Quality Assurance and Global Optimization

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Introduction

- Background and Motivation
- Global Optimization with GAMS
  - Available solvers
  - Issues specific to global optimization codes
- Framework for reliability and performance testing
- Example application

GAMS Overview

- Started as a Research Project at the World Bank 1976

- GAMS went commercial in 1987

- Opened European Office in Cologne, Germany 1996

- 10,000s of users in over 100 countries

- Unique position between the academic and commercial world

Basic Principles

- Separation of model and solution methods
- Model types
  - LP, MIP, **NLP**, **MINLP**, MCP, MPEC
  - Stochastic Programming, MPSGE
- Multiple solvers
- Computing platform independence

Supported Solvers

BDMLP	LP solver that comes with any GAMS system
CONOPT	Large scale NLP solver from ARKI Consulting and Development
CPLEX	High-performance LP/MIP solver from Ilog
DECIS	Large scale stochastic programming solver from Stanford University
DICOPT	Framework for solving MINLP models. Needs both an NLP solver and a MIP solver. From Carnegie M
MILES	MCP solver from University of Colorado at Boulder that comes with any GAMS system
MINOS	NLP solver from Stanford University
MPSGE	Modeling Environment for CGE models from University of Colorado at Boulder
OSL	High performance LP/MIP solver from IBM
OSLSE	OSL Stochastic Extension for solving stochastic models
PATH	Large scale MCP solver from University of Wisconsin at Madison
SBB	Branch-and-Bound algorithm from ARKI Consulting and Development for solving MINLP models, requi
SNOPT	Large scale SQP based NLP solver from Stanford University
XA	Large scale LP/MIP system from Sunset Software
XPRESS	High performance LP/MIP solver from Dash

Beta Solvers

GAMS

Beta Solvers

BARON	Branch-And-Reduce Optimization Navigator for proven global solutions from The Optimization Firm
CONVERT	Frame work for translating models into scalar models of other languages
LGO	Lipschitz global optimizer from Pinter Consulting Services
MOSEK	Large scale LP/MIP plus conic and convex non-linear programming system from EKA Consulting
NLPEC	MPEC to NLP translator that uses other GAMS NLP solvers
OQNLP	Multi-start method for global optimization from Optimal Methods Inc.
PATHNLP	Large scale NLP solver for convex problems from University of Wisconsin at Madison

Contributed Plug&Play Solvers

AMPLwrap	Framework for using AMPL solver for GAMS models
DEA	Large scale Data Envelop Analysis Solver from University of Wisconsin at Madison
Kestrel	Framework for using remote NEOS solvers with a local GAMS system
QPwrap	Quadratic programming in GAMS

