U S E R ' S G U I D E

TestWorks
for
Unix
Version 3.1

Software T*est*W*orks* Test Tool Suite

SOFTWARE RESEARCH, INC.

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home/l1/documentation/user-manual/regression/97UNIXbooks/testworks/97twrkux.book

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Preface

Congratulations!

By choosing the TestWorks integrated suite of testing tools, you have taken the first step in bringing your application to the highest possible level of quality.

Software testing and quality assurance, while becoming more important in today's competitive marketplace, can dominate your resources and delay your product release. By automating the testing process, you can assure the quality of your product without needlessly depleting your resources.

Software Research, Inc. believes strongly in automated software testing. It is our goal to bring your product as close to flawlessness as possible. Our leading-edge testing techniques and coverage assurance methods are designed to give you the greatest insight into your source code.

TestWorks is the most complete solution available, with full-featured regression testing, coverage analyzers, and metric tools.

Audience

This manual is intended for software testers who are using TestWorks tools. You should be familiar with the X Window System and your workstation.

Content of Chapters

Chapter 1	*INTRODUCTION TO TESTWORKS* introduces the concepts of automated testing.
Chapter 2	*FREQUENTLY ASKED QUESTIONS* answers a wide range of questions about TestWorks and software testing.
Chapter 3	*UNDERSTANDING THE USER INTERFACE* gives a brief overview of the **TestWorks** window and its commands.
Chapter 4	*USING THE TESTWORKS WINDOW* explains how to use the **TestWorks** window.
Chapter 5	*A NOTE ABOUT THE GUI RESOURCE FILE* gives information about the default settings for **TestWorks** GUI's.
Chapter 6	*GLOSSARY* lists terms concerning software testing that are commonly used in the SQ community and includes specifics to the **TestWorks** product set.
Chapter 7	*TESTWORKS INDEX* provides an approach to assess the relative quality of a software system.
Chapter 8	*TESTWORKING MOTIFBURGER* explores the entire suite of Software Research testing tools using the sample application MotifBurger.

Typefaces

The following typographical conventions are used in this manual.

boldface Introduces or emphasizes a term that refers to TestWorks' window, its sub-menus and its options.

italics Indicates the names of files, directories, pathnames, variables, and attributes. Italics are also used for chapter, manual and book titles.

"Double Quotation Marks"

Indicates chapter titles and sections. Words with special meanings may also be set apart with double quotation marks the first time they are used.

`courier` Indicates system output such as error messages, system hints, file output, etc..

`Boldface Courier`

Indicates any command or data input that you are directed to type. For example, prompts and invocation commands are in this text. (For instance, **stw** invokes TestWorks.)

CHAPTER 1

Introduction to TestWorks

This chapter introduces the *TestWorks*™ suite of tools and its components.

1.1 TestWorks Overview

TestWorks™, the broadest suite of leading-edge testing tools available, is designed to automate your software testing process. It is comprised of three product bundles that work independently or as a fully integrated tool suite to create an efficient, automated testing environment. They are the following:

- STW / Regression™
- STW / Coverage™
- STW / Advisor™

STW/Regression™ automates and manages the execution and verification of tests on your software applications, significantly increasing test speed and accuracy. The suite includes True-Time and Object-Level capture / playback and sophisticated test management capabilities for completely unattended execution of tests. **STW/Regression** is ideal for host and client-server applications as it uses automated load generation from a single workstation for multi-user applications.

The **STW/Coverage**™ tools use three independent measurements to ensure the thoroughness of test cases: logical branch (C1) for unit testing, function-call (S1) for system and integration tests, and path class (Ct) for critical functions. Using recursive descent compiler technology, the S**TW/Coverage** tools can easily handle standard constructs and dialects of C and C++. The suite also supports programs written in Ada and FORTRAN.

STW/Advisor™ provides static source code analysis and measurement. Seventeen metrics measure a program's data, logic and size complexity. Building on existing tests to create new ones, test data / file generation more fully tests your applications.

1.1.1 STW/Regression

STW/Regression™ is designed to overcome the tedious and error-prone process of manual testing by automating the execution, management and verification of a suite of tests. Three component are included in *STW/Regression*:

- *CAPBAK*™ for automated capture and playback of user sessions.
- *SMARTS*™ for test organization and management.
- *EXDIFF*™ for test verification.

