GMO:
GAMS' Next-Generation Model API

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GMO: A Team Effort

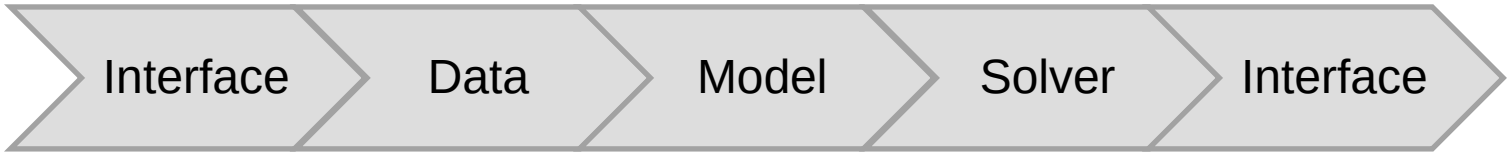
- Michael Bussieck
- Jan-Hendrik Jagla
- Alex Meeraus
- Paul van der Eijk
- Lutz Westermann

- Team projects introduce challenges and advantages
  → more on this later

Background

GAMS' Fundamental concepts

- Different layers with separation of
  - model and data
  - model and solution methods
  - model and operating system
  - model and interface



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Solver Links – Different Perspectives

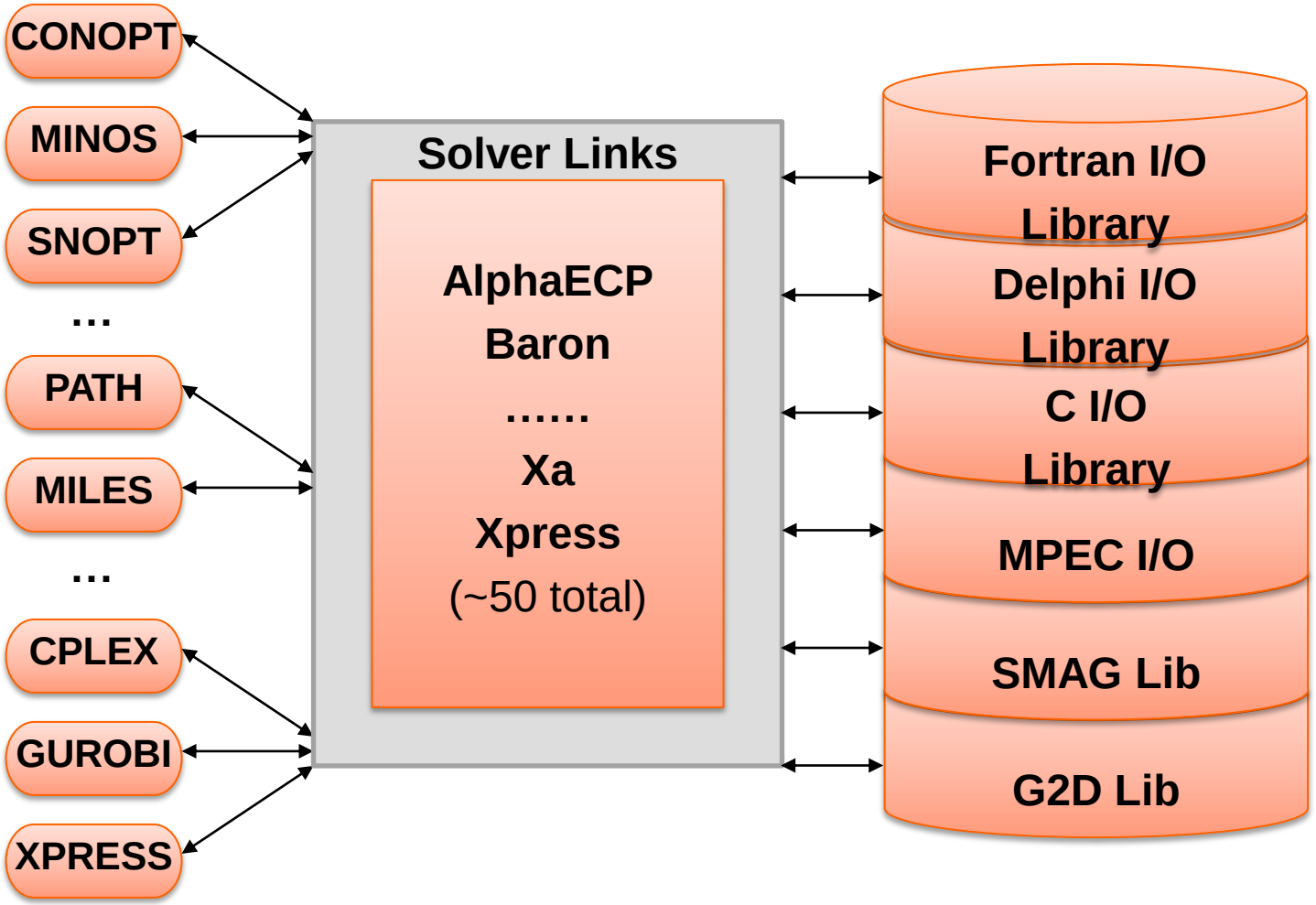
GAMS User

- Standardized solver interface allows “hassle free” replacement of solvers: *option nlp=conopt;*

Solver & Solver-link Developer – *our focus here*

- IO Library provides access to
  - Matrix
  - Function/Gradient/Hessian evaluations
  - Solution file writer
  - Output handling
  - GAMS Options (e.g. resource limit)
  - Problem attributes (SOS, semicont, semiint, priorities, scales)
  - Utility routines - problem rewriting, matrix reordering, SBB, …

Reuse? What's that?!?