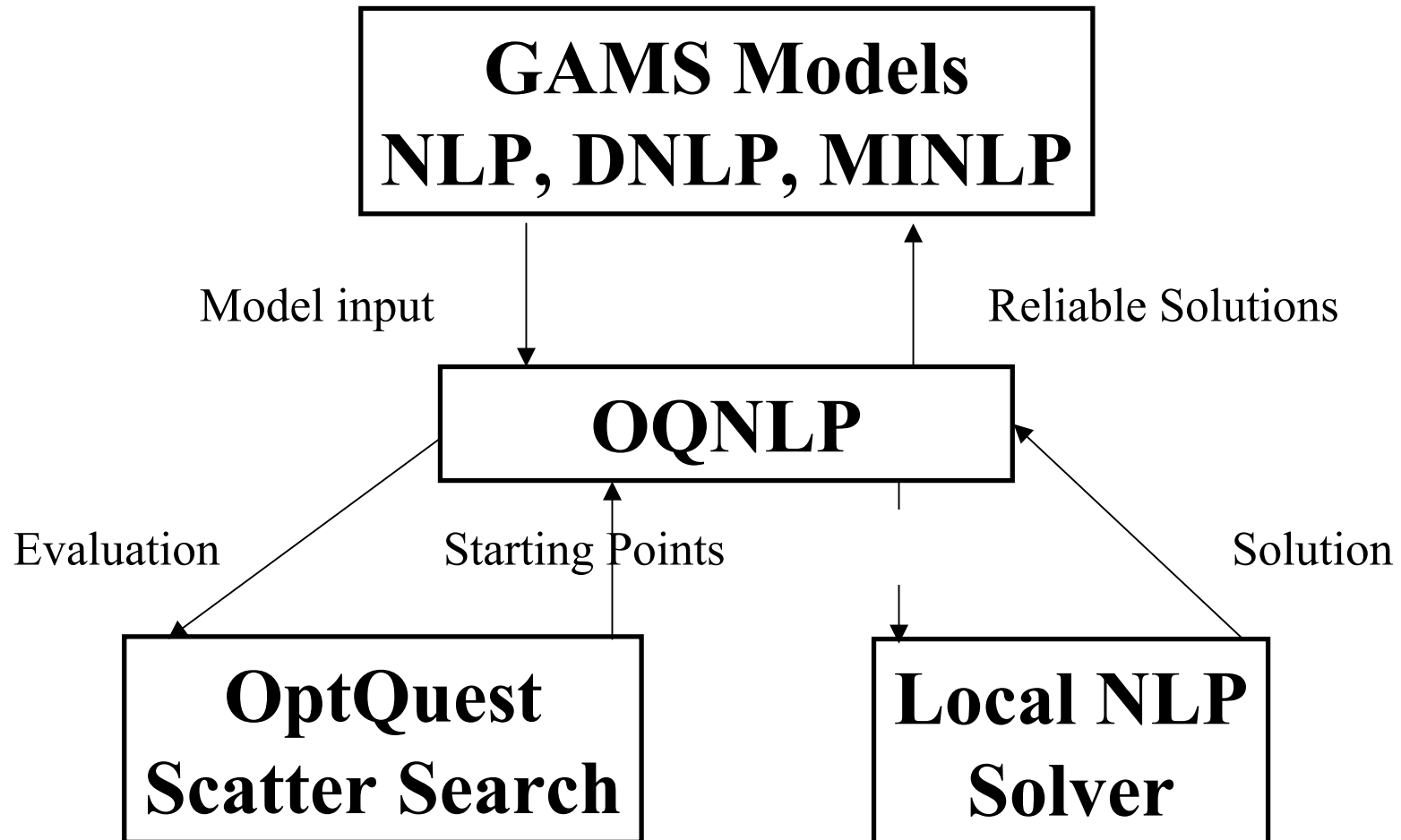# **Supported Platforms**

Solver/Platform availability - 20.7 June 14, 2002							
	Intel		Sun Sparc	HP 9000	DEC Alpha	IBM RS-6000	SGI
	Windows 95/98/Me/NT/2000/XP	Linux	Solaris	HP-UX 10	Digital Unix 4.0	AIX 4.3	IRIX
BDMLP	✔	✔	✔	✔	✔	✔	✔
CONOPT	✔	✔	✔	✔	✔	✔	✔
CPLEX 7.5	✔	✔	✔	✔	✔	✔	✔
DECIS	✔	✔	✔		✔		✔
DICOPT	✔	✔	✔	✔	✔	✔	✔
MILES	✔	✔	✔	✔	✔	✔	✔
MINOS	✔	✔	✔	✔	✔	✔	✔
MPSGE	✔	✔	✔	✔	✔	✔	✔
OSL V3	✔	✔	✔	✔		✔	✔
PATH	✔	✔	✔	✔	✔	✔	✔
SBB	✔	✔	✔	✔	✔	✔	✔
SNOPT	✔	✔	✔	✔	✔	✔	✔
XA	✔	✔	✔	✔	✔	✔	
XPRESS 13.02	✔	✔	✔	13.01			

GAMS/GLOBAL Solvers

The solvers differ in the methods they use, in whether they find globally optimal solution with proven optimality, and in the size of models they can handle, and in the format of models they accept.

