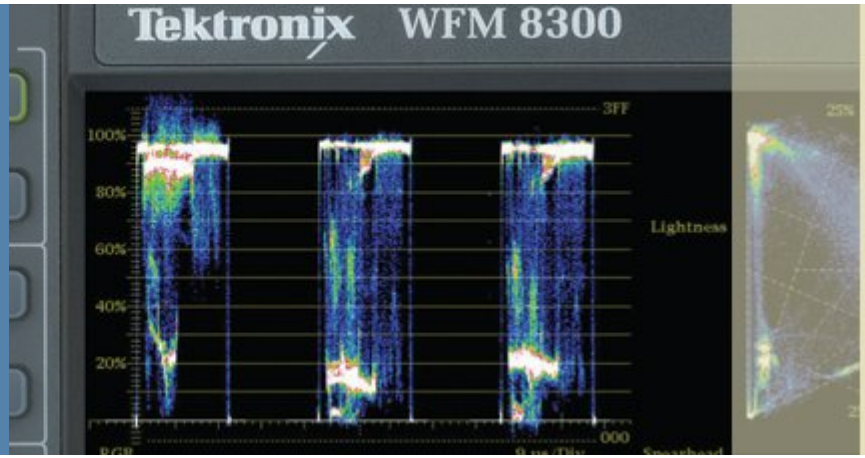
Using Static Code Analysis to Find Bugs Before They Become Failures



Presented by Brian Walker

Senior Software Engineer,
Video Product Line, Tektronix, Inc.

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In the Beginning, There Was Lint

- Syntactic analysis found many simple coding mistakes
  - Mismatched arguments
  - Incompatible data type usage
  - Uninitialized variables
  - Printf() format argument mismatch
- Analyzed one source file at a time
- Generated lot's of warnings
  - Not all of them useful
- Function is now integrated into most compiler

Beyond Lint

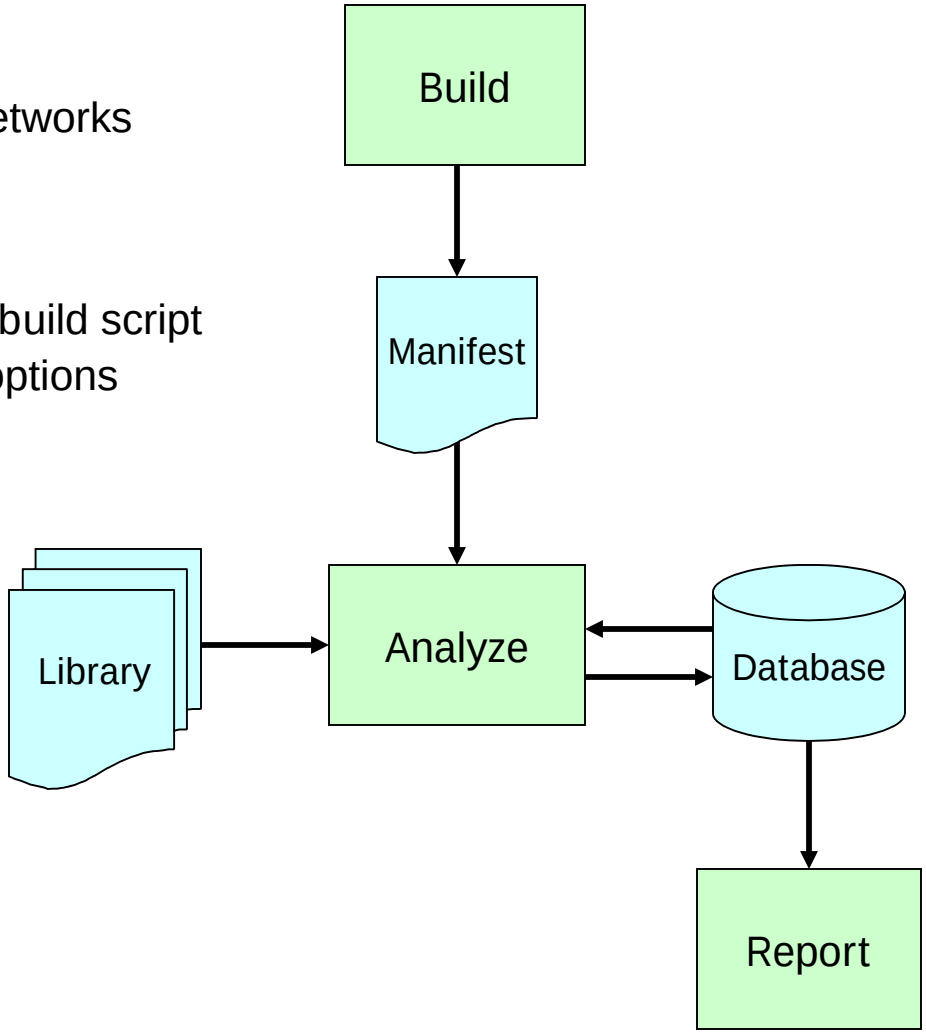
- Functional analysis without execution
  - Functional analysis, not just compilation errors
  - Data flow and control flow analysis
  - Typically automated
- Incorporates some aspects of reverse engineering
  - Analyzes objects and their usage
  - Follows resource allocation, initialization and de-allocation
- Considers the whole program
  - Analyses entire build, not just individual files
  - Examines all execution paths within functions and between functions
  - Calculates range of possible values for each variable
  - line by line, complete coverage (for known issues)
- Quality, not quantity
  - Balance aggressiveness with restraint

