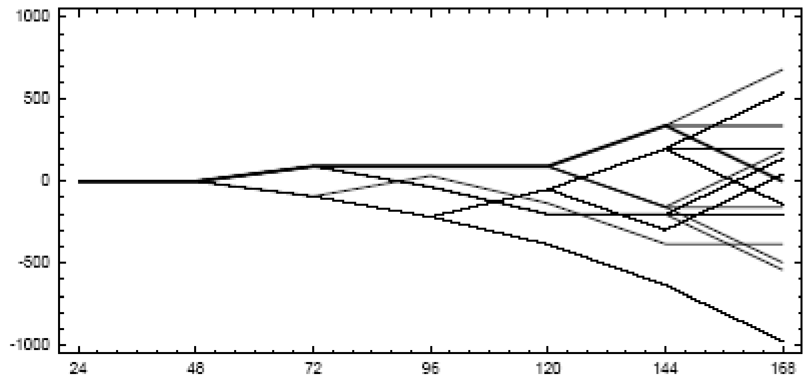
Relative Sales of Global Optimization



ScenRed

- Prof. Römisch et. al. at HU Berlin
- Stochastic Optimization
- Scenario reduction aims to reduce the number of scenarios and to maintain the probability information as good as possible





GAMS

ScenRed

- ScenRed helps reducing the size of stochastic linear programs so they can be solved by today's LP technology.
- Seamless integration into GAMS

C:\Documents and Settings\bussieck\Desktop\OR2010\myspmodel.gms

myspmodel.gms

```
objective..
profit =e= sum(nodes, prob(nodes)*(revenue(nodes)-cost(nodes));

Model myspmodel / all /;

solve myspmodel maximizing profit using lp;

$batinclude runscenred2 myspmodel scen_red nodes anc prob price

solve myspmodel maximizing profit using lp;
```

Extended Mathematical Programming (EMP)

- Extended Nonlinear Programs
- Embedded Complementarity Systems
- Bilevel Programs
- Disjunctive Programs
- …

  - Breakouts of traditional MP classes
  - No conventional syntax
  - Limited support with common model representation
  - Incomplete/experimental solution approaches
  - Lack of reliable/any software

Hierarchical Models

- Bilevel Program:

$$\begin{aligned} \min_{x,y} \quad & f(x,y) \\ \text{s.t.} \quad & g(x,y) \leq 0, \\ & y \text{ solves } \min_{s} v(x,s) \text{ s.t. } h(x,s) \leq 0 \end{aligned}$$

- Additional Information:

```
$onecho  > %emp.info%
Bilevel x min v h
$offecho
```

- EMP Tool automatically creates an MPEC by expressing the lower level optimization problem through its optimality conditions

Model Users & Model Use

Solution Technology

Researcher

Model used to write Research Paper/Thesis

Model Management

Domain Expert

Combining models and algorithms to find answers for problems in the application domain

IT APIs

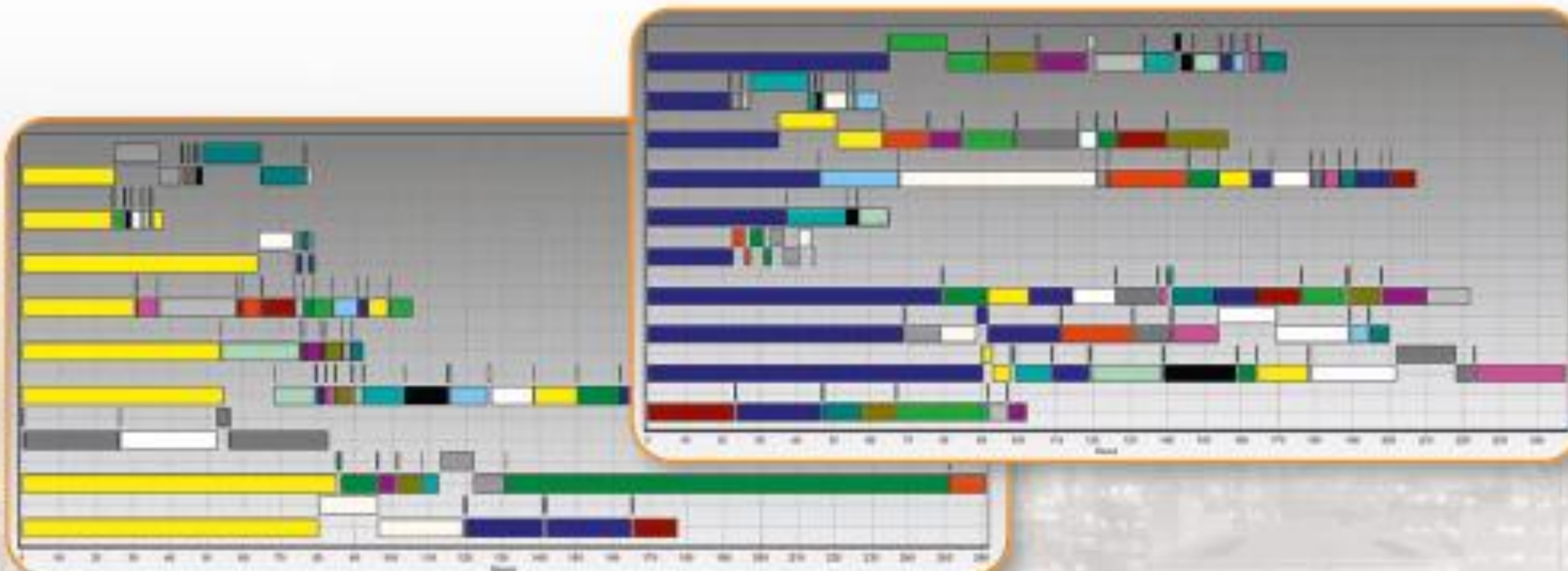
Black Box

"Innocent" user of sophisticated optimization based approaches

Scheduling and Planning at BASF

Close cooperation between logistics, information services and the scientific computing group of BASF, Prof. Dr. C. A. Floudas (Princeton University), Dr. A. V. Eremeev and Dr. P. A. Borisovski (Omsk Branch of Sobolev Institute of Mathematics SB RAS), SAP AG, and Mathesis GmbH led to a number of successfully deployed applications based on exact and hybrid optimization techniques. One of the results is a novel modeling approach of batch and continuous plants:

- State-task network formulation resulting in mixed-integer linear program
- Unit-specific, event-specific continuous-time formulations
- Hybrid methods and decomposition schemes to handle large instances
- Tight lower bounds derived from auxiliary models
- Implementation in GAMS with parallel GAMS/CPLEX
- New interfacing technology and integration approaches to connect to SAP-APO
- Used on a daily basis to improve planning and scheduling



Distributed Models – Distributed Modelers

Planning & Scheduling at BASF

Floudas,
Princeton

Decomposition of MIP model for state-task model formulations

Polyletic Modeling

Kallrath
BASF

Hybrid Methods

MIP & Local Search

Eremeev/Borisovski
Sobolev Inst., Omsk

Kallrath/Schreieck
BASF Scientific
Computing Group
Ludwigshafen

Planning and Scheduling for batch and continuous plants

BASF IS, SAP,
Mathesis

SAP/APO Interface

Thank you !

Europe

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

Phone: +49 221 949 9170
Fax: +49 221 949 9171

http://www.gams.com
info@gams.de
support@gams.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