Formal Methods in Industrial Software Standards Enforcement

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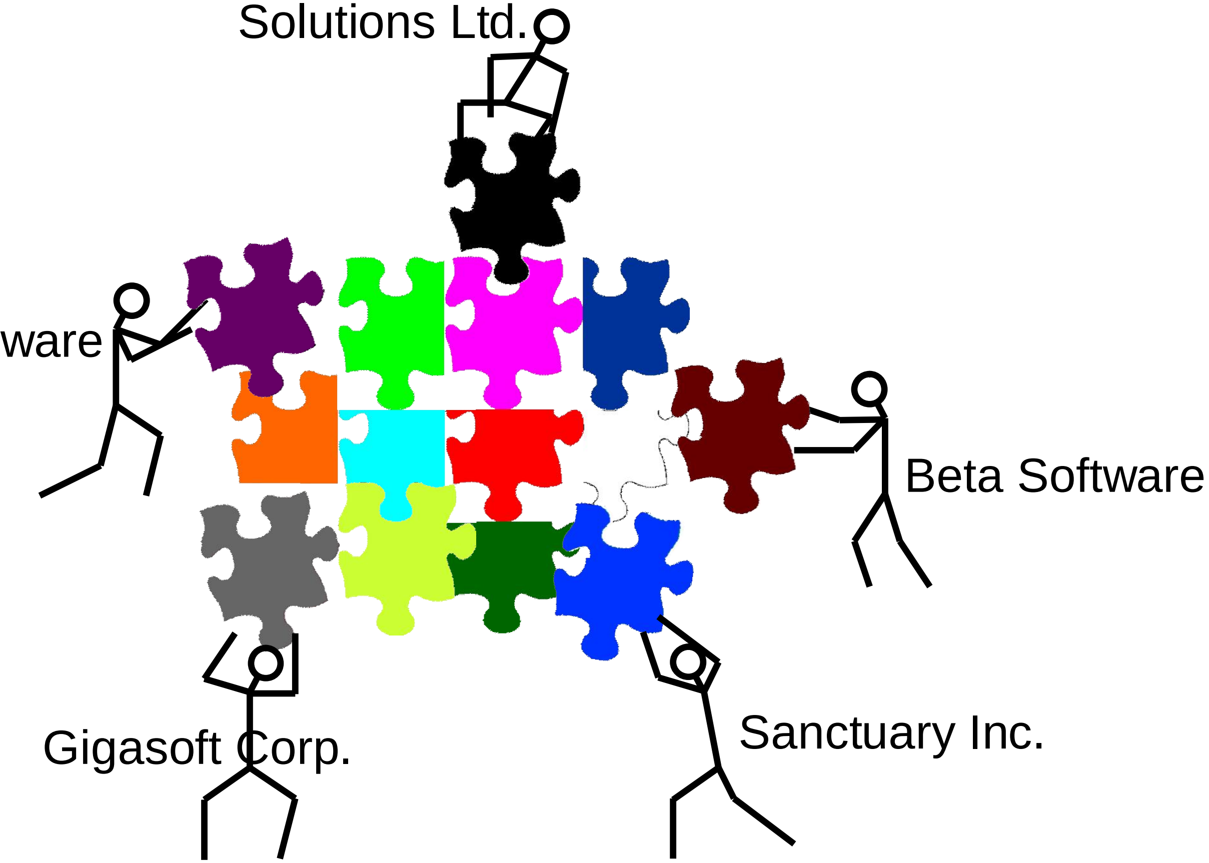
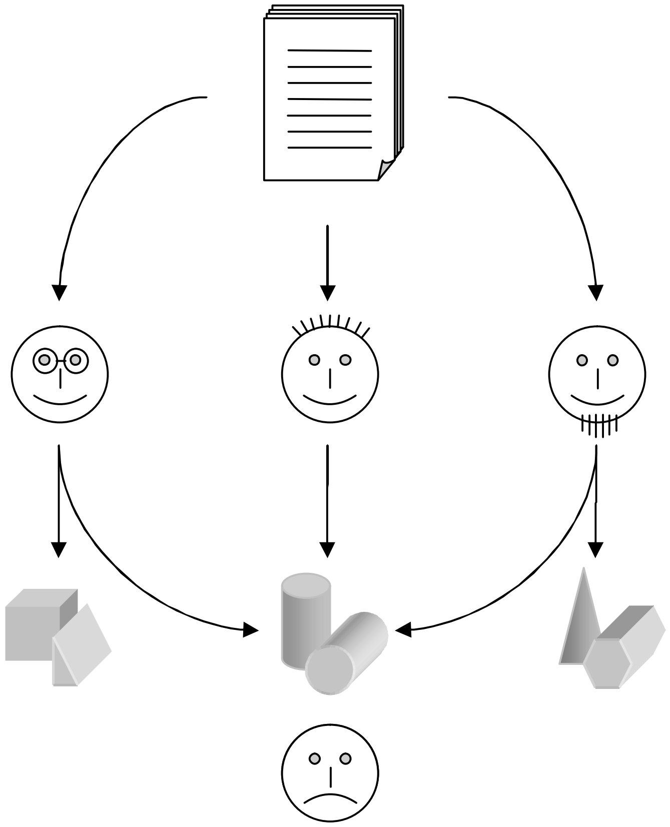
Modern Software Development