Elements of a Static Code Analysis System

- Library of issues and patterns
  - Identifies problem severity
  - Ability to define new patterns or suppress unwanted patterns
- Database for tracking issues
  - Manage issue priority and ignore false positives
  - Identify new issues over time and track as source files change
  - Identify fixed issues
- Accessible issue reporting interface
  - Detailed description of specific issue and location in source code
  - Assist developers to understand, investigate and fix bugs
  - Sometimes integrated into IDE
- Compilation process to perform analysis
  - May require as much time as actual build
  - Must be run with the same options and compiler flags

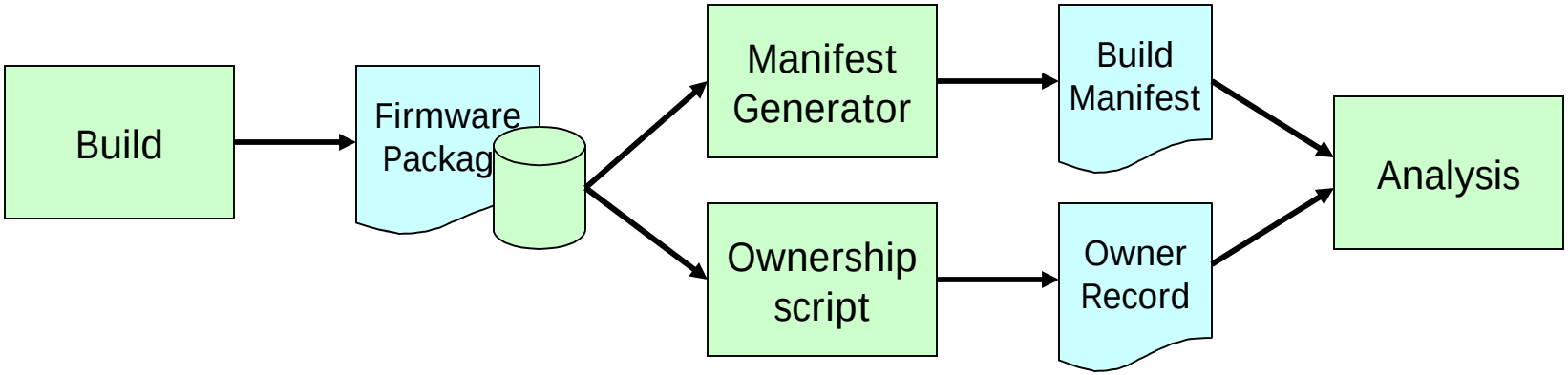
Using the Klocwork Static Analysis Tool

- Klocwork Insight
  - Software developed at Nortel Networks
  - Analyzes C, C++, C# and Java
- Uses build auditing approach
  - Manifest generator runs normal build script
  - Captures files, commands and options
  - Generates manifest
  - Directs analysis
  - Consults library
  - Queries database
  - Updates database
  - Generates reports



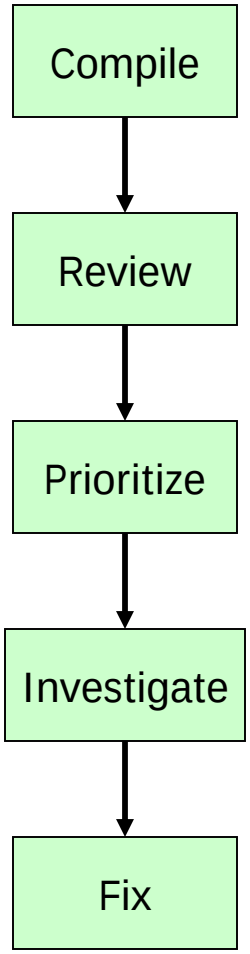
Configuring the Analysis

- Klocwork does not support incremental builds
  - Needs to know all of the files in the build, needs to be reminded
  - Vendor suggested rebuild the manifest after adding/removing files
  - or, Perform full build every time
- Integration with ClearCase
  - ClearCase records complete configuration record for build
  - Build manifest file format clearly described in Klocwork documentation
  - Developed simple script to create manifest from ClearCase config record
  - Generate file ownership from version history



Integrating Static Analysis in our Environment

- Incorporated into nightly builds
  - Klocwork analysis runs as a step in the nightly build
  - Uses ClearCase configuration record to produce manifest
  - Uses ClearCase version history to determine file ownership
- Manual review of new issues reported
  - Review of new and uncited issues
  - Set status according to severity and priority
  - Forward new issues to team members
- Investigate and make changes to source code
  - Analysis usually provides enough detail to quickly fix issue
  - Use browser to search for declarations and implementation



Managing Issues in Klocwork

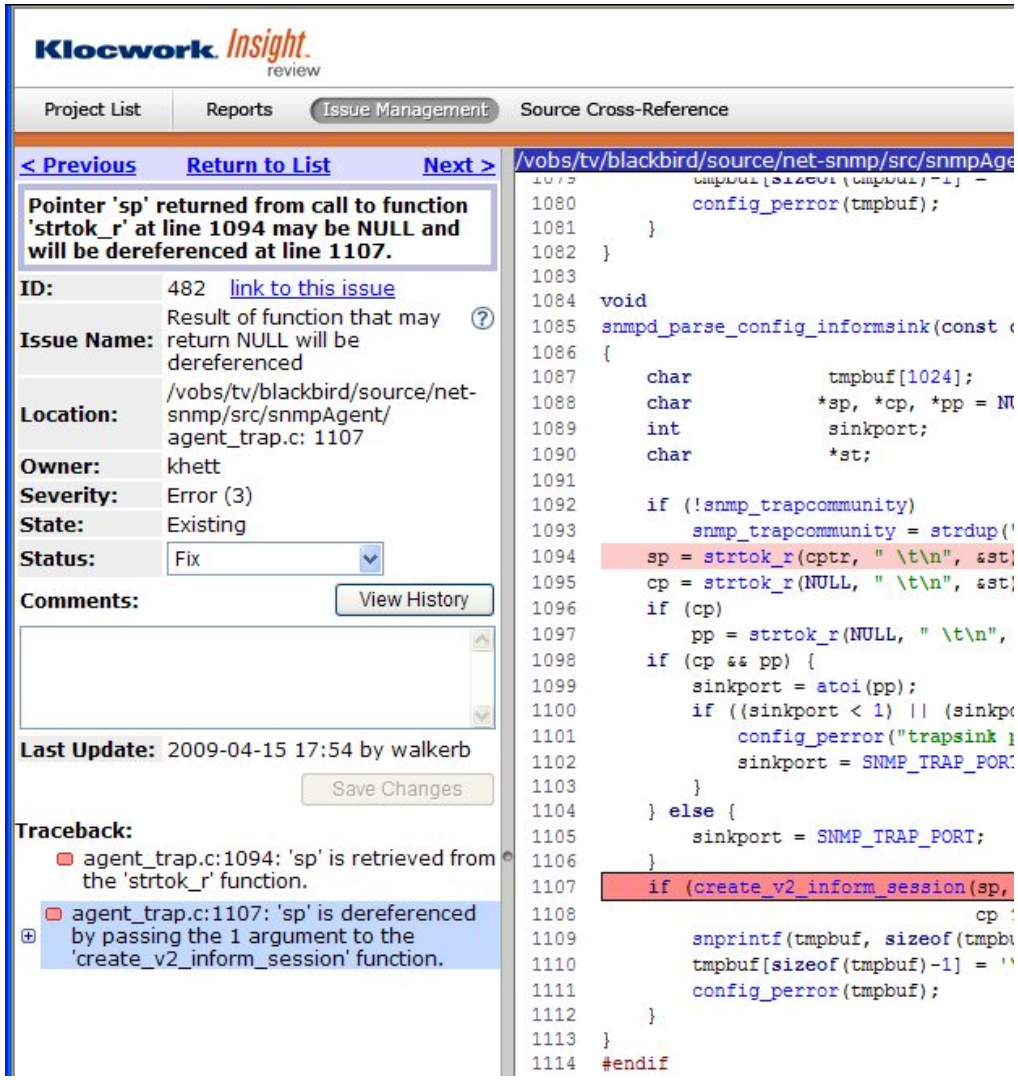
- Klocwork determines the “state” of an issue
  - Identifies issues as new, existing, recurred, fixed or not in scope
  - Maintains history of current issues
  - Detects when new issues are discovered
- Reviewer determines the “status” of an issue
  - Analysis -> Citing -> Resolution
  - Every new issue starts with status set to analyze (uncited)
  - Users choose fix, fix in next release, fix in later release, not a problem
  - Reviewer and implementer can add notes to issue record
  - Analyze or Fix status identifies open issues
- Issues with issue management process
  - Would be nice if citing could automatically generate bug report
  - Does not provide real tracking capability

Klocwork Issue Reports

- Contains a specific description of the problem
  - “Array ‘foo’ of size 22 may use index values or -2 .. -1. Also there are similar errors on lines 491, 494.”
  - Provides traceback of analysis showing all locations that affect value
  - Traceback references highlighted in source code listing
  - Nested references can be expanded for deeper dive
- Cross reference interface allows exploration of source code
  - Finds declarations functions, variables, macros and constants
  - Finds where items are used, referenced, read or written
  - Welcome feature to aid in the investigation of issues

Klocwork Issue Detail Display

- Issue description
  - Summary
  - Link to record
  - Name
  - Location
  - Owner
  - Severity
  - State
  - Status
  - Comments
- Traceback of problem path
  - Listed in order of execution
  - References to lines of code
  - Nested references to other functions
  - Nested references expand for deeper investigation



Klocwork Issue Identification

- Klocwork uses short hand notation to identify problem types
  - ABR: Array Buffer Overrun
  - NNTS: Non-Null-Terminating String
  - Tends to be concise and memorable
  - Can often determine type of problem in a glance
- Online documentation tends to be well written and informative
  - Provides description, specific vulnerabilities, risks, mitigation and prevention
  - Focus on security
- One common distinction: must vs. might
  - “Must” issues indicate error that occur as a result of a single failure
    - NPD.FUNC.MUST: NULL pointer returned by function always dereferenced
  - “Might” indicates a failure might occur if more than one condition is true
    - NPD.FUNC.MIGHT: NULL pointer dereferenced under certain conditions

Types of Issues Found by Static Analysis

- Null pointer dereferences
  - Very effective in discovering null pointer dereference issues
  - Many due to not checking pointer parameters for NULL
  - NPD.CHECK.MIGHT: pointer checked for NULL but still dereferenced
  - Can be quite insidious and may be overlooked in code review

```
int handle_request( int op, int reqid, PduType *pdu, SyncState *state)
{
    if (reqid != state->reqid && pdu && pdu->command != MSG_REPORT) {
        return 0;
    }
    if (op == RECEIVED_MESSAGE) {
        if (pdu->command == MSG_REPORT) {
            blah;
            blah;
            blah;
        }
    }
```