CAPBAK records all user activities during the testing process including keystrokes, mouse movements, and captured bitmap images and ASCII values. The captured images and characters provide baselines against which future test runs are compared. *CAPBAK*'s automatic synchronization ensures reliable playback of these test sessions, allowing tests to be run unsupervised as many times as the tester wants.

SMARTS organizes *CAPBAK*'s test scripts into a hierarchy for execution individually or as a part of a test suite, and then evaluates each test according to the verification method selected.

EXDIFF compares bitmap images or ASCII value files, while discarding extraneous discrepancies during the differencing process.

1.1.2 STW/Coverage

STW/Coverage's coverage analyzer tools give a numerical value to the completeness of a set of tests. They also show what parts of an application have been tested, so that effort can be focused on creating test cases that will exercise the parts of your code that were not previously tested.

STW/Coverage measures runtime coverage at the following levels:

- **Logical Branch**: For unit testing; measures the number of times each branch has been exercised for both True and False conditions.
- **Call-Pair:** For integration and system tests; measures the number of times each function-call has been exercised, as errors in parameters are extremely common.
- **Path**: For critical functions; measures the number of times each path, which is a sequence of branches, was exercised.

Three analyzers and an observation tool are included in *STW/Coverage*:

- *TCAT*™ for logical branch analysis**.**
- *S-TCAT*™ for call-pair analysis.
- *TCAT-PATH*™ for path analysis.
- *T-SCOPE*™ for dynamic visualization of coverage results.

STW/Coverage's analyzers gather usage statistics on programs (as they are being exercised) and create coverage reports. Dynamically, *STW/Coverage* generates graphs which reveal the control-flow structure of a module and call-trees which show the caller-callee structure of a program. These displays show very quickly what is and what is not being exercised in a set of tests.

1.1.3 STW/Advisor

As software complexity grows, developers, testers and managers have to manage the development process and allocate limited resources. *STW/Advisor* analyzes source code to provide measurements and reports that enable these key decisions to be made. Three components are included in *STW/Advisor*:

- *METRIC*™ for quantitative analysis.
- *STATIC*™ for semantic and syntax analysis.
- *TDGEN*™ for test data / file generation.

METRIC analyzes C, C++, Ada or FORTRAN source and calculates the Halstead Software Science Metrics to measure data complexity, the Cyclomatic Complexity Metrics to assess logic complexity, and basic size metrics, such as number of lines, comments and executable statements. User-definable thresholds can be used to establish code acceptance standards, locate error-prone functions, and help better schedule and control projects.

C programs are often the source of obscure bugs; many compilers pass bugs as legal C statements. *STATIC* handles C's unique problems by providing detailed syntax and semantic error / inconsistency reports for C programs. *STATIC* performs more detailed analyses than compilers, including locating non-portable constructs. Analysis results are presented in an easy-to-read report.

In order to make up for limited resources and more fully test applications, *TDGEN* creates additional tests from existing tests. *TDGEN* accomplishes this by mapping a template file and an input test values file into a test case, creating additional tests by substituting either random or sequential selections of values.

Note: For certain product sets, we have included postscript (**.ps**) files of the user manuals. Check your media to see if these files are available.

1.2 TestWorks Supported Platforms

TestWorks products are available on the following platforms: DEC Alpha using OSF/1; HP9000/7xx-8xx under HP-UX; IMB RS-6000 under AIX; NCR 3000 under SVr4; SGI under IRIX; Sun SPARC under SunOS and Solaris; 80x86 under SCO/ODT, Solaris, MS/Windows 3.1X, Windows NT and MS/Windows 95.

In addition to the most complete line of software testing products on the market, **Software Research, Inc.** offers extensive seminars, training, and high-quality technical support.

TestWorks Supported Platforms

Hardware Platforms	OS	Graphic Interface
DEC Alpha	OSF/1	X11/Motif
HP 9000/700,800	HP-UX	X11/Motif
IBM RS/6000	AIX	X11/Motif
NCR 3000	SVR4	X11/Motif
Silicon Graphics	IRIX	X11/Motif
Sun SPARC	SunOS, Solaris	X11/Motif
X86/Pentium	SCO/ODT,Solaris	X11/Motif
X86/Pentium	MS-DOS, Windows	Microsoft Windows 3.1X Windows 95 Windows NT

CHAPTER 2

Frequently Asked Questions About Testworks

2.1 About Testing

1. Why is it necessary to test software? Shouldn't software be built so that it doesn't have any errors?

- Software testing is essential to building high-quality software because testing is effective in reducing defects in software products.
- Testing saves money. Estimates of savings are as much as 100:1 over field-discovered errors.
- Testing is insurance that high-quality software is built.