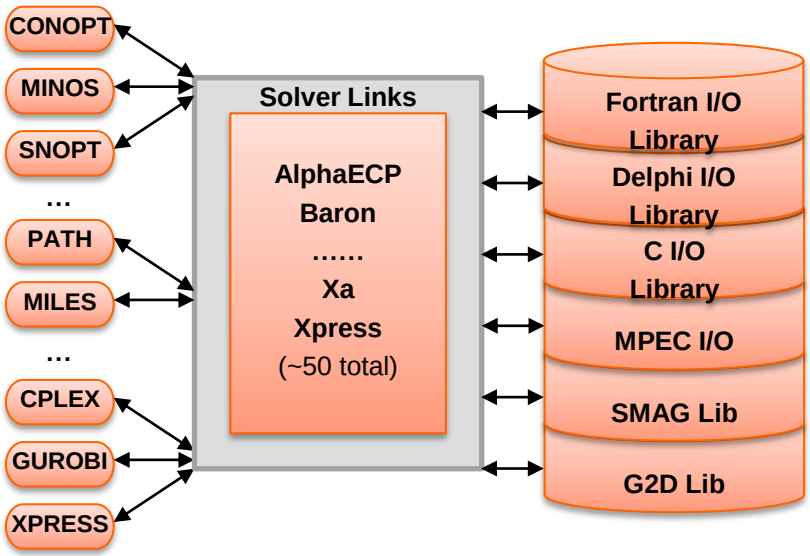


Talk Outline

- Why a new model API?
- What do we need it to do?
- What does it look like? How is it put together?
- How did we do it?
- When are we going to be finished?

Multiple I/O Libraries - Advantages

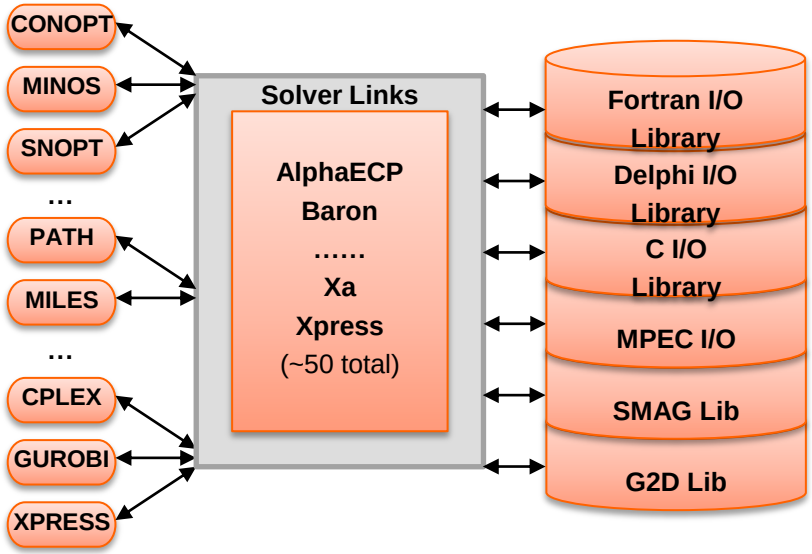
- proven over many years
- all platforms supported
- all GAMS-features available



- written by language experts, use all language features
- resulted in high-quality links across solvers and platforms
  → has been one factor in our success

Multiple I/O Libraries - Disadvantages

- Not always intuitive to use
  Linking your Solver to GAMS - THE COMPLETE NOTES (160 pages !!)



- Outdated design – I/O, STOP
- feature-poor (e.g. no automatic reformulation of objective func/var)
- inconvenient & expensive to maintain
- painful to move 'inert mass' forward – **not agile**
- linking your solver (without buddy at GAMS) is very difficult

Philosophy behind GMO

- Then
  - Computing environment: limited time and memory
  - Algorithm APIs not uniform or language-neutral
  - Expert users who understand optimization
  - *Don’t use unnecessary space or time*
  - *If the link gets in trouble, just abort, the user will fix things up and re-run.*
- Now
  - Most users won’t hit space/time limits
  - APIs look similar, are language-neutral
  - Users may be domain experts, not MP experts
  - *Use of additional space & time to give the GMO and GAMS user a better experience is justified.*

Checklist for GMO

- Powerful & convenient API – a few calls do the job
- In-core communication between GAMS and the solver, making potentially large model scratch files unnecessary
- Implement once, run everywhere (multiple platforms & multiple languages)
  - Platform-independent code, isolate the “dirty bits”.
  - API wrapper & multi-language interface
- Support meta-solvers (e.g. DICOPT, SBB, Examiner)
- Separate Model from Environment
- Comprehensive – one-stop shop for all linking needs
- Support shared-library implementation of solver links
- Support multiple models

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GMO: Powerful and Convenient API

- What's a powerful call?
  - Basic CS: information hiding, encapsulation, object model, abstraction
  - One call to do the job required, e.g. Hessian setup
  - No preconditions, magic calls, or nasty side effects
  - Should handle failure gracefully

- Convenience - multiple routines and "flavors"
  - Jacobian row- vs. column-wise, tuples
  - Objective reformulation – function or variable
  - Free rows - yes or no
  - Column evals: dense or sparse, all or just NL
  - Common/typical tasks done in GMO, not the link

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Solver Integration

```
solve mymodel minimizing z using lp
mymodel.solvelink = {ChainScript, CallScript,
   CallModule, AsyncGrid,  AsyncSimulate, LoadLibrary};
```

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

- Call{Script/Module}: Solver process, GAMS stays live
  - \+ protection against solver failure (*hostile* link)
  - \+ no swap of GAMS database
  - \- file based model communication

Solver Integration – cont.

- LoadLibrary: Solver DLL in GAMS process
  + fast memory based model communication
  + update of model object inside the solver (hot start)
  - not (yet) supported by all solvers

- trnsport.gms (LP) solved 500 times with CPLEX:

```
set ss /s1*s500/;   loop {ss,
   solve transport minimizing z using lp};
```

–	ChainScript:	33.04 s (28.9s)*
–	CallModule:	13.78 s (12.7s)
–	LoadLibrary:	2.37 s (2.0s)
–	Hot Start:	0.37 s (0.4s)