- **BARON**. Branch-and-Reduce algorithm from N.Sahinidis, University of Illinois Urbana-Champaign
- **LGO**. Lipschitz Global Optimization from Pinter Consulting Services, Canada
- **OQNLP**. OptQuest/NLP algorithms by OptTek Systems and Optimal Methods

GAMS/OQNLP

GAMS Models
NLP, DNLP, MINLP

Model input   Reliable Solutions

OQNLP

Evaluation   Starting Points   Solution

OptQuest
Scatter Search

Local NLP
Solver

Local Optimization Today

- Nonlinear modeling available in GAMS from the very beginning
- Variety of local solvers
  - NLP: MINOS, CONOPT, SNOPT, LSGRG,PATHNLP
  - MINLP: DICOPT, SBB

  implementing different methods (SLP, SQP, GRG, B&B, outer approximation…) improve reliability of nonlinear modeling
- Initial point is crucial for success

Global Codes and GAMS

- Global codes provide
  - Independence of starting point
  - Global/improved solutions
  - Bounds for solution quality
- (Almost) seamless exchange of local solvers with global solvers: `Option nlp=oqnlp;`
- Minimize risk of new technology for customers
  - Multiple Global Codes
  - Fallback to Local Solvers

Open Issues for Global Codes

- Termination criteria
  - When to stop a multi-start method?
- Problem modification
  - Global solvers require bounding box
- Limited algebra
  - E.g. External functions (black box)
- Solution quality metrics

Research v. Commercial Codes

- Run in "expert mode" tuned by the developer for a particular problem

- User wants to solve his business problem and wants to treat the solver as a black box

- Solver has to work decently in *all* cases

- Even if the algorithm fails, the solver has to be "*fail-safe*"

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QA Tests for Reducing Risk

- Replication of quality assurance results critical factor for establishing a new solver technology in the commercial world

- Non-reproducible tests damage the reputation of a solver

- Requirement: low cost replication of such results by an independent auditor

Effective Testing

- Test cases
  - Widely available collection of standardized test instances

- Solution Verification - `GAMS/Examiner`

- Data collection tools
  - Automatic collection of solution and statistics
  - Capture test environment setting (hardware, software)

- Data analysis tools
  - Standard quality and performance measurements

Test Cases

- Classification
    - Toy models
    - Academic Application Models
    - Commercial Application Models (difficult to collect)

- Growing GAMS Model Collections
    - GAMS Model library http://www.gams.com/modlib/modlib.htm, with about 250 models from over 18 application areas
    - GLOBALLib http://www.gamsworld.org/global/globallib.htm, with about 250 scalar NLP models
    - MINLPLib http://www.gamsworld.org/minlp/minlplib.htm, with about 180 scalar MINLP models
    - MPECLib http://www.gamsworld.org/mpec/mpeclib.htm, which produces over 10,000 NLP models

GAMS World Home Page

GAMS World

The Worlds
  GLOBAL
  MINLP
  MPEC
  MPSGE
  Performance
  Translation
Search
Contact
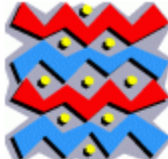
Welcome to the GAMS World

This is the home page of the GAMS World, a web site aiming to bridge the gap between academia and industry by providing highly focused forums and dissemination services in specialized areas of mathematical programming.

Substantial progress was made in the 1980s and 1990s with the development of algebra based modeling systems, algorithms, and computer codes to solve large and complex mathematical programs. The application of these tools, however, was less than expected. The abstraction, expression, and translation of real world problems into reliable and effective operational systems requires highly specialized and domains specific knowledge. The process of acquisition and dissemination of this knowledge is complex and poorly understood and the number of "good modelers" is much less than we all hoped for. Similarly, the process of transforming a new algorithm into a reliable and effective solution system is a slow and expensive process and there are few "good implementers". This web site hopes to address some of these problems by helping with the collection and dissemination of domain specific information and knowledge that is outside the established channels because of its content or form.

For example, model structures and results get published in commercial and academic papers but it is virtually impossible to reproduce any of those results or lift model components and data from one study to be used in some other study. Algorithm implementers face a similar dilemma when trying to get their hands on real world data models and data to test and refine their systems. This web site offers a few, well focused and maintained services to help with the dissemination of problems and solutions.