2. Why are automated tools needed?

Because the size and complexity of applications have grown so rapidly, "old style" methods of testing are no longer as effective. In the late 1990s, the economic choice is automated testing or no testing at all.

3. Why not continue doing manual testing?

Manual testing is difficult, costly, and not especially reliable or effective. Complicated programs virtually require some kind of automated testing. Furthermore, some kinds of analyses, such as code coverage analysis, cannot be done manually.

2.2 About TestWorks

1. What is TestWorks?

TestWorks is a collection of software test tools that supports all of the major functions of most software test project including the following:

- Static analysis
- Metrics
- Test file generation
- GUI testing
- Test management
- Test validation
- Branch and call-pair coverage analysis

2. Why is TestWorks organized into bundles?

Two reasons:

1. To provide lower license fees.
2. The use of one tool, like CAPBAK/X, generally leads to the use of a companion tool, like SMARTS.

3. Why is it important to purchase automated testing tools from Software Research, the long-established technical leader of the software testing industry?

Experience is the best teacher, and Software Research has put years of real-world test experience into TestWorks.

4. How will TestWorks save time and money?

Savings can be as high as 10:1 to 50:1 when a defect is found and repaired before the product goes to the field. Automated testing does have some setup cost, but most organizations receive a return on their investment after two or three months of TestWorks use.

5. How do TestWorks products work together?

Each of the TestWorks products have the same “look and feel,” and they work well together because they share common features and approaches.

6. Do the TestWorks tools work across platforms?

Yes, but you have to be very cautious. No tool works perfectly across platforms regardless of what people think.

2.3 Regression Testing

1. What is the benefit of regression testing?

Regression tests confirm that an application under test works on each test run the same way it worked on the previous run. The lack of confirmation indicates a problem.

2. Can tests be moved from one platform to another? How much work is required to accomplish this task?

With careful planning and organization of tests, tests can usually be moved from one platform to another. It is important that the platforms are not vastly different.

3. Why is GUI testing important?

GUI testing has two advantages.

1. GUI testing is easy for a user to understand.
2. GUI testing makes an excellent testbed for running tests that have a high likelihood of revealing defects.

4. What are the main modes of GUI test capture/playback?

TestWorks' CAPBAK test capture / playback engine has three main operating modes:

1. TrueTime Mode

   In TrueTime Mode, the test is played back exactly the way it was recorded. TestWorks' TrueTime Mode includes the powerful Automatic Output Synchronization capability, so tests are very reliable without much extra work.

   - PROS: You keep the user's real timing the way it was recorded.
   - CONS: Test may be excessively sensitive to changes in the GUI.

2. Character Mode

   The recorded test uses the built-in OCR engine to synchronize or to capture essential test validation data.

   - PROS: You can base a test on what is written on the screen, independent of font and type size.
   - CONS: There is a bit of local testware that has to be written to get the most out of the scripts.

3. Object Mode

   The test is recorded in such a way that playback is less sensitive to the locations of buttons and other "widgets" on the GUI.

   - PROS: Test are insensitive to GUI layouts, other "noncritical" formatting details.
   - CONS: Test may miss out on catching missing or invisible buttons, and they don't preserve any actual-user timing information.

5. How many defects are actually detected by regression testing?

It is estimated that a 5% functionality change in a 1000 suite test will reveal 5-25 new defects.

6. Is it true that capture/playback tools are dangerously invasive? Exactly how do these tools work?

Every kind of recording mechanism is to some extent "invasive," but most users do not consider this low level of interaction with the underlying operating system software much of a risk.

CAPBAK/X works with X windows on UNIX by using the XtestExtension1 or Xtrap extension to the X11 server (display driver). The "xdpyinfo" command on the UNIX machine tells which extension(s) are available. CAPBAK/X also uses a special version of the Xt toolkit for ObjectMode recording from X/Motif GUIs.