Cplex simplex time: 0.2 s

* without Virus Scanner

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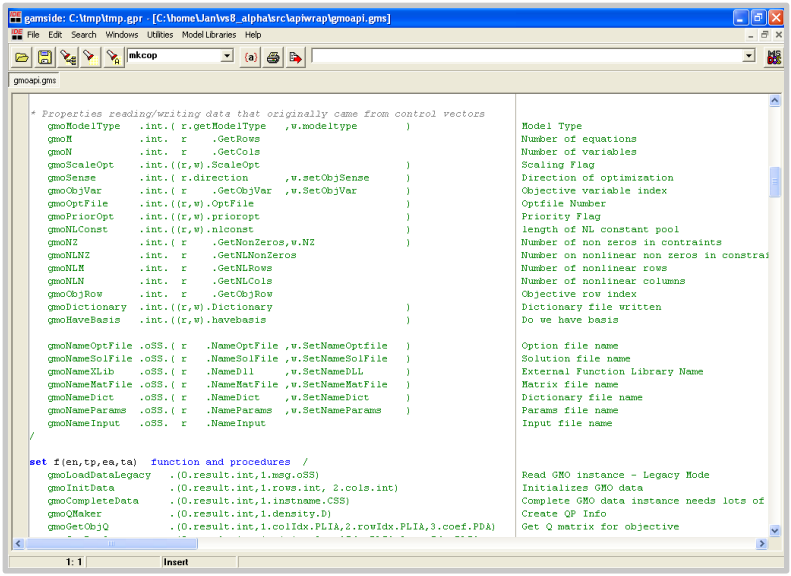
Implement Once, Run Everywhere

- All GMO coding done in a single language and style
  - Allows code sharing with other components
  - Allows for shared development
- All GMO coding is platform-independent
  - Makes writing code faster, more reliable
  - Maintenance is simplified
- Platform-dependent code isolated in utility libraries
  - Makes adding a new platform easier
  - Maintenance is simplified
  - Unit testing is easy and effective

Automated Generation of APIs

‘The GAMS Wrapper’

- API is defined using the GAMS language
- A tool written in GAMS is used to regenerate APIs for all languages
- Executed on request and nightly



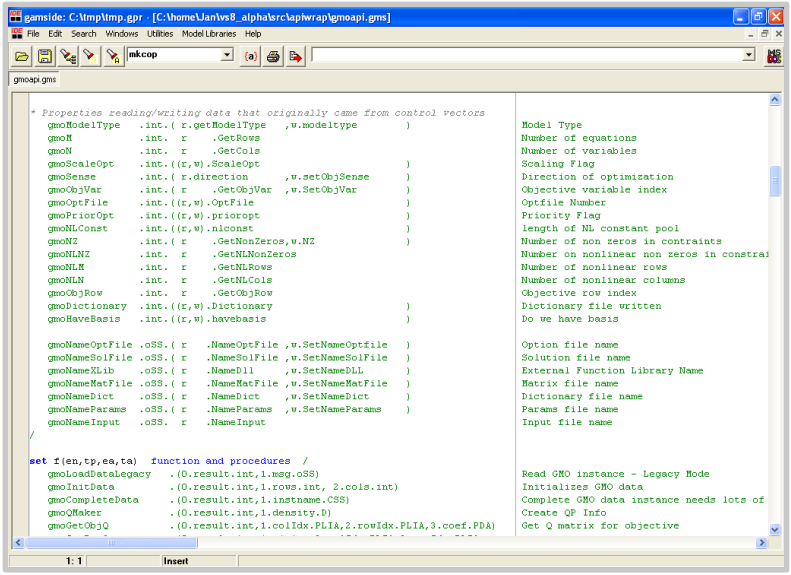
→ A change in the definition of the API immediately makes it into all language interfaces

→ No manual and therefore error-prone efforts required

Automated Generation of APIs

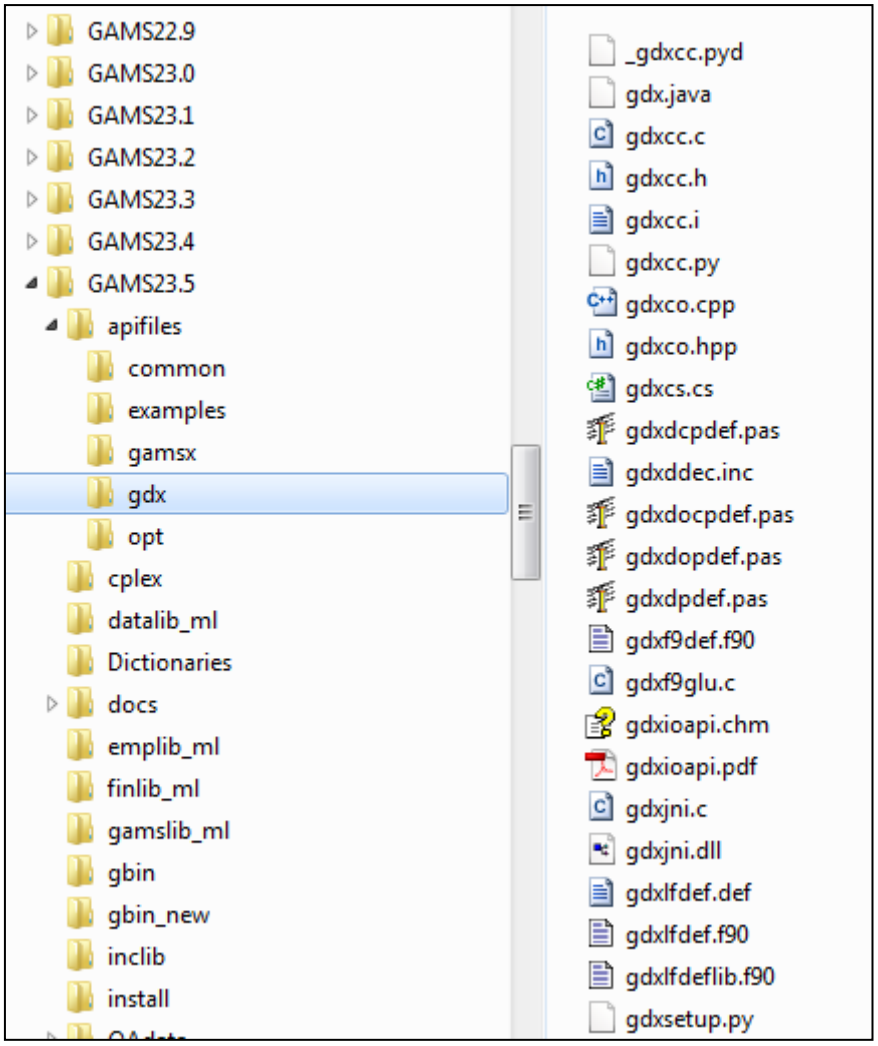
‘The GAMS Wrapper’

- Automated nightly testing
- API version checks
- Reusable for multiple GAMS component libraries
  - GMO
  - GAMS
  - GDX
  - Option



Distributed GAMS APIs

- Component Libraries
  - GAMS
  - GDX
  - Option
- Supported languages
  - C, C++, C#
  - Delphi
  - Fortran
  - Java
  - VBA, VB.Net
  - Python
- Examples/Documentation



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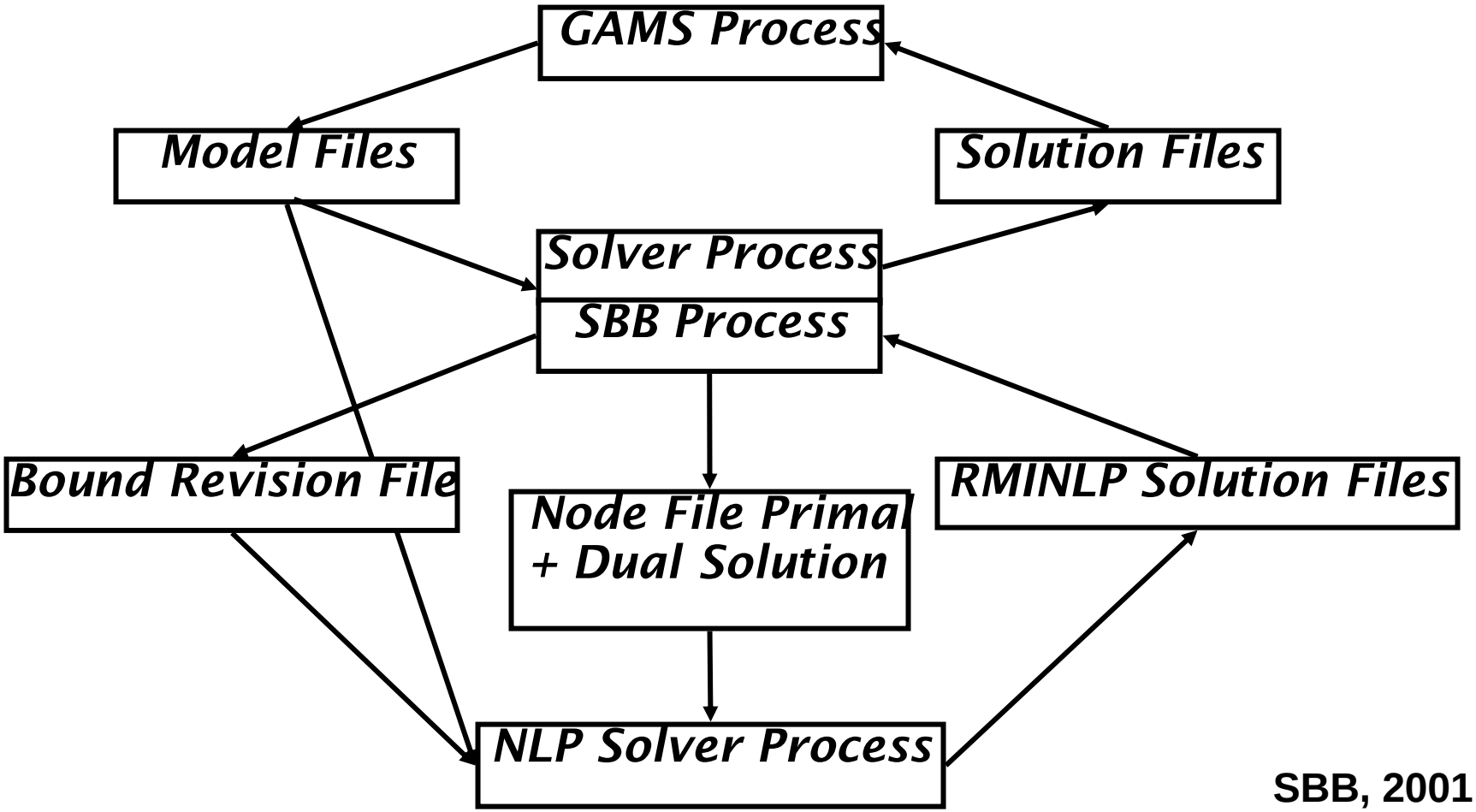
Separating Model & Environment

- Detach GMO from ‘GAMS Environment’
- Ease linking of experimental solvers to GAMS
- Simplify use of GAMS as one piece of a puzzle

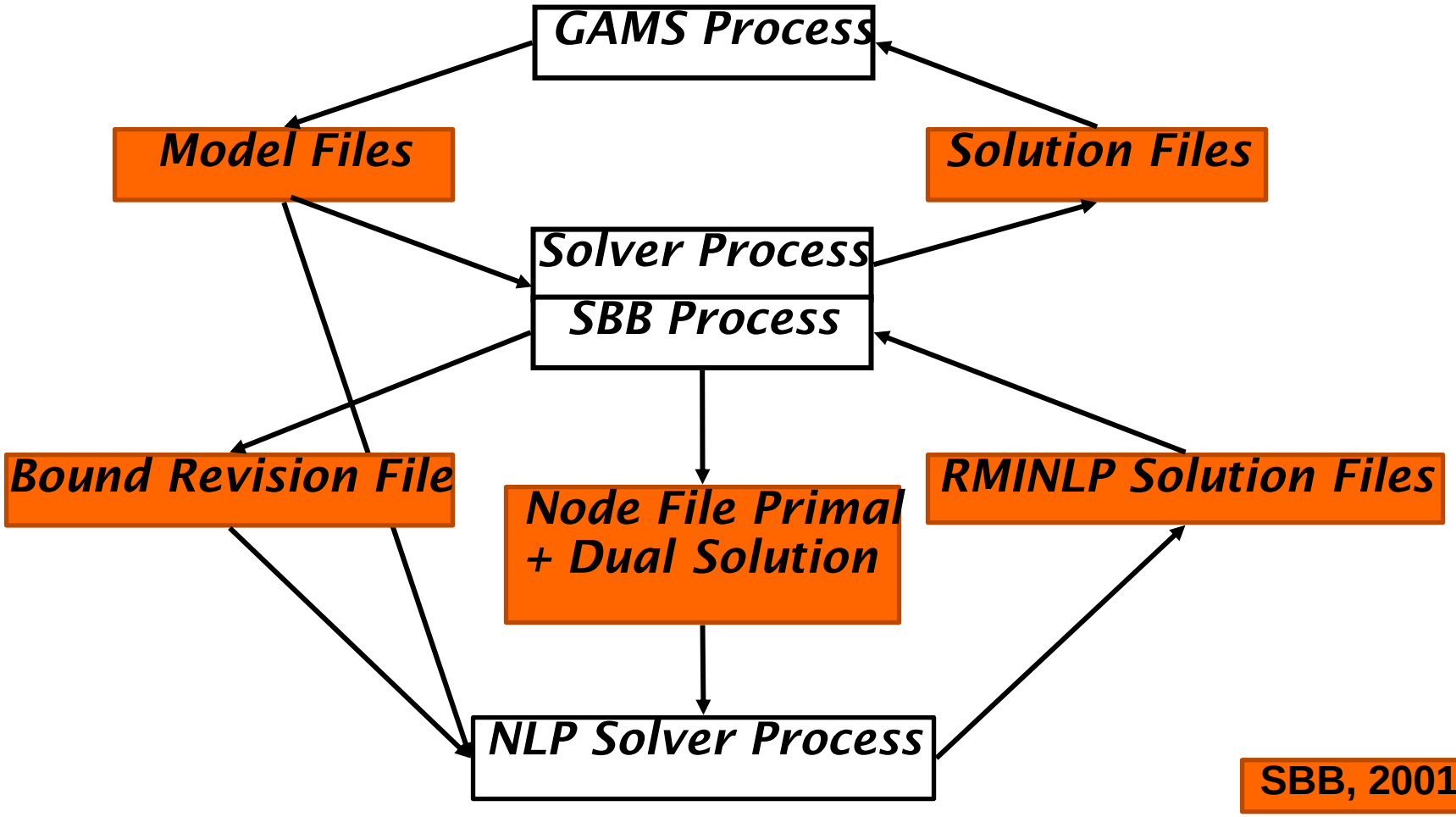
- E.g. sophisticated solvers use basic MP technology:
  - SBB (B&B requires NLP technology)
  - DICOPT (OA requires NLP+MIP)
  - BARON (requires NLP+LP)
  - LogMip (NLP+MIP)

‘Efficient’ Implementation of B&B



SBB, 2001

‘Efficient’ Implementation of B&B



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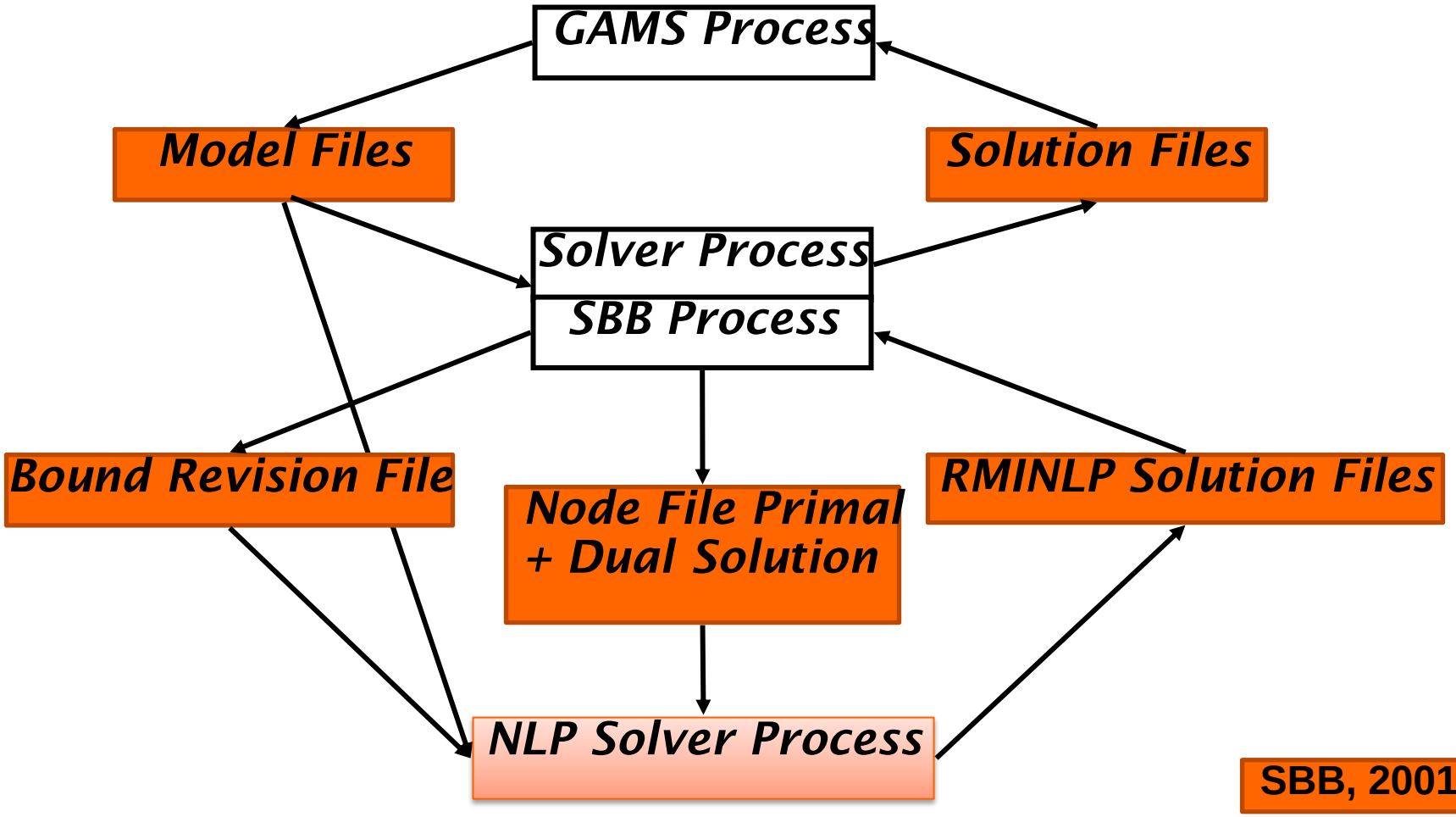
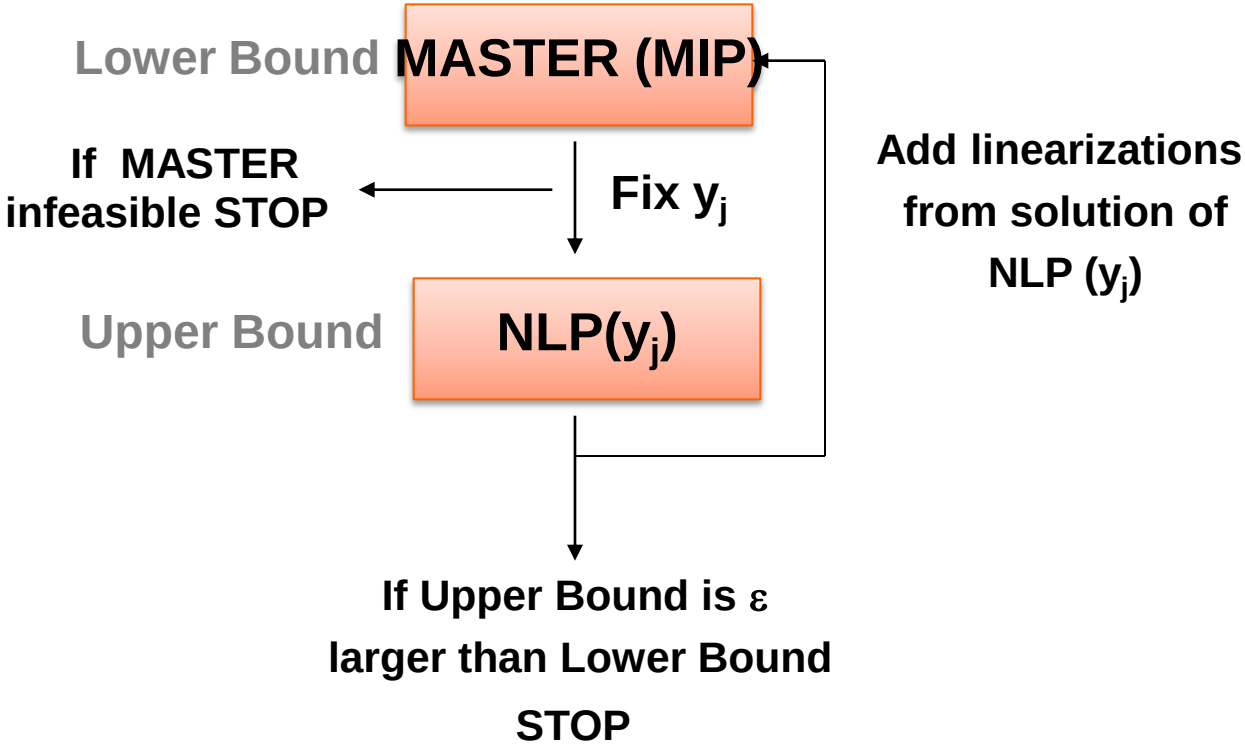


Dicopt (Outer Approximation)



Series of NLP and MIP solves

```
--- DICOPT: Log File:
Major Major      Objective     CPU time   Itera-  Evaluation Solver
Step  Iter        Function      (Sec)     tions    Errors
 NLP     1          1.04923       0.02        38        0      conopt
 MIP     1          9.07274       0.09        28        0      cplex
 NLP     2         *Infeas*       0.00        10        0      conopt
 MIP     2         13.02091       0.13        32        0      cplex
 NLP     3          1.26864<      0.03        27        0      conopt
 MIP     3         13.93760       0.11        29        0      cplex
 NLP     4         *Infeas*       0.02         7        0      conopt
 MIP     4         13.99258       0.11        19        0      cplex
 NLP     5         *Infeas*       0.02        13        0      conopt
 MIP     5         21.03812       0.11        23        0      cplex
 NLP     6          1.26864       0.02        17        0      conopt
--- DICOPT: Terminating...
```

- Lots of file writing and reading to communicate between Dicopt, MIP, and NLP solver

- Basically start a whole new process over and over

New Dicopt Implementation

Joined work with Ignacio Grossmann, Juan Pablo Ruiz (Carnegie Mellon University)

- Object Oriented
- Use C++ Interface to GMO
- Use standardized solver interface to call NLP/MIP solver in-core (pass GMO ‘handle’ on to solver)
- Algorithmic improvements

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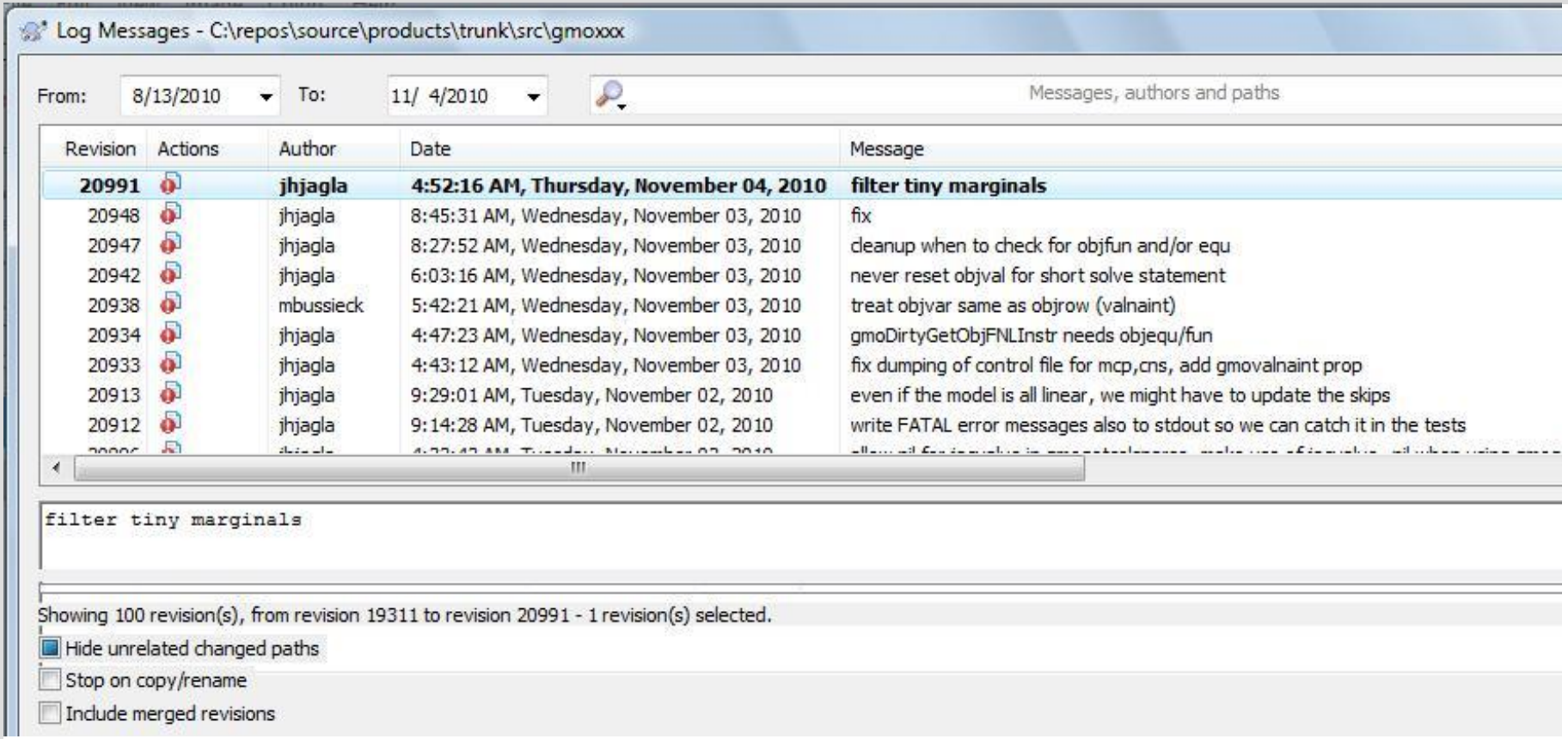
How We Did It: SVN



- Everybody agrees: SVN is a game-changer

How We Did It: Automation & Testing

GAMS

[Home | Support | Sales | Solvers | Documentation | Model Library | Search | Con

Latest GAMS System Builds and Test Results

Tuesday 09Nov10 15:

[Latest Builds | Alpha Builds | Beta Builds | Nightly Builds | System Codes | History]

nightly α	System	Libraries	Build	Rev	Status and Time (UTC)		Initial Tests		Full Tests
Monday	lnx	Download	23.7.0	21065	Test done	09Nov2010 06:52:24	712 runs 0 failures (q=0,s=0)	Report	8902 runs 2 failures (q=1,s=1)
Monday	lx3	Download	23.7.0	21065	Test done	09Nov2010 09:11:56	732 runs 0 failures (q=0,s=0)	Report	9385 runs 2 failures (q=1,s=1)
Tuesday	vs8	Download	23.7.0	21075	Test done	09Nov2010 14:32:06	734 runs 0 failures (q=0,s=0)	Report	9397 runs 2 failures (q=1,s=1)
Monday	wei	Download	23.7.0	21072	Test done	09Nov2010 07:05:24	682 runs 1 failures (q=1,s=0)	Report	8364 runs 5 failures (q=2,s=3)

nightly β	System	Libraries	Build	Rev	Status and Time (UTC)		Initial Tests		Full Tests
Monday	lnx	Download	23.6.0	21070	Test done	09Nov2010 07:22:45	712 runs 0 failures (q=0,s=0)	Report	8901 runs 2 failures (q=1,s=1)

How We Did It: Automation & Testing

- SVN, other tools automate builds on all platforms

- Extensive, automated tests
  - Test library (501 models), other libraries (hundreds)
  - Runs over all solvers, some NLP/MIP combinations
  - Recent beta: 17 test machines, each ~ 3K – 10K
  - Collecting, archiving, sharing of test results

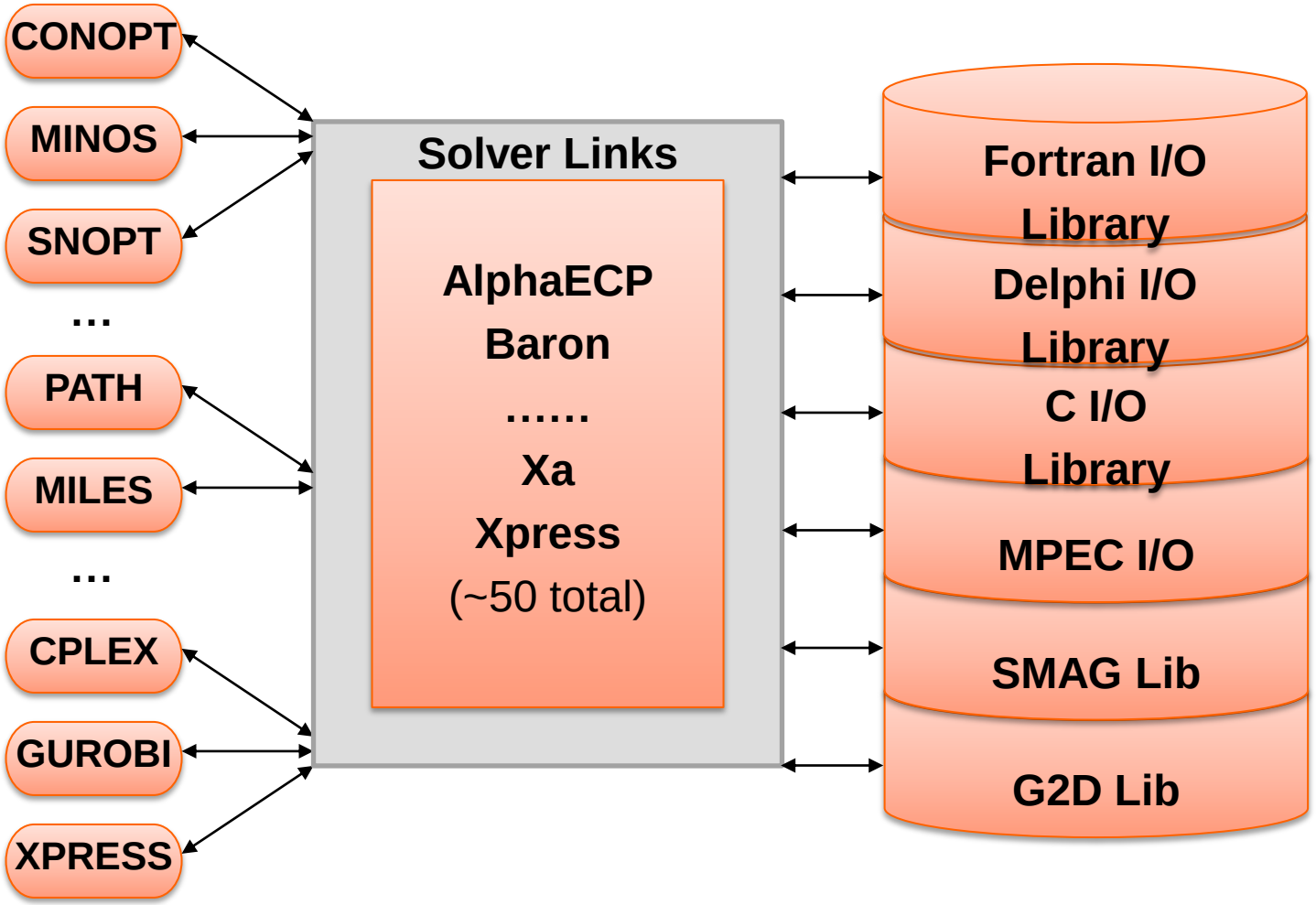
- PAVER used to compare to previous versions
  - Helps find outliers (bugs), problem cases
  - http://www.gamsworld.org/performance/paver/

When Will We Be Finished?

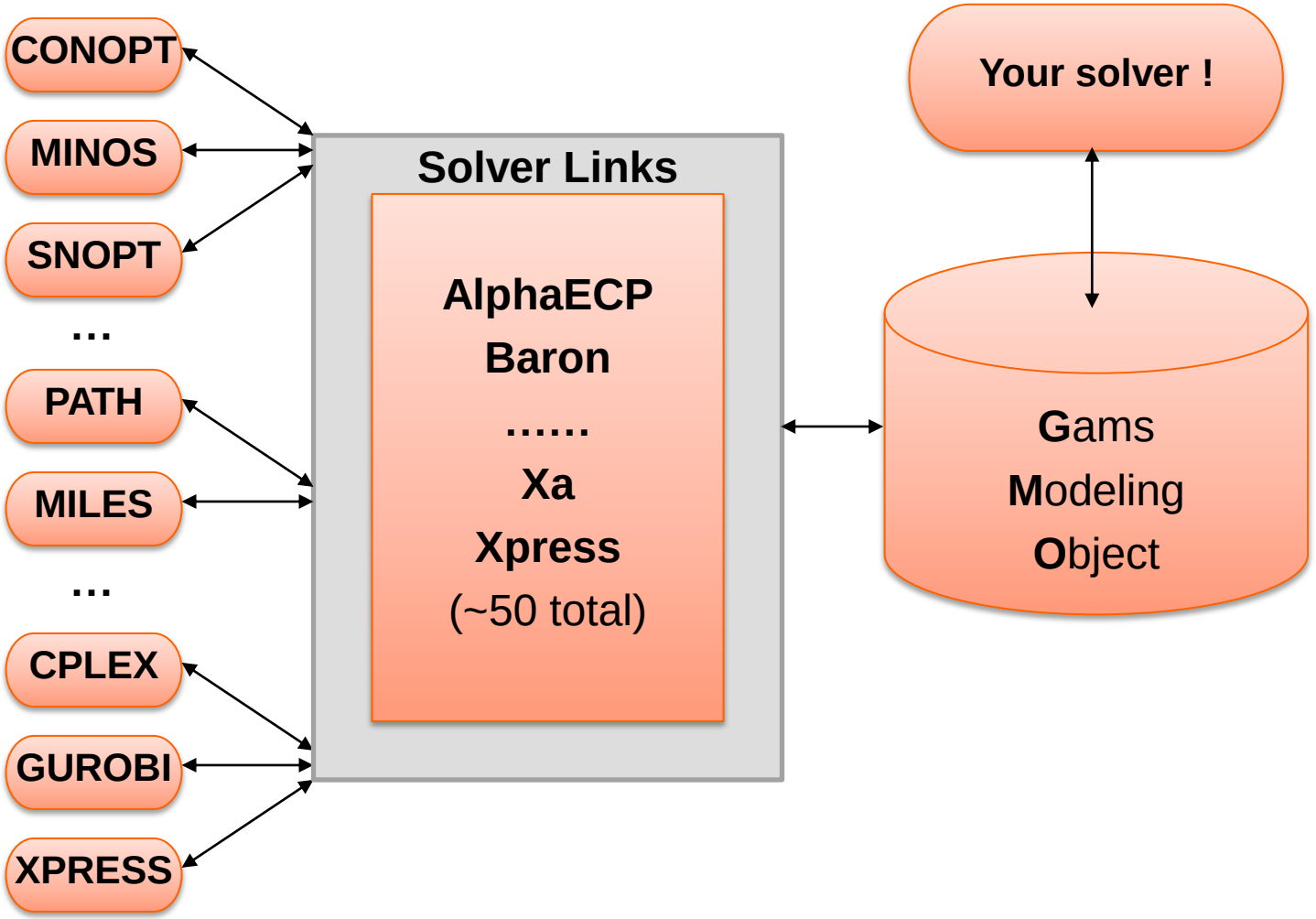
- GAMS 23.6.2 (current distribution)
  - Couenne, IPOPT
  - Gurobi
  - OSI-based links to CPLEX, GUROBI, GLPK, MOSEK, XPRESS
  - All previous Fortran links (e.g. CONOPT, MINOS, SNOPT)
  - All links using 2nd-order info (e.g. KNITRO, PATH, MOSEK)
  - Misc others

- GAMS 23.7 – possibly out in April 2011
  - All MCP solvers
  - Meta-solvers like BENCH, Examiner ??

Summary


CONOPT
MINOS
SNOPT
…
PATH
MILES
…
CPLEX
GUROBI
XPRESS
Solver Links
AlphaECP
Baron
……
Xa
Xpress
(~50 total)
Fortran I/O Library
Delphi I/O Library
C I/O Library
MPEC I/O
SMAG Lib
G2D Lib

Summary


CONOPT
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……
Xa
Xpress
(~50 total)
Your solver !
Gams
Modeling
Object

Summary

- GMO is part of GAMS distribution
- GMO is used by the majority of GAMS Solver Links - eventually by all
- GMO eases maintenance and makes development process more flexible, more agile
- GMO opens up new possibilities for moving GAMS forward
- GMO interfaces are not yet public but alpha version can be made available on request

Contacting GAMS

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