Types of Issues Found by Static Analysis

- Array buffer overruns
  - Klocwork has discovered quite a few flavors
  - String handling is common theme, especially regarding numbers

```
char buffer[8];
sprintf( buffer, “%s%d”, type, value);
```

- Memory leaks
  - Often caused by improper error handling
  - Often not covered by functional testing
  - Might be covered by unit testing
  - C++ class constructors and destructors
    - Expects that memory allocated in a constructor is freed in destructor
    - Also expects copy constructor and assignment operator
  - Death by a thousand pin pricks

Types of Issues Found by Static Analysis

- Use of freed memory
  - Checks for use of memory pointer after return to system heap
  - Did not expect to see in our software
  - Found in third-party and open source components
- File Resource Leaks
  - Like memory leaks, often the result of improper error handling
  - Klocwork reports as lower priority
  - Have found instances where file handles can be lost
- Concurrency violations
  - Our software is often multithreaded
  - Uncovered problems with semaphore handling
    - Warns when semaphores taken but not returned within a function
    - Warns when thread goes to sleep while still holding semaphore

Types of Issues Found by Static Analysis

- Security vulnerabilities
  - Becoming a greater concern as more devices become connected
  - Secure programming practices less obvious and often overlooked
  - Vulnerable program will still pass functional tests
  - Testing requires effort to actively exploit vulnerabilities
- Number of reported vulnerabilities continues to grow
  - Risk of failure includes potential for exposure of sensitive data
  - Prevention is far more effective than remediation
- Most vulnerabilities can be traced to a relatively small number of programming errors
  - Klocwork references Common Weakness Enumeration dictionary
  - Klocwork recently added support for MISRA C and C++ coding standards
    - Adopted by aerospace, telecommunications, medical, defense and others

Analyzing the Analysis

- Finds many high-quality issues in the source code
  - From 500,000 lines of C/C++ in more than 2000 files
  - Found 1500 issues
  - Rejected 175 issues
- Somebody had to look at those 1500 Issues
  - Established code base, and third-party contributions
  - Examine, prioritize and eventually fix
- True value seen after bug debt has been paid
  - Problems found can be quickly identified and corrected
  - Most useful when employed on new software as preventative

Analyzing the Analysis

- Potential to save many hours of frustration
  - Hours spent trying to reproduce and capture and instance of a crash bug
  - Race conditions can be the most devious and time consuming
  - Found in Klockwork database after the fact.
- Other bugs are more treacherous
  - Array access may overflow into unrelated data structure
  - May cause mayhem in unrelated thread
  - Or write over a virtual table causing mysterious crash
  - Debugging requires setting watch point to catch in the act
- But, not perfect
  - Has reported at least one false positive
  - Has missed at least one array buffer overrun that caused random crash
  - Ideally maintains a balance between useful and annoying
- Promotes good programming practices

Looking Forward

- Desktop integration
  - Potentially provide instant feedback to developers
  - Developers could fix errors before committing to version control system
  - Many vendors provide integrations for Eclipse and Visual Studio
  - Still perform bulk of analysis nightly
- Compiler integration
  - Some vendors provide static analysis in compiler
  - Integrated with build processes
  - Limits choice of compiler

Fitting it all Together

- Excellent tool for finding bugs early in development
  - Compliments compiler warnings
  - Does not require actual hardware to analyze software
- Complements dynamic analysis (functional testing)
  - Able to follow all/most paths within each function
  - Testing and analysis are adept at finding different kinds of faults
    - Cannot test functional requirements through static analysis
    - Cannot reproduce all scenarios through emulation
- Complements formal code review and peer review
  - Consistently finds instances of known issues
  - Cannot replace expert eyes of peers
- Best option for testing third-party and open source software
  - Most open source software is provided “as-is and without warrantee”
- Increases the tribal knowledge of an organization

Questions and Answers

Brian Walker

Brian.R.Walker@tektronix.com