How to Make Software Robust?

Interface Standards

- Provide
  - Interoperability
- Require
  - Consistency
  - Completeness
  - Precision



Standard Formalization

- Helps to detect and remove inconsistency, incompleteness, ambiguity
- Conformance test suite

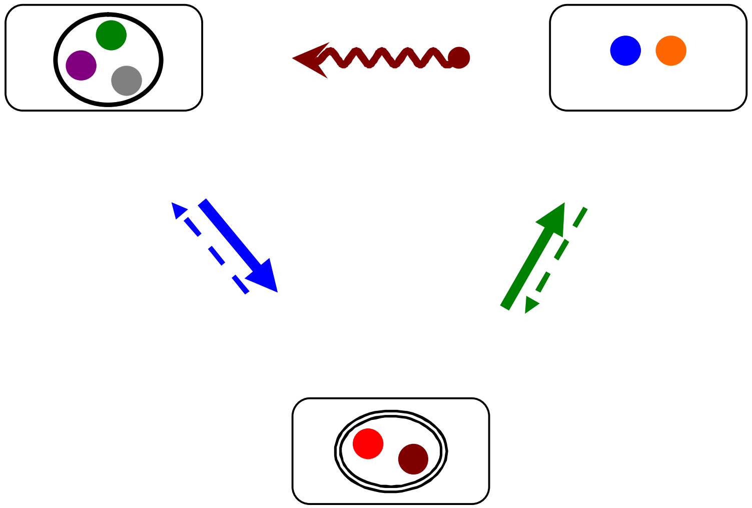
- Technical issues
  - Adequacy of formal models
  - Requirements traceability
  - Component-wise treatment of standard
  - Configurations
- Organizational issues
  - Coordination, skilled staff, etc.
  - Politics