GAMS World is featured by GAMS Development Corp. and GAMS Software GmbH

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MINLP Lib

Address 🌐 http://www.gamsworld.org/minlp/minlplib/minlpstat.htm   ▼ ⮫Go   Links »

[**MINLP World Home** | **Board** | **Solvers** | **MINLPLib** | **Links** | **MINLP-List** | **Search** | **Contact**]

MINLPLib Model Statistics

Name	#Eqns	#Vars	#DVars	#NZ	#NNZ	BestInt	at Point
4stufen	99	150	48	319	87	116329.7000	p1
alan	8	9	4	24	3	2.9250	p1
batch	74	47	24	191	22	285506.5000	p1
batchdes	20	20	9	53	10	167427.7000	p1
beuster	115	158	52	398	159	116348.0000	p1
cecil_13	899	841	162	2812	360	-115570.3000	p1
contvar	285	297	87	1281	530	809149.8000	p1
csched1	23	77	63	174	8	-30639.2600	p1
csched2	138	401	308	958	58	-166102.0000	p1
deb10	130	183	11	692	432	209.4278	p1
deb6	508	476	20	2342	1432	201.7393	p1
deb7	898	814	10	4116	2816	116.5846	p1

🌐   🌐 Internet

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Global Lib

GAMS

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ex7_3_6.gms:

References:

- Floudas, C A, Pardalos, P M, Adjiman, C S, Esposito, W R, Gumus, Z H, Harding, S T, Klepeis, J L, Meyer, C A, and Schweiger, C A, Handbook of Test Problems in Local and Global Optimization. Kluwer Academic Publishers, 1999.
- Barmish, B R, New Tools for Robustness of Linear Systems. MacMillan Publishing Company, New York, NY, 1994.
- Abate, M, Barmish, B, Murillo-Sanchez, C, and Tempo, R, Application of Some New Tools to Robust Stability Analysis of Spark Ignition Engines : A Case Study. IEEE Trans. Contr. Syst. Tech. 2 (1994), 22.
- Original source: Global Model of Chapter 7 ex7.3.6.gms from Floudas e.a. Test Problems

Point: p1
Best known point: p1 with value 0.0000

MPEC Lib

Address http://www.gamsworld.org/mpec/mpeclib/credits.htm ▼ Go | Links »

Hill, J E	Jiang, H	Kehoe, T	Kennington J L	Klepeis, J L
Liu, Y H	Luo	Maier, G	McZeal C M	Meyer, C A
Murphy, F H	Nappi, A	Nemhauser, G L	Niemi, S	Outrata, J V
Pang	Pardalos, P M	Qi, L	Quandt, R E	Ralph
Savard, G	Savelsbergh, M W P	Scholtes, S	Schweiger, C A	Sherali, H D
Soyster, A L	Stohr, M	Tin-Loi, F	Townsley, R	Trick, M A
Westerberg, A W	Wichmann, S J	Zowe, J		

Credit List:

Adjiman, C S:

- Floudas, C A, Pardalos, P M, Adjiman, C S, Esposito, W R, Gumus, Z H, Harding, S T, Klepeis, J L, Meyer, C A, and Schweiger, C A, Handbook of Test Problems in Local and Global Optimization. Kluwer Academic Publishers, 1999.
- Models:
  - ex9_1_1m
  - ex9_1_2m
  - ex9_1_3m
  - ex9_1_4m

Internet

Data Collection Tools

- Status/performance/exception information
- GAMS Trace facility automatically collects
  - Model statistics
  - Non-default input options
  - Solver and solution statistics
  - Execution environment information
    - Version control of solvers

Data Analysis Tools

- Integral part of the quality assurance process at GAMS

- Processing of trace results
  - Build-in tools for status information
  - Custom GAMS programs
  - Performance World Tools
    - Performance measurements
    - Graphical/tabular representations

Performance World

Performance World

Welcome to the Performance World!

Performance World is a forum for discussion and dissemination of information and tools about all aspects of performance testing of mathematical programming problems. This world has been established in response to user demands for independent and reproducible performance results.

