Quality Assurance For Mathematical Modeling Systems

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Agenda

- 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 (small community)
- Specific QA issues for modeling systems (initially expensive)
- Different focus for industry and academic

Focus on reliability

Focus on performance

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

Key components of SQA (which includes monitoring of *products* and *processes*):

- Software configuration management (SCM): All activities related to version control and change control
- 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

GAMS

Components

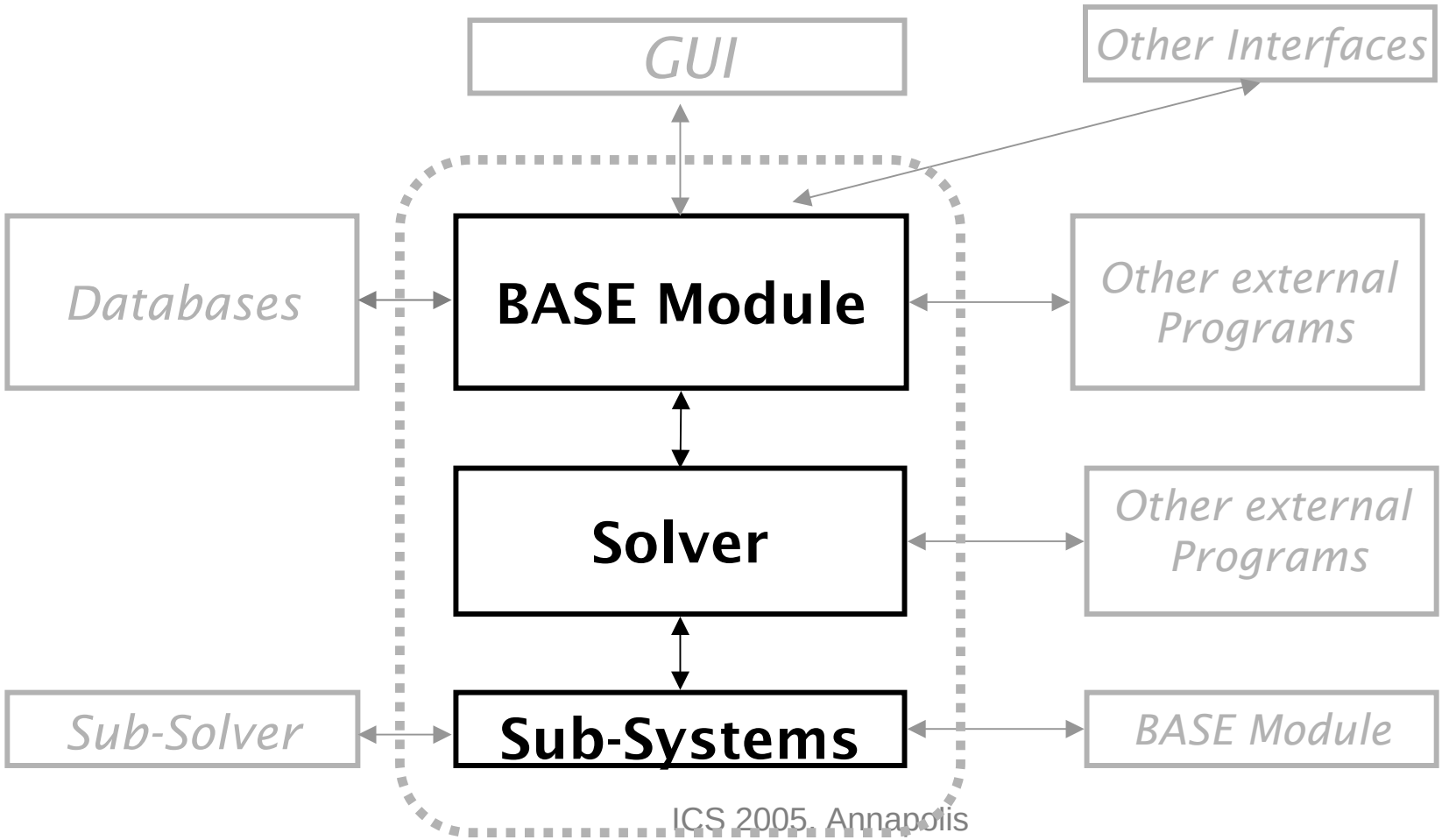
Quality control and testing of the product

- Unit testing (initial tests by developer)
- Regression testing (interaction with other modules)
- System Integration Testing (full scale testing)
- Metrics
- Bug tracking tools

Goal: Uncover defects during the complete life cycle of the software as *early as possible*

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

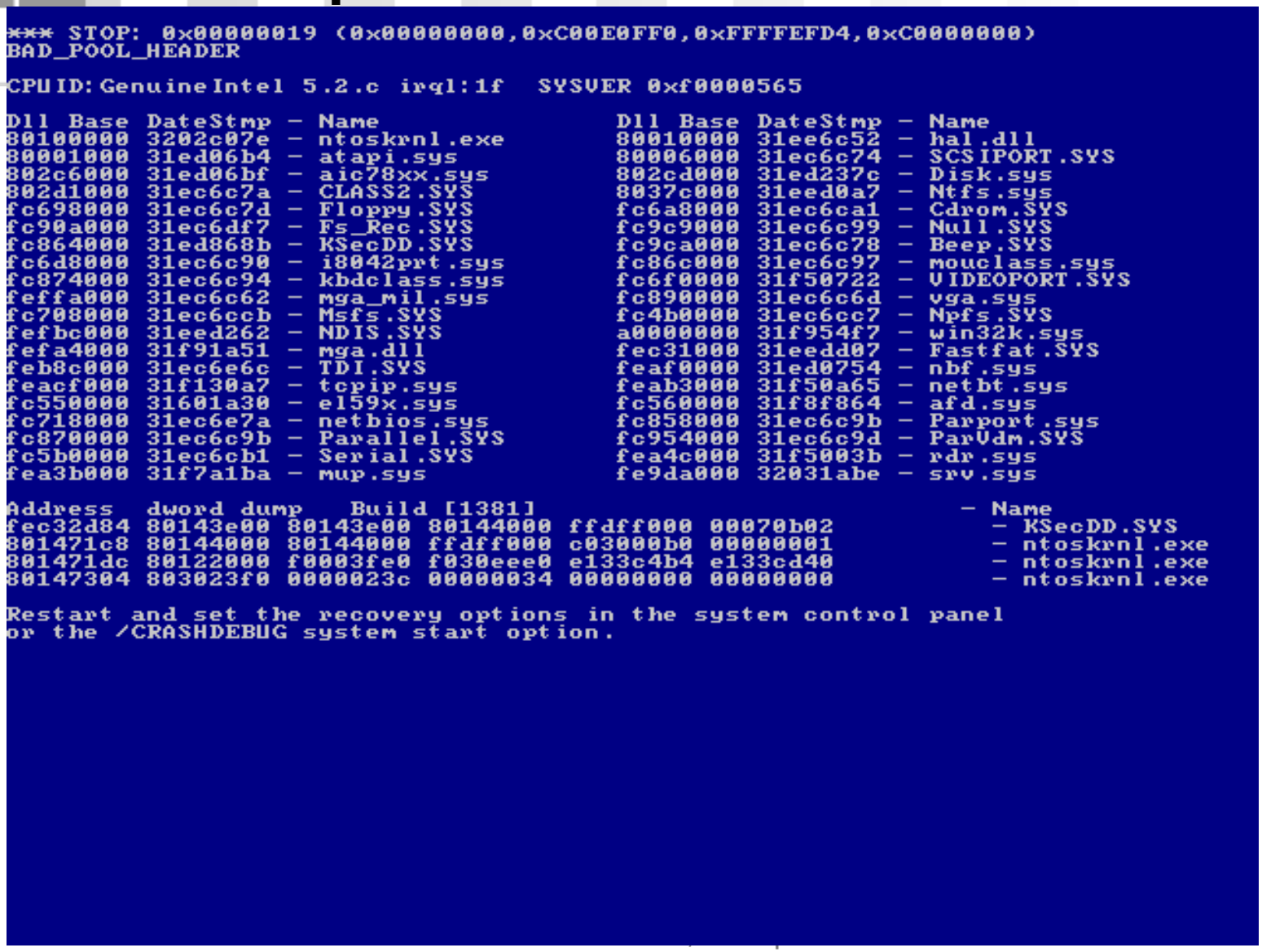
Challenges

- Expense: Rigorous SQA is initially expensive
  - MP industry is small
- Limited control about certain parts of the system
  - solvers are black box modules
- Distributed development of the system and various components

Challenges: Chance of Failure

QA issues specific to Modeling Systems:

Implementation Defect



Blue Screen of Death in Microsoft Windows NT

Not acceptable

Solver Failure

Solver does not find a solution

Acceptable

```
               S O L V E      S U M M A R Y

     MODEL   one                     OBJECTIVE  output
     TYPE    NLP                     DIRECTION  MAXIMIZE

**** SOLVER STATUS     4 TERMINATED BY SOLVER
**** MODEL STATUS      6 INTERMEDIATE INFEASIBLE
**** OBJECTIVE VALUE              948403.4844

 RESOURCE USAGE, LIMIT          1.906      1000.000
 ITERATION COUNT, LIMIT         0         10000
 EVALUATION ERRORS              0             0
```

Challenges: Chance of Failure

QA issues specific to Modeling Systems:

- Additionally, must protect the user in case of solver failure
- Complex metric for return codes is necessary
- Complicates QA activities since this adds an additional level of complexity

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 (SCM)

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 - *build early and build often*
- Simple source management system (automatic version and audit string checks)

Version Check of Source

More than 46 components!

GAMS Distribution Version Information

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

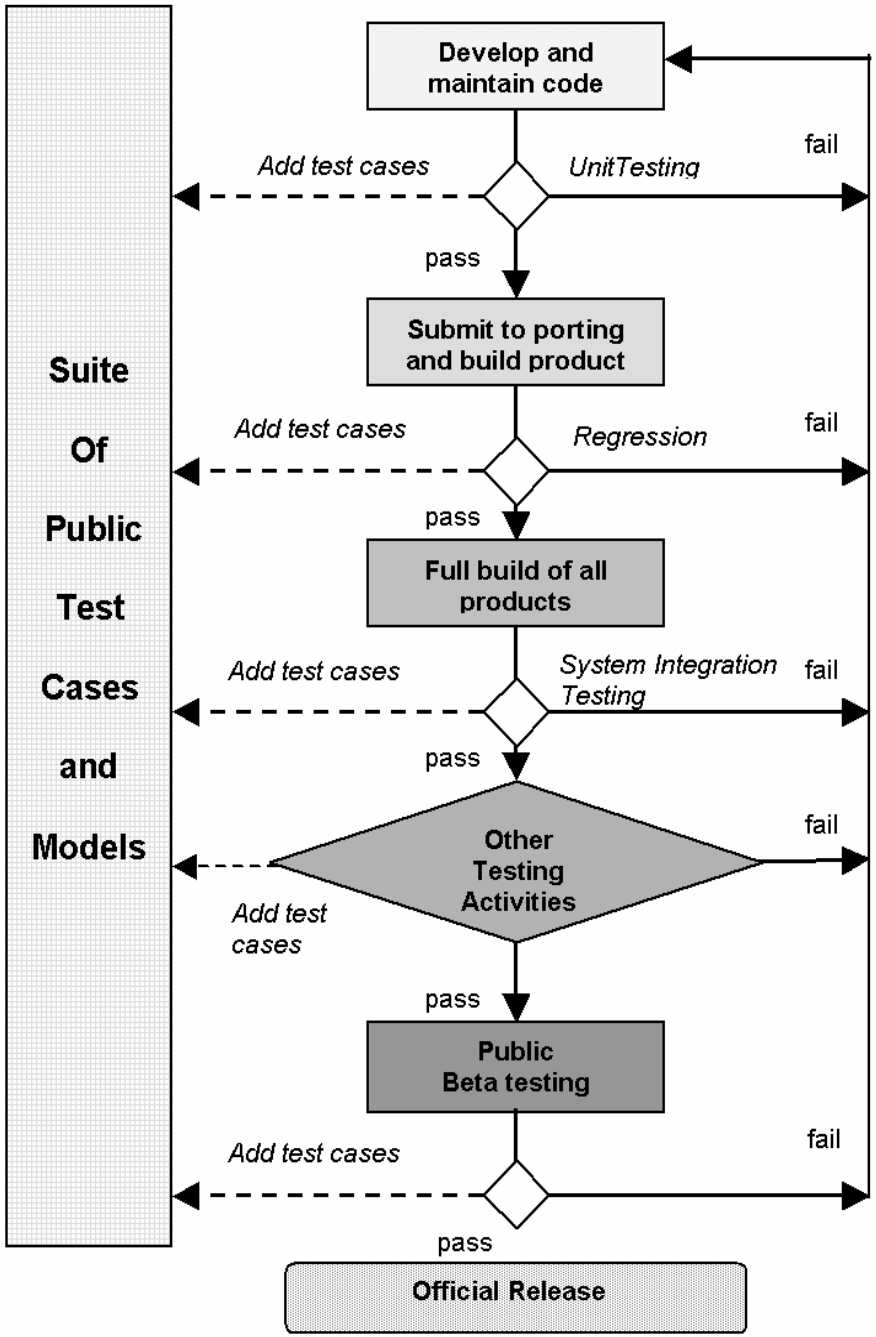
	207	210	211	212	213	BETA 214	ALFA 215
AMPLLINK:	002	002	002	003	004	005	005
AMPLM:	---	001	001	002	002	002	002
AUDITTEST:	002	002	002	002	002	002	002
BARON:	003	004	005	005	006	007	007
BARONLIB:	005	006	006	007	008	009	009
BDMLP:	057	057	057	058	058	059	059
BENCH:	---	001	001	003	004	005	005
CGAMSLIB:	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 (Testing)

Quality control and tests of the product

- Goal: Continuous quality improvement using automated and reproducible tests
- Test libraries (available online):
  - GAMS Model Library (solver tests)
  - GAMS Quality Test Models Library (modeling system test)
- Continuous addition of new test models

General testing process



Continuous addition of new test models throughout life cycle

SQA at GAMS

Quality Test Models Library

- Include tests to verify proper behavior of the system
- More than 180 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';
```

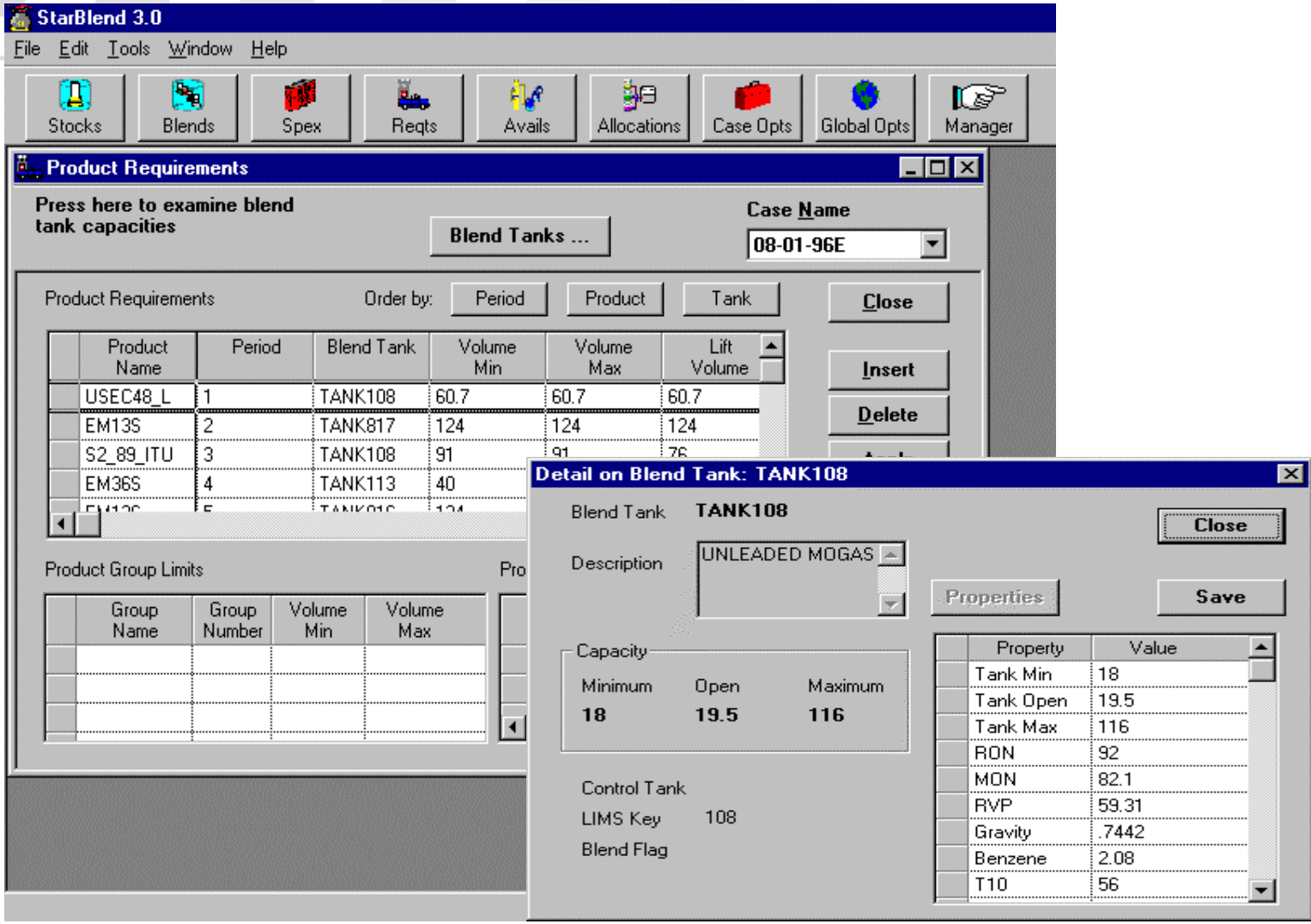
- Gives developer and users assurance about the basic functionality of the link and the solver

Client Model Testing

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

Client Model Testing

Client Application: Gasoline Blending



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 early and *build often*
- *Incorporate* QA tools into the software and share the QA process
- Make the QA process *transparent and reproducible*
- *Involve solver developers and clients* 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

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