On Windows machines, CAPBACK/MSW uses built-in features of the Windows 3.x, Windows '95, or Windows NT operating systems.

2.4 Coverage Testing

1. What is the benefit of coverage testing?

Test coverage indicates whether a test missed something. Good test coverage is necessary for thorough testing.

Manual testing seldom exercises more than one-third of the overall structure of code. Therefore, without coverage testing, applications can go to the field with major sections never executed.

2. What is the difference between "BlackBox" testing and "WhiteBox" testing?

With "BlackBox" testing, the tester cannot see what's going on inside the application under test whereas with "WhiteBox" testing, the tester can see what's going on.

Most of the time, BlackBox testing means that functional testing is being executed. WhiteBox testing usually means that coverage analysis is being executed.

3. What is a segment? What is a [logical] branch?

A segment, sometimes called a [logical] branch, is a piece of code that is always executed as a unit after some piece of program logic happens. For example, an "IF" statement has two segments: the "true" and the "false" outcomes.

4. Why not just use "statement coverage?"

Statement coverage turn out to be 100% identical to branch coverage if every piece of logic in your program starts on a new line. Obviously, this never happens, so statement coverage tends to overstate the actual coverage by 50% or more. You can get 100% statement coverage and only 50% branch coverage. CAUTION: This overstatement may be dangerous to the health of your software!

5. Why do we need automated tools at all?

Because the size and complexity of applications have grown so rapidly, "old style" methods of testing just don't work anymore.

6. What is a call-pair?

When two functions (programs) call one another, they make a call-pair.

The caller function could call the callee many times, and TestWorks' view of coverage analysis holds that all call-pairs must be checked.

7. Do all these coverage measures have names?

Yes, because it helps to keep track of the facts.

- Statement coverage is called C0. (SR does not support C0 because it's too misleading.
- Segment / branch is called C1.
- Module coverage is called S0.
- Call-pair coverage is called S1.

8. Why not just do module coverage?

You can, and we recommend it as a minimum step. But remember, errors in interfaces happen most often when the calling sequence doesn't match up with the called-function's definition. Call-pair coverage overcomes this by requiring every caller-callee pair to be tested at least once.

9. What is a test path?

TestWorks treats test paths as sequences of segments, counted up to a repetition count for a loop. (See the TCAT-PATH manual for full details.)

10. How many defects are actually detected by coverage testing?

It is estimated that increasing branch coverage from 50% to around 90% will expose 5-10 defects per 1000 lines of code (KLOC).

11. Can I set up my makefiles to do coverage analysis automatically?

Yes. Make a one or two line modification to the makefile to tell it how to call the TestWorks' Instrumentor when you want to "make" an instrumented target. Then you **`make instrumented version`** rather than **`make normal version`**.

Some users make instrumentation the normal and only take out the instrumentation prior to shipping.

2.5 Static Testing

1. Why should I do static analysis of my source code?

Using a simple mechanical check that finds an error inexpensively saves money. The alternative is finding errors from the field, a more costly method in terms of money and reputation.

2. How many defects are actually detected by advisor/static testing?

It is estimated that static and metric analyses can yield as many as 2-8 defects per 1000 lines of code (KLOC).

3. About how many defects are there in code?

There are approximately 30-50/KLOC (1000 Lines of Code) in new software. QA testers aim to get defects down to 1/KLOC; some critical aerospace applications must get below 0.1/KLOC.

4. Why are software metrics so important?

Experience shows that the most complicated pieces of a software product often contribute to most of the errors. The best use of resources is knowing how to identify the most complex pieces of software and then concentrating efforts there.

2.6 Integration Testing

1. What is integration testing and how is it beneficial?

Most of the time, two or more pieces of a large system are put together after they have been tested separately. Testing two or more parts of a program together is called integration testing.

Many defects are discovered in integration testing, and TestWorks is effective by insisting on high levels of call-pair coverage during the integration test process.

2. What must I do to make TestWorks integrate into my software process smoothly?

Make sure that your software process runs smoothly in the first place. If it does, then TestWorks adds to the existing processes quite nicely.

2.7 About TestWorks Licensing

1. What platforms does TestWorks run on?

TestWorks runs on the following:

- UNIX platforms (SUN SPARC Solaris, HP-9000, SