Quality Assurance and Algebraic Modeling Systems

available at:
http://www.gams.com/presentations/gor-2004.pdf

Stephan Eidt (edt@ast.iitb.fhg.de),
Fraunhofer Application Center of System Engineering, Ilmenau
Franz Nelissen (FNelissen@gams.com),
GAMS Software GmbH, Cologne

OR 2004, Tilburg

Overview

- Motivation
- Definitions and Components
- Challenges
- Software Quality Assurance at GAMS
- Testing new Solver Links
- Client Model Testing
- Summary

Motivation

- **Quality Assurance**
  - Essential component in most industries
  - Important in most software engineering sectors
- **Mathematical Programming**
  - Less attention to quality assurance
  - Focus on performance (academic)
  - But: Reliability becomes more and more important (commercial)

→ **How deals a small MP company like GAMS with quality assurance and what are the benefits for our clients and our software partners?**

Definitions

- **Quality**: *The totality of features and characteristics of a product or service that bear on its ability to satisfy specified or implied needs* (ISO 8402)
- **Software Quality Assurance (SQA):** "*Set of systematic activities providing evidence of the ability of the software process to produce a software product that is fit to use*" (Schulmeyer and McManus)

Definitions
cont‘d

SQA includes monitoring of *processes* and *products* throughout the software development lifecycle to ensure the quality of the delivered product

- Software configuration management (monitoring the process)
  - Provides management with objective feedback regarding process compliance to approved plans, procedures, standards, and analyses
- Quality control and testing (monitoring the products)
  - Focus on the quality of product within each phase of the software development lifecycle
  - Objective: identify and remove defects throughout the lifecycle, as early as possible

Components

Software configuration management

All activities related to version control and change control

Goals:

- Identify and control changes
- Ensure that change is being properly implemented
- Report changes in the software to others who may need to know of them

Components

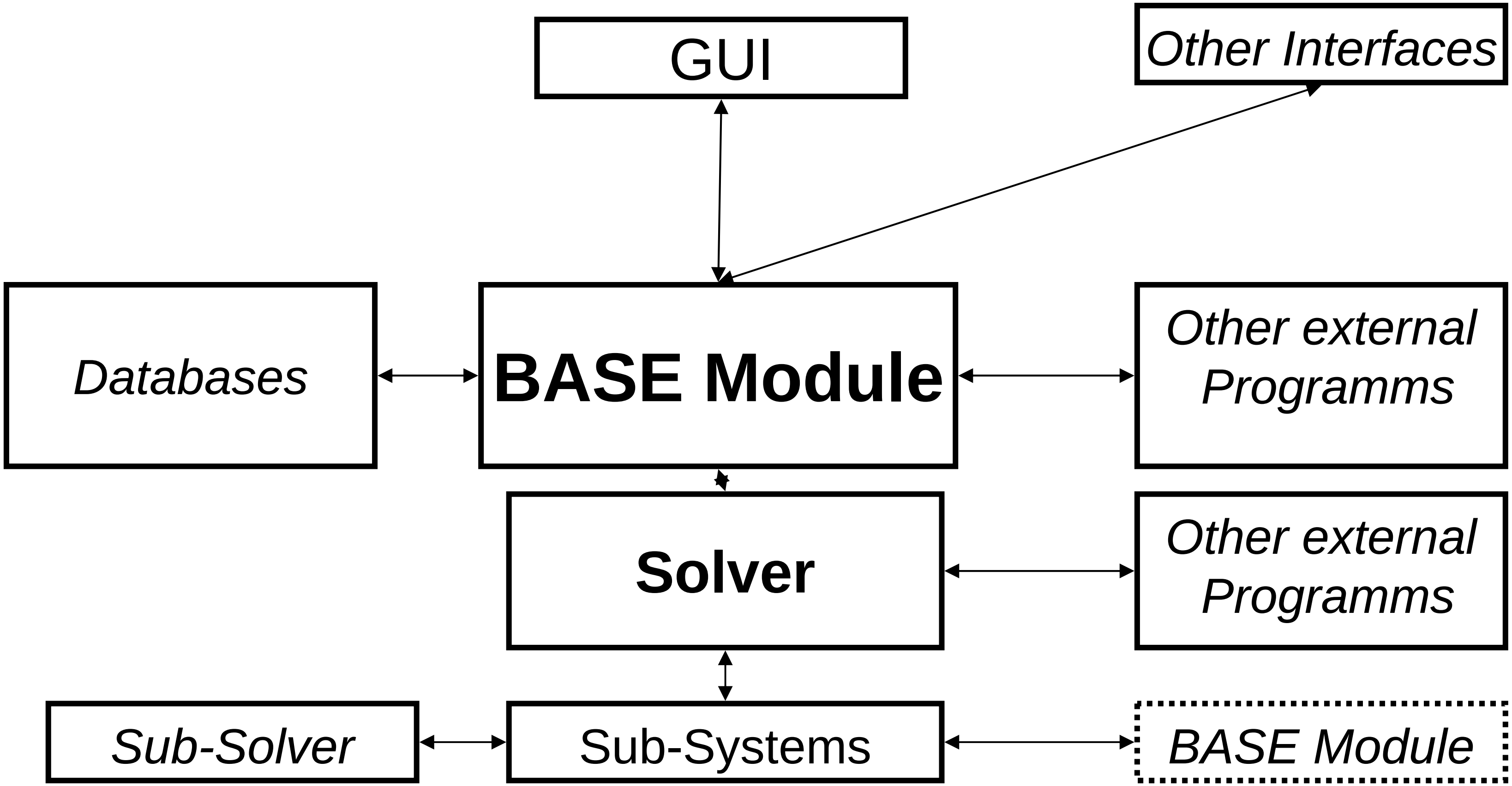
Quality control and testing of the product

- Unit testing
- Regression testing
- System Integration Testing
- Metrics
- Bug tracking tools

Goal: Uncover defects during the complete life cycle of the software

Algebraic Modeling Systems

Architecture



Algebraic Modeling Systems

Basic Principles

- Separation of model and solution methods
- Balanced mix of declarative and procedural approaches
- Computing platform independence
- Multiple model types, solvers and platforms

Algebraic Modeling Systems

Multiple Model Types

- LP Linear Programming
- MIP Mixed Integer Programming
- NLP Nonlinear Programming
- QCP/MIQCP Quadratic Programming
- Conic Programming
- MCP Mixed Complementarity Programming
- MINLP Mixed Integer Nonlinear Programming
- MPEC NLP with Complementarity Constraints
- MPSGE General Equilibrium Models
- Stochastic Optimization
- Global Optimization

Challenges

- Rigorous SQA is expensive – MP industry is small
- Failure vs. Defects → Complex metric for return codes necessary
- Only limited control about certain parts of the system
- Distributed development of the system and various components

SQA at GAMS

1. **Software configuration management**
2. **Quality control and tests of the product**
3. **Client model testing**
4. *Performance comparison tools:*
   - *Paver*
   - *Bench*
5. *Solution verification tool: Examiner*
6. *Model converter and “encryption“ tool: Convert*

SQA at GAMS

Software configuration management

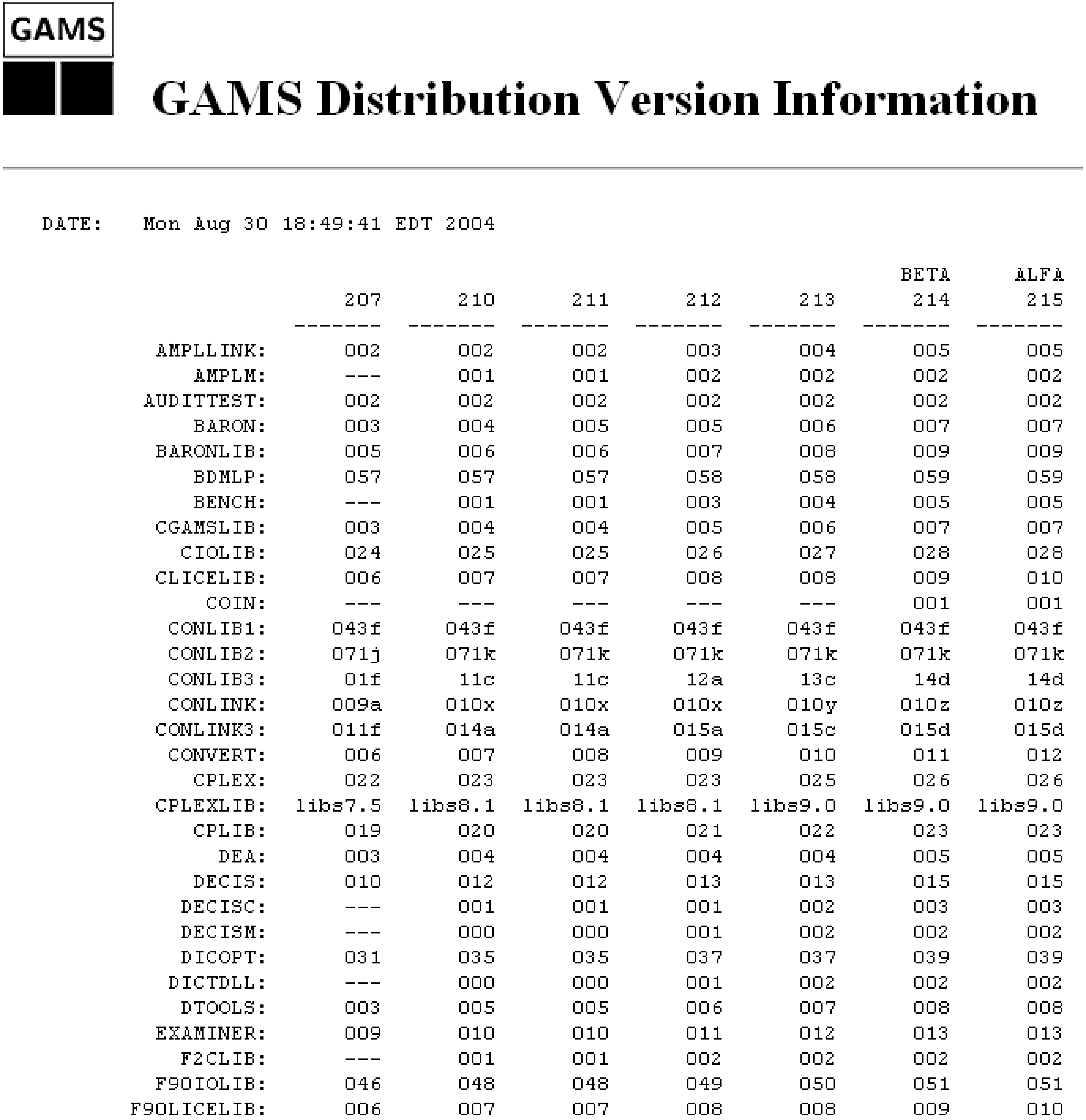
- Audit strings

```
C O N O P T 3 Jan 19, 2004 WIN.CO.CO 21.3 015.050.041.VIS Library 313C
C O N O P T 3 BETA 28Jul04 WIN.CO.CO 21.4 015.051.041.VIS Library 314D
```

- Build automation tools: Automatic build of the whole system every week
- Simple source management system
- E-Mail based bug tracking system

Audit Strings

More than 46 components!



GAMS Distribution Version Information

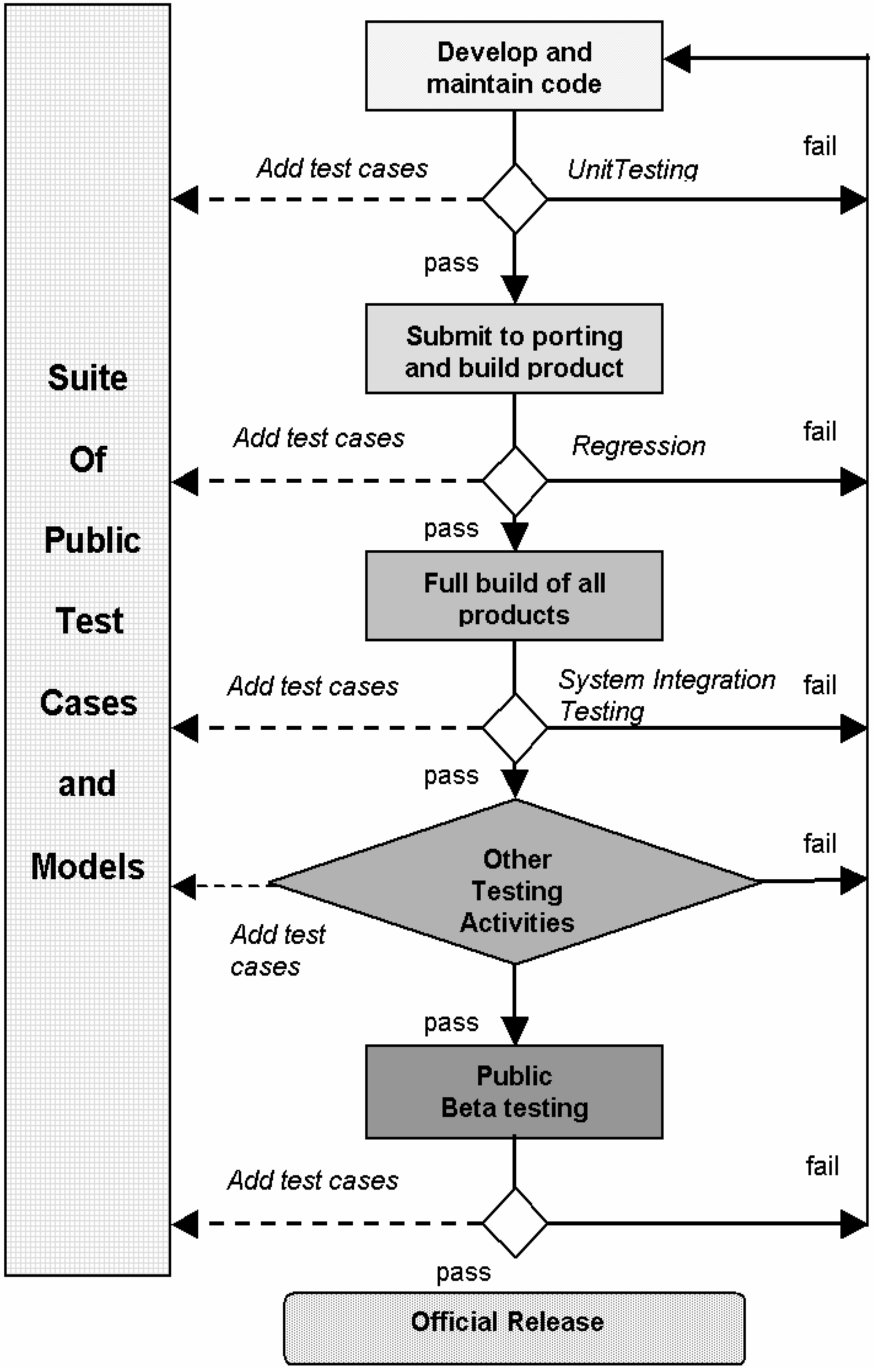
```
DATE:    Mon Aug 30 18:49:41 EDT 2004

                                                                       BETA     ALFA
                     207      210      211      212      213      214      215
                 -------  -------  -------  -------  -------  -------  -------
      AMPLLINK:      002      002      002      003      004      005      005
         AMPLM:      ---      001      001      002      002      002      002
     AUDITTEST:      002      002      002      002      002      002      002
         BARON:      003      004      005      005      006      007      007
      BARONLIB:      005      006      006      007      008      009      009
         BDMLP:      057      057      057      058      058      059      059
         BENCH:      ---      001      001      003      004      005      005
      CGAMSLIB:      003      004      004      005      006      007      007
        CIOLIB:      024      025      025      026      027      028      028
      CLICELIB:      006      007      007      008      008      009      010
          COIN:      ---      ---      ---      ---      ---      001      001
      CONLIB1:      043f     043f     043f     043f     043f     043f     043f
      CONLIB2:      071j     071k     071k     071k     071k     071k     071k
      CONLIB3:       01f      11c      11c      12a      13c      14d      14d
      CONLINK:      009a     010x     010x     010x     010y     010z     010z
     CONLINK3:      011f     014a     014a     015a     015c     015d     015d
      CONVERT:       006      007      008      009      010      011      012
         CPLEX:      022      023      023      023      025      026      026
      CPLEXLIB:  libs7.5  libs8.1  libs8.1  libs8.1  libs9.0  libs9.0  libs9.0
         CPLIB:      019      020      020      021      022      023      023
           DEA:      003      004      004      004      004      005      005
         DECIS:      010      012      012      013      013      015      015
        DECISC:      ---      001      001      001      002      003      003
        DECISM:      ---      000      000      001      002      002      002
        DICOPT:      031      035      035      037      037      039      039
       DICTDLL:      ---      000      000      001      002      002      002
        DTOOLS:      003      005      005      006      007      008      008
      EXAMINER:      009      010      010      011      012      013      013
        F2CLIB:      ---      001      001      002      002      002      002
      F90IOLIB:      046      048      048      049      050      051      051
    F90LICELIB:      006      007      007      008      008      009      010
```

SQA at GAMS

Quality control and tests of the product

- Goal: Continuous quality improvement using automated and reproducible tests
- Test libraries (available online):
  - GAMS Model Library
  - GAMS Quality Test Models Library
  - Solved for all relevant solvers: More than 16.000 solves for each platform

General testing process



SQA at GAMS

Quality Test Models Library

- Include tests to verify proper behavior of the system
- More than 140 quality test models, each containing numerous pass/fail tests:

```
...
abort$card(delta) 'time routines have an error';
...
```

- Automatic generated test summaries with different level of information

SQA at GAMS

Summary of two quality runs

```
*** Status: Normal completion
--- quality.gms(284) 4 Mb
--- quality.gms(287) 4 Mb 1 Error
There were errors: 4 out of 267 tests failed.
See the file failures.gms to reproduce the failed runs
--- Putfile this D:\support\testlib\onetest.gms
--- quality.gms(287) 4 Mb 1 Error
*** Status: Execution error(s)

==============================================

*** Status: Normal completion
--- quality.gms(284) 4 Mb
--- quality.gms(295) 4 Mb
Congratulations!  All 267 tests passed.
See the file alltests.gms to reproduce all the runs
--- Putfile this D:\support\testlib\onetest.gms
*** Status: Normal completion
```

Testing New Solver Links

Solver developer has connected his solver to GAMS (e.g. a COIN solver)

- Automated tests to check basic functionality of the solver and the link to GAMS:

```
$title Simple level and sign test (LP02,SEQ=67)
* In this test series we status if a solver gets the levels
* and marginals right.
..
abort$( abs(cost.m-cost_m) > tol) 'bad cost.m';
```

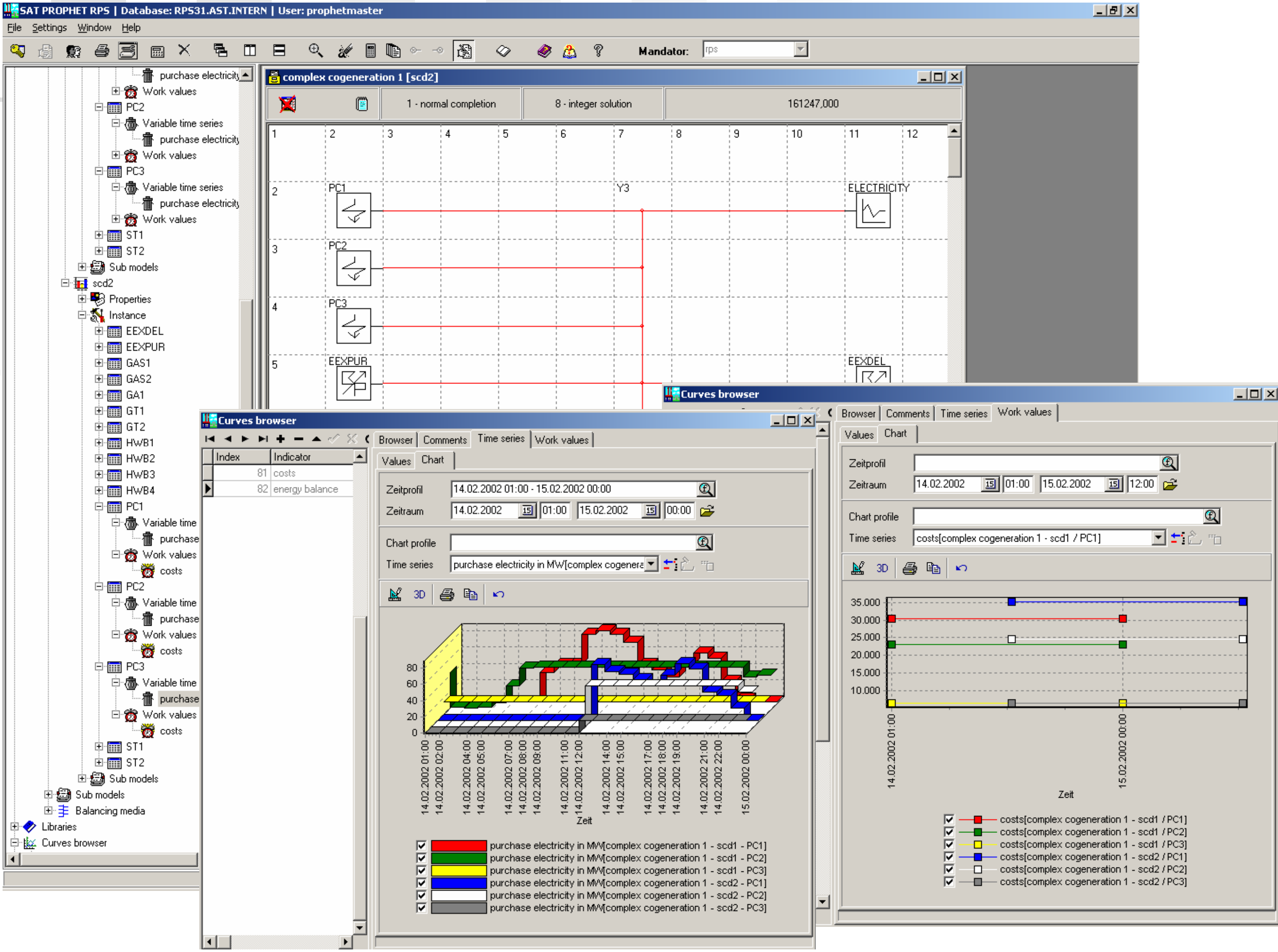
- Gives him and users assurance about the basic functionality of the link and the solver

Client Model Testing

- Client with complex application (energy management system)
- New GAMS version available:
  - Relevant new features?
  - Performance gains?
  - No surprises?
    - Bugs
    - Different results (MIP models)

Client Model Testing

SAT-PROPHET



SAT PROPHET RPS | Database: RPS31.AST.INTERN | User: prophetmaster

- purchase electricity
- Work values
- PC2
  - Variable time series
    - purchase electricity
  - Work values
- PC3
  - Variable time series
    - purchase electricity
  - Work values
- ST1
- ST2
- Sub models
- scd2
  - Properties
  - Instance
    - EEXDEL
    - EEXPUR
    - GAS1
    - GAS2
    - GA1
    - GT1
    - GT2
    - HWB1
    - HWB2
    - HWB3
    - HWB4
    - PC1
      - Variable time
        - purchase
      - Work values
        - costs
    - PC2
      - Variable time
        - purchase
      - Work values
        - costs
    - PC3
      - Variable time
        - purchase
      - Work values
        - costs
    - ST1
    - ST2
  - Sub models
- Sub models
- Balancing media
- Libraries
- Curves browser

complex cogeneration 1 [scd2]

1 - normal completion | 8 - integer solution | 161247,000

Curves browser

Index	Indicator
81	costs
82	energy balance

Zeitprofil: 14.02.2002 01:00 - 15.02.2002 00:00

Zeitraum: 14.02.2002 01:00 15.02.2002 00:00

Chart profile:

Time series: purchase electricity in MW[complex cogenera

- ☑ 🟥 purchase electricity in MW[complex cogeneration 1 - scd1 - PC1]
- ☑ 🟩 purchase electricity in MW[complex cogeneration 1 - scd1 - PC2]
- ☑ 🟨 purchase electricity in MW[complex cogeneration 1 - scd1 - PC3]
- ☑ 🟦 purchase electricity in MW[complex cogeneration 1 - scd2 - PC1]
- ☑ ⬜ purchase electricity in MW[complex cogeneration 1 - scd2 - PC2]
- ☑ ⬛ purchase electricity in MW[complex cogeneration 1 - scd2 - PC3]

Curves browser

Zeitprofil:

Zeitraum: 14.02.2002 01:00 15.02.2002 12:00

Chart profile:

Time series: costs[complex cogeneration 1 - scd1 / PC1]

- ☑ 🟥 costs[complex cogeneration 1 - scd1 / PC1]
- ☑ 🟩 costs[complex cogeneration 1 - scd1 / PC2]
- ☑ 🟨 costs[complex cogeneration 1 - scd1 / PC3]
- ☑ 🟦 costs[complex cogeneration 1 - scd2 / PC1]
- ☑ ⬜ costs[complex cogeneration 1 - scd2 / PC2]
- ☑ ⬛ costs[complex cogeneration 1 - scd2 / PC3]

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Client Model Testing

- Want guarantee that their application will work with the new version
- Only limited ressources to do major testing themselves
- *Confidentiality issues: Running tests without having access to internal model structures and model data (in a human readable format)*

Client Model Testing

- Gives clients assurance that their application will also work with new GAMS releases
- Includes:
  - Ability to solve (= no bugs)
  - Returns the same solution back
  - Similar or better performance
- Requires changes to the model of the clients to allow automated pass/failure tests
- Improves communication between development team and clients (specific wishes)

Lessons

- Automate the QA process and the certification
- Build the QA tools into the software and share the QA process
- Make the QA process transparent and reproducible
- Involve solver developers and clients (academic and commercial) into the QA process

Summary

- SQA becomes more and more important for MP industry
- Our focus is on automated configuration management and automated testing (reproducible full life cycle testing)
- Most of the test components are available as transparent GAMS models
- Involvement of the clients in the QA process is essential
- Benefits both for solver developers, for clients and for GAMS

References

- Bussieck, M.R., Drud, A.S., Meeraus, A. and Pruessner, A. (2002), Quality Assurance and Global Optimization, C. Bliek, C. Jermann, A. Neumaier, eds. Global Optimization and Constraint Satisfaction, First International Workshop on Global Constraint Optimization and Constraint Satisfaction, COCOS 2002, LNCS2861. Springer Verlag, Heidelberg Berlin, (223-238).
- Bussieck, M.R., Dirkse, S.D., Meeraus, A. and Pruessner, A. (2004), Software Quality Assurance for Mathematical Modeling Systems, forthcoming
- GAMS Development Corporation, (2004), GAMS - The Solver Manuals, GAMS Development Corporation, Washington, DC, online at: http://www.gams.com/solvers/allsolvers.pdf
- International Organization for Standardization (2004), online at:http://www.iso.org.
- PAVER Server (2004), online at http://www.gamsworld.org/performance/paver
- Pruessner, A. (2002), Automated Performance Testing and Analysis, online at http://www.gams.com/presentations/present_automation.pdf
- Schulmeyer, G.G. and McManus, J.I. (1998), Software Quality Handbook, Prentice Hall