Overall performance highly depends on problem formulation, solver, and tuning parameters. Our performance tools are designed to serve the different needs of our user community. One user may be interested in finding the most reliable way to solve a proprietary or classified model. On the other hand, an academic researcher may be interested in testing a new algorithm against a set of existing test problems and competing approaches. The main features are:

- Uniform access to a comprehensive set of established and new test problems
- Automation tools for collecting performance measurements
- Tools for analyzing and visualizing test results

What's New:

- Try our online PAVER Server for automated performance analysis and batch file creation
- New tools for analyzing non-convex or discrete models
- MINLP type models from the MINLP World have been added to the PerformanceLib A tutorial (August, 2002)

Editorial Board

PerformanceLib

Performance Tools

Performance List

Related Links

Search

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Open Testing Architecture

- Test models
  - Open source GAMS models
  - Automatic translation into different formats, e.g. AMPL
  - Web/Email interface for this translation service
- Trace facility API
  - import/export of trace files (solution info, CSV format)
- Analysis tools
  - open source GAMS programs
  - Web interface for PAVER (**P**erformance **A**nalysis and **V**isualization for **E**ffortless **R**eproducibility)

Translation Services

Instructions

In order to use the GMS2XX translation service which is based on the "solver" GAMS/CONVERT you have to attach your model to an email and send it to our translation server at gms2xx@gamsworld.org. You specify the language in the subject line, for example

```
Subject: GAMS
```

At the moment we support the following *languages*:

- AMPL
- BARON
- CplexLP
- CplexMPS
- GAMS
- LGO
- LINGO
- MINOPT
- ALL (this creates scalar versions of all supported languages, listed above)

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Performance Tools

Download Performance tools:

Download the Performance Tools and sample data.

- Ptools.zip

Includes the following tools:

- pprocess.gms - performs all performance tools on a given set of trace files and combines output in a summary HTML page.
- pprofile.gms - performance profile routine for solver comparisons
- plotprof.gms - performance profile plotting routine using Gnuplotxy (Windows only)
- restime.gms - Resource time comparison utility
- schulz.gms - termination routine to ensure solvers terminate at resource time limit
- square.gms - solver outcome comparison utility

Also includes the following sample data files, where solvers have been renamed to generic A, B, C to hide proprietary data:

PAVER Web Submission

GAMS
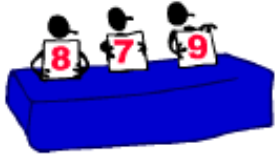
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PAVER - Performance Analysis Web Submission Tool

Email Address (required): SDirkse@gams.com

	Submit trace file:		Rename solver:
Trace 1 (required)	CONOPT.TXT	Browse...	
Trace 2 (required)	MINOS.TXT	Browse...	
Trace 3	SNOPT.TXT	Browse...	
Trace 4	OQNLPCONOPT.TXT	Browse...	OQNLP/CONOPT
Trace 5	OQNLPMINOS.TXT	Browse...	OQNLP/MINOS
Trace 6	OQNLPSNOPT.TXT	Browse...	OQNLP/SNOPT
Trace 7		Browse...	
Trace 8		Browse...	

Submit Trace Files   Clear Form

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Open Testing Architecture

AMPL,MINOPT,…
Models

"Solve" →

Collect Trace Information

→ **Custom Analysis**

Web →

CONVERT/ GMS2XX

GAMS Models

GAMS Solve →

Import/Export

GAMS Trace Facility

→ **PAVER**

GAMS Or Web

GAMS System →

GAMS Trace Analysis
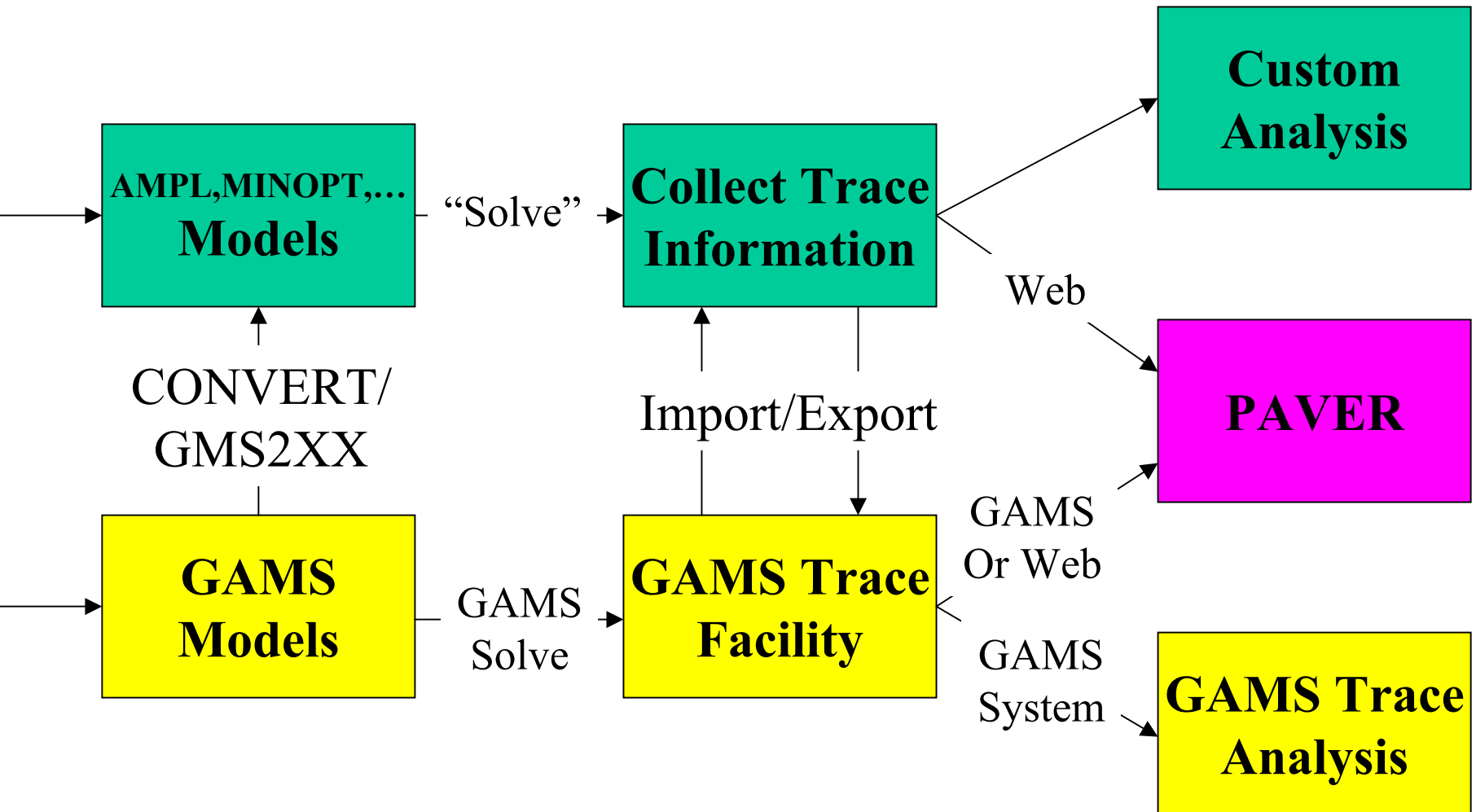
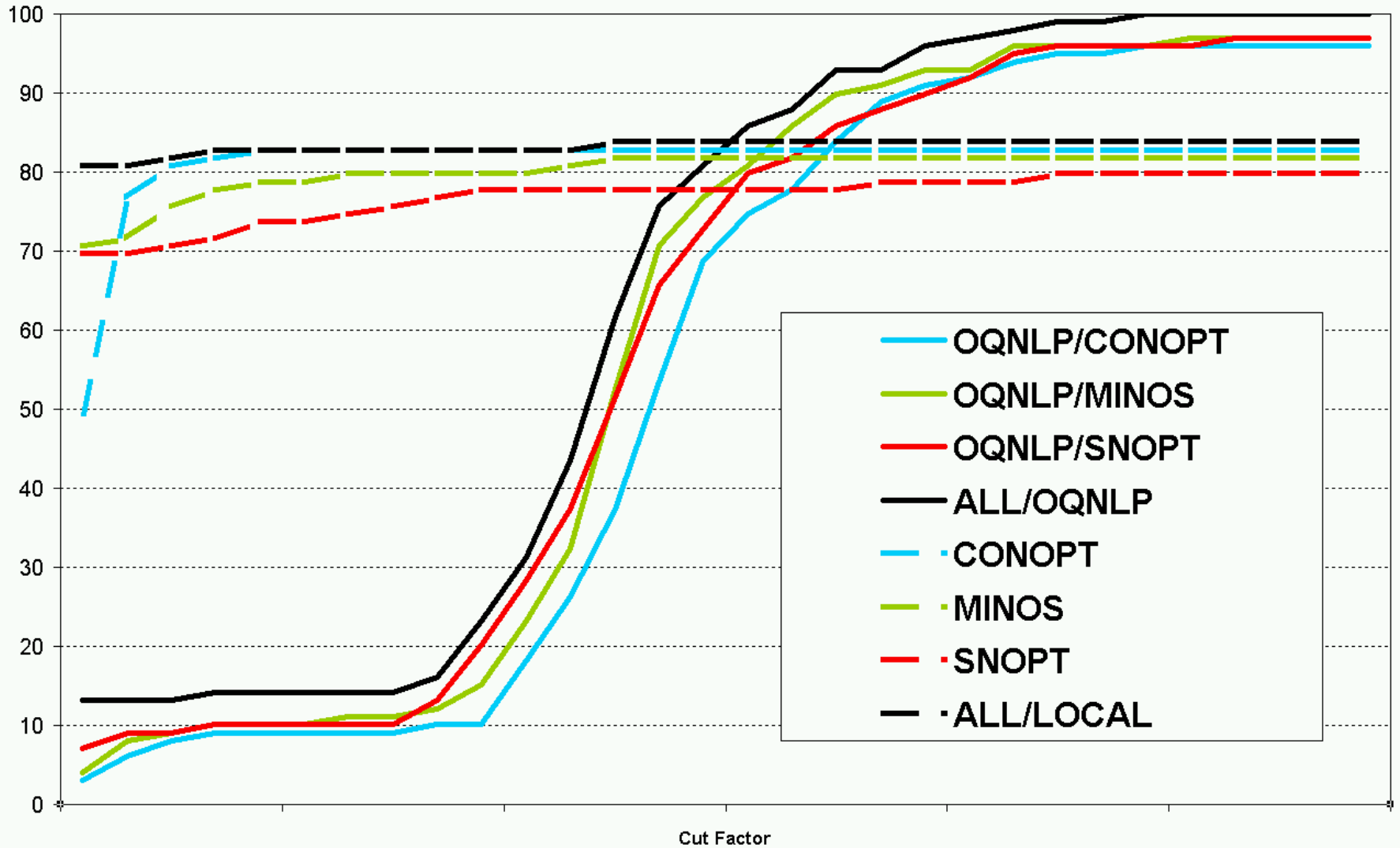# **Example**

- 99 instances of NLP models from *Floudas, C A, Pardalos, P M, Adjiman, C S, Esposito, W R, Gumus, Z H, Harding, S T, Klepeis, J L, Meyer, C A, and Schweiger, C A, Handbook of Test Problems in Local and Global Optimization. Kluwer Academic Publishers, 1999*

- Run all GAMS local NLP solvers and OQNLP in default mode.

- Compare Performance using PAVER.

Performance Profile - Local Solvers with and without OQNLP

Legend:
- OQNLP/CONOPT
- OQNLP/MINOS
- OQNLP/SNOPT
- ALL/OQNLP
- CONOPT
- MINOS
- SNOPT
- ALL/LOCAL

Cut Factor

Conclusions

- Framework for reliability and performance testing of (global) optimization codes.

- Open architecture for using this framework with models, modeling languages and solvers that are not necessarily connected with GAMS.

- Commitment to quality assurance in the optimization world (critical for success in the commercial environment).

- Presentation with all examples (will be) available at `http://www.gams.com/presentations`