Approach

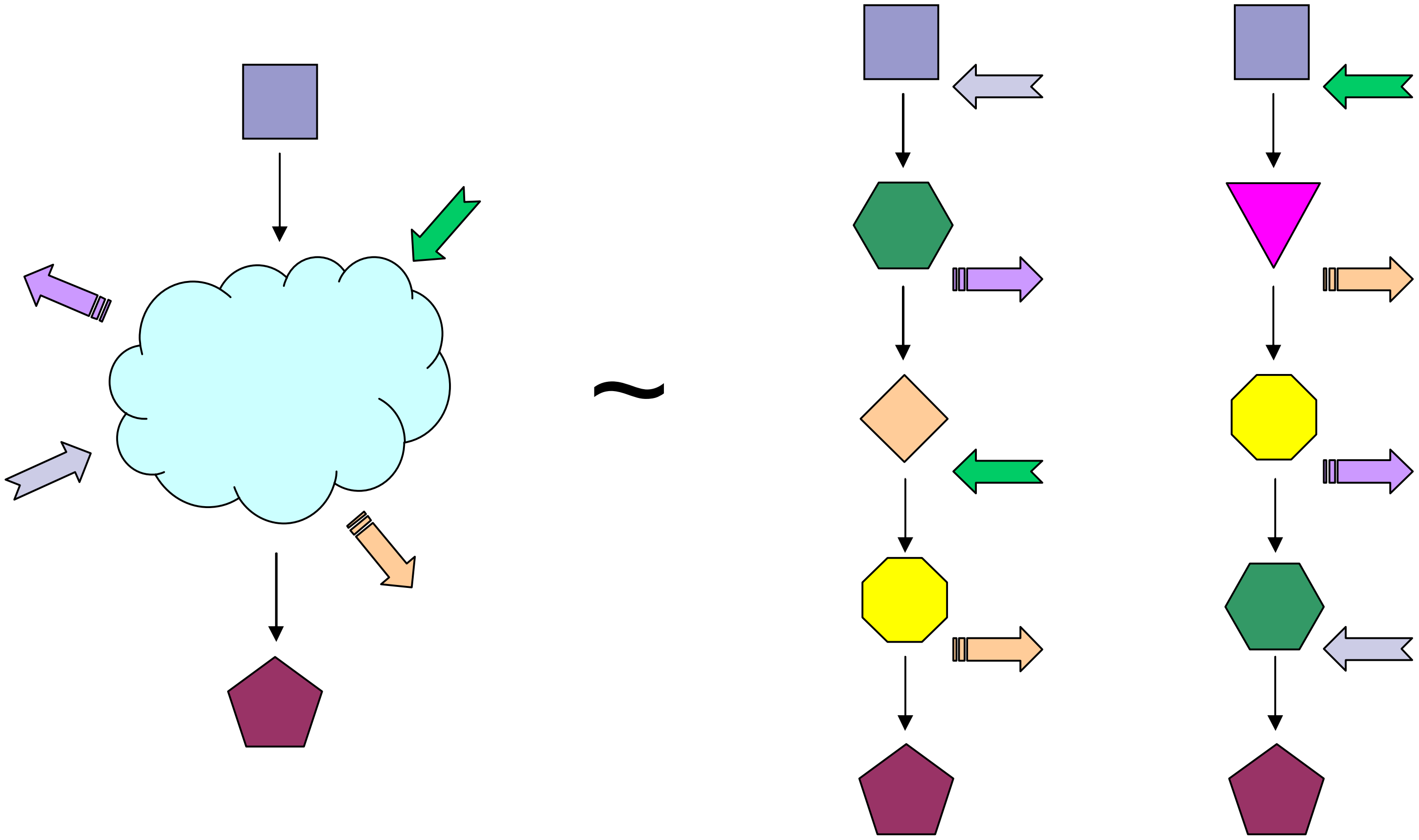
- Light-weight formal methods (model-based testing)
  - Formal specifications
    - Software contracts
    - Explicit links between specifications and standard text
  - Automated conformance test construction
    - Primary test goal – coverage of requirements
- Development process
  - Iterative development
  - Quality control
  - Training
- Propagation of results
  - Communications with standard committee
  - Participation in maintenance of standard

Software Contracts

- Components
- Internal states
  - Invariants
- Operations and ***events***
  - Preconditions
  - Postconditions



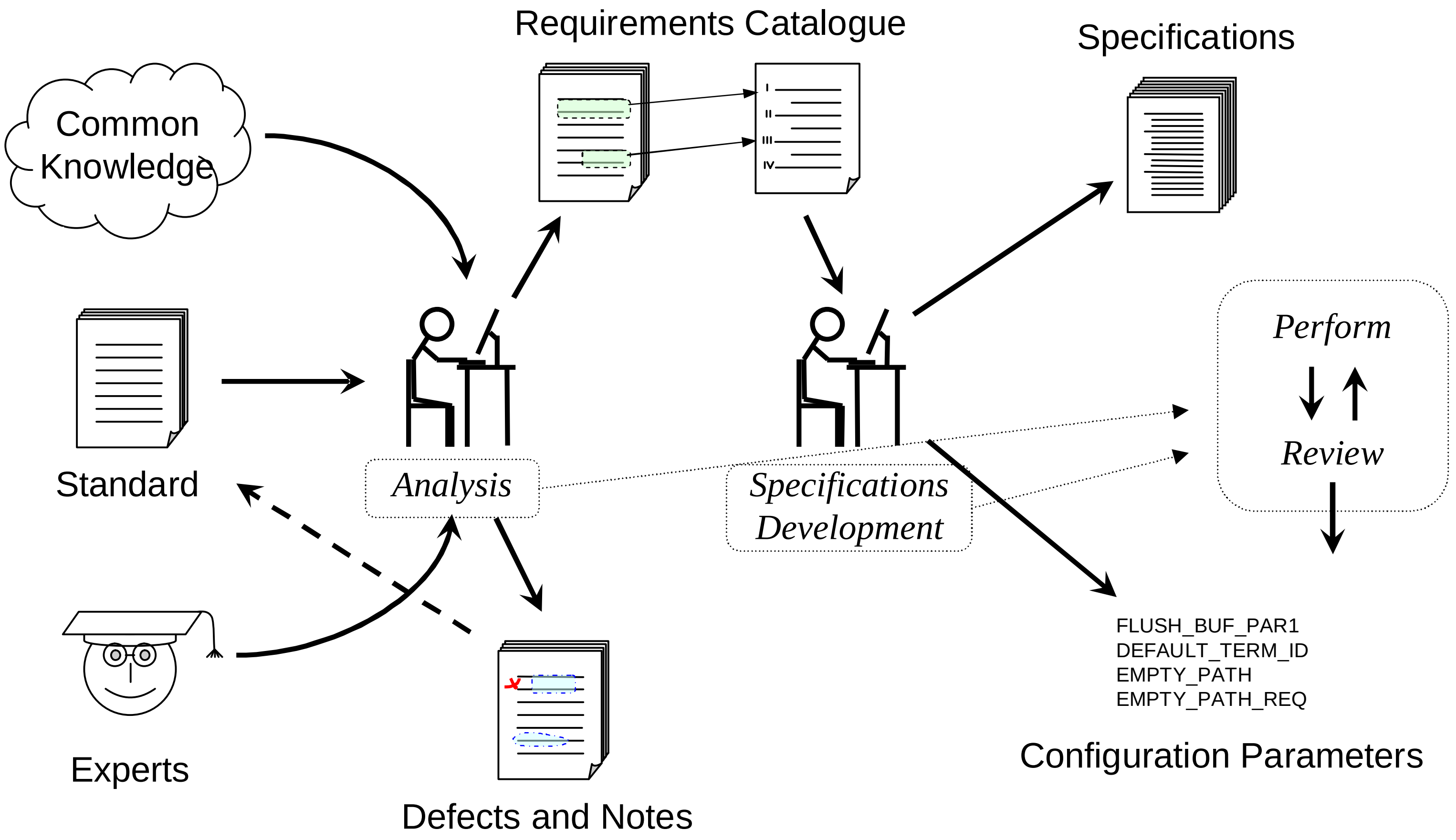
Concurrency Semantics



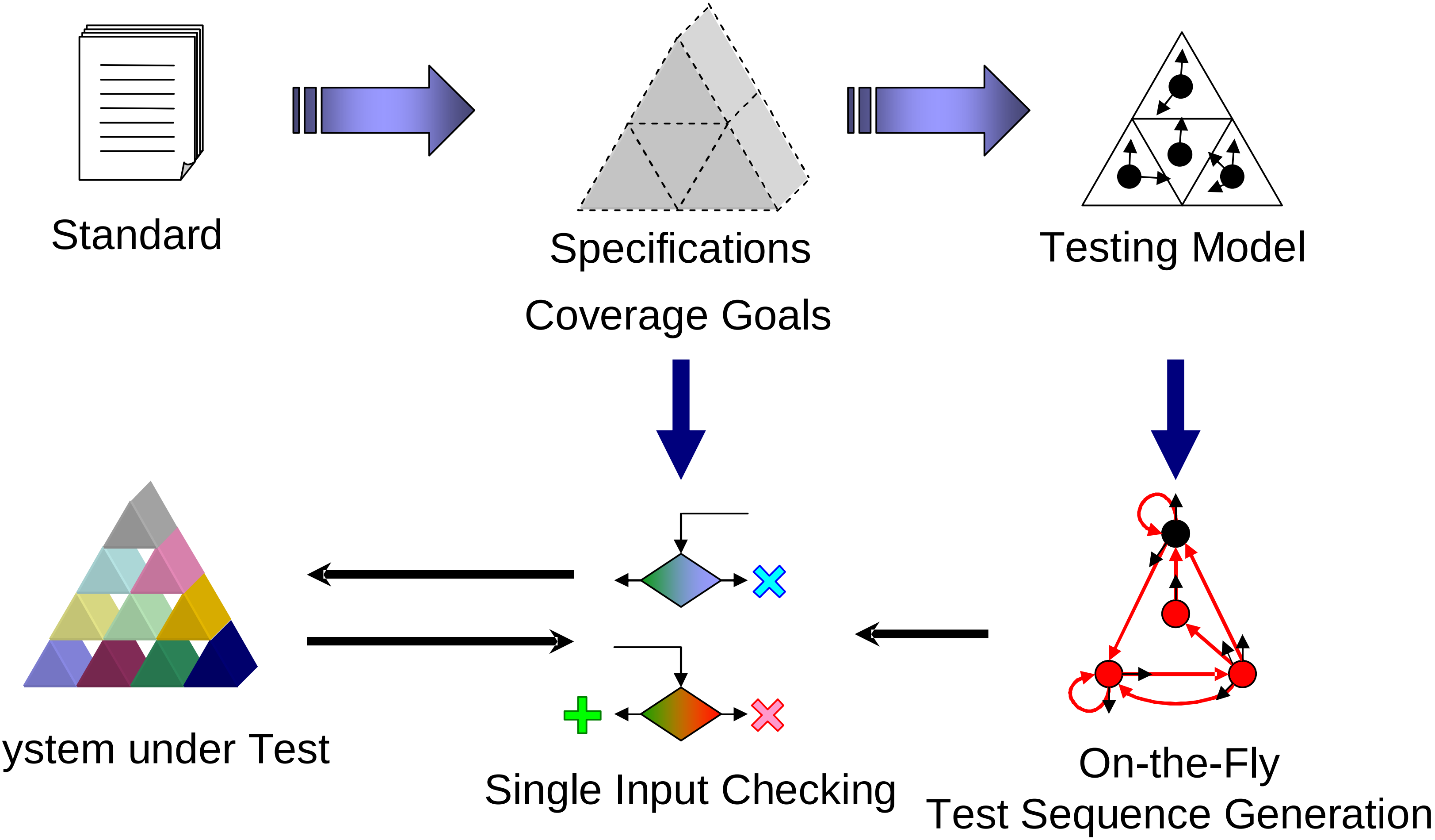
Requirements Traceability

```
specification CString* basename_spec( CString* path )  {
  post  {
    if( @path == NULL )
      REQ( "basename.04",  "If path is null, basename() shall return \".\"",
           equals( basename_spec, create_CString(".") )  );

    if( equals ( @path, create_CString("") ) )
      REQ( "basename.04", "If path is empty string, basename() shall return \".\"",
           equals( basename_spec, create_CString(".") )  );

    if( equals ( @path, create_CString("//") ) )
      REQ( "basename.03",  "If path is \"//\", basename() shall return \"//\" or \"/\"",
           (   equals( basename_spec, create_CString("/") )
            || equals( basename_spec, create_CString("//") ) )  );

    if( basename_all_slash(@path) )
      REQ( "basename.02", "If path contains only slashes, basename() shall return \"/\"",
           equals( basename_spec, create_CString("/") )  );

    CString* expected_basename = basename_model(path);
    REQ( "basename.01.01", "basename() shall return final component of path",
         equals( expected_basename, basename_spec )  );
  }
}
```

Formalization Process



Conformance testing – UniTESK



Standard

Specifications

Coverage Goals

Testing Model

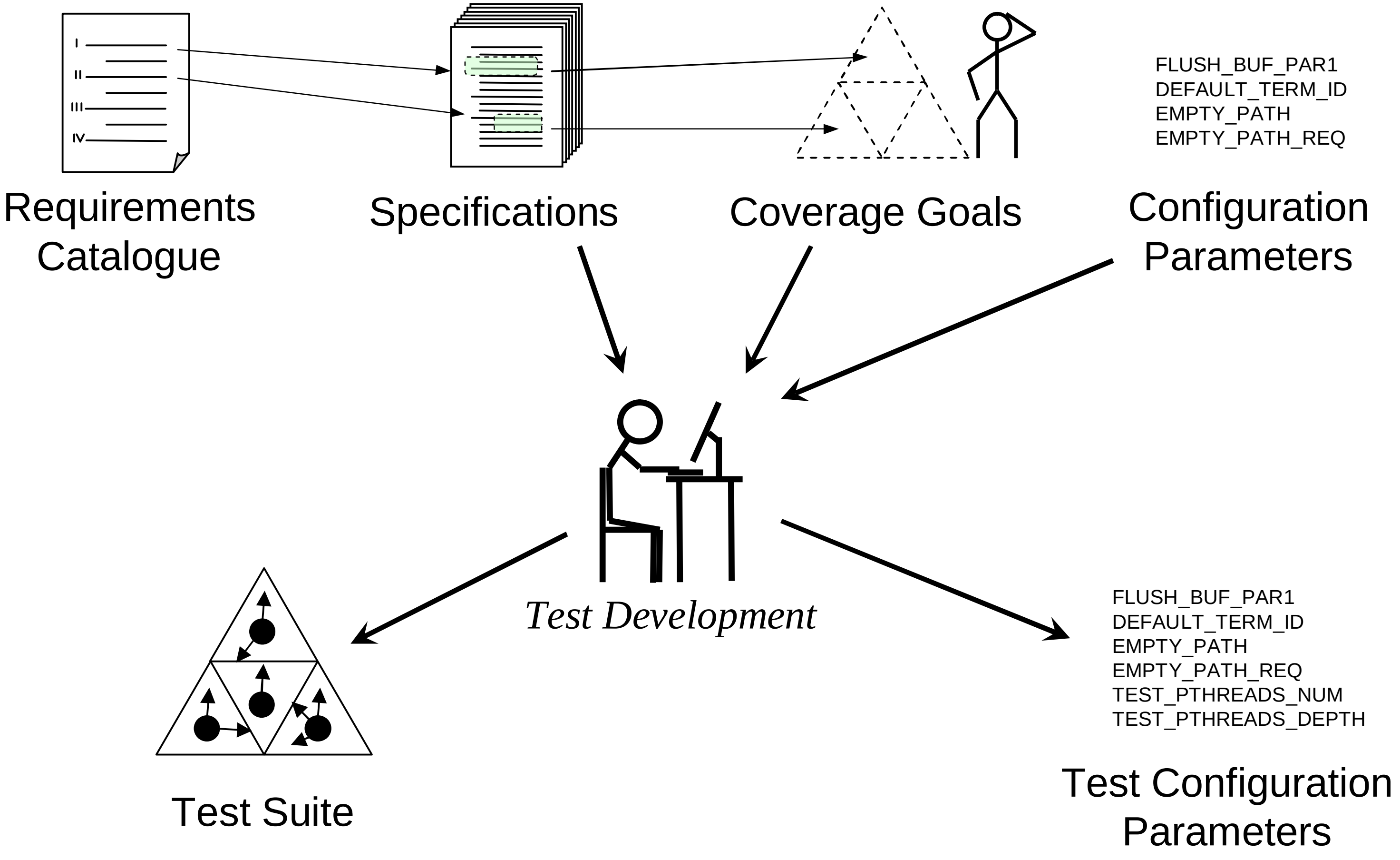
System under Test

Single Input Checking

On-the-Fly

Test Sequence Generation

Test Development Ins and Outs



Requirements Catalogue

Specifications

Coverage Goals

FLUSH_BUF_PAR1
DEFAULT_TERM_ID
EMPTY_PATH
EMPTY_PATH_REQ

Configuration Parameters

Test Development

Test Suite

FLUSH_BUF_PAR1
DEFAULT_TERM_ID
EMPTY_PATH
EMPTY_PATH_REQ
TEST_PTHREADS_NUM
TEST_PTHREADS_DEPTH

Test Configuration Parameters

Case Studies

- Test Development for IPv6 2001-2002
- Formalization of IPMP-2 (ISO/IEC 13818-11:2004) 2004
- Formalization and conformance test development for LSB 3.1 (**OLVER**) 2005-2006

OLVER Project

- **Customer** : Russian Federal Agency for Science and Innovations
- **Task** :

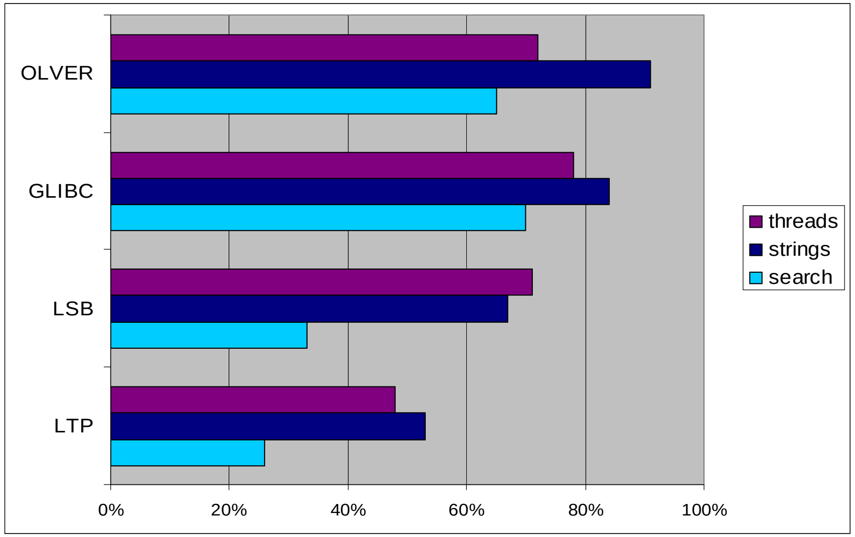
  Develop formal specification of standard reqs and conformance test suite
- **Standard** : Linux Standard Base (LSB) 3.1 Core (ISO/IEC 23360-1:2005)
  - Extensive references (~85%)
    - ISO/IEC 9945-1,2:2003 – POSIX
    - ISO/IEC 9899-1999 – C Language (Library)
    - X/Open Curses, System V Interface Definition, Large File Support
  - > 6000 pages of different standards
  - 1532 functions
  - threads, inter process communication, timers, signals, sockets, RPC, memory management, terminals, file system, large file support, formatted input/output, string manipulation, locales, maths, etc.

Project Progress

Current Results (01.06.2006)

- Standard text analysis
  - ~170 groups of functions
  - ~ 930 functions
  - ~ 10500 primary requirements
  - ~ 40 defects found
- Formalization & test development
  - ~ 740 functions
  - ~ 400 KLOC specifications & tests
- Test quality (code coverage)
  - Higher, than in analogous projects (LTP, LSB TS)
  - Roughly equivalent to implementation-based test suites
- http://www.linuxtesting.org

	LTP	LSB	GLIBC	**OLVER**
threads	48%	71%	78%	72%
strings	53%	67%	84%	91%
search	26%	33%	70%	65%



Application of results

- Active contacts with standard committee (FSG)
  - All defects in standard during last 3 months are reported by OLVER team
- Future integration with official LSB conformance test suite

Conclusion

- Long-history standards are stable enough to get significant and practically important benefits from formalization
- Light-weight formal methods are capable to manage with such huge tasks
- Most issues are common with generic huge projects (without formal methods)
  - Iterative development process
  - Adequate planning
  - Project repository
- Necessary skills can be trained

Contacts

- Linux Verification Center web site
  http://www.linuxtesting.org
- UniTesK projects web site
  http://www.unitesk.com
- Group leader
  Alexander K. Petrenko
  petrenko@ispras.ru

References

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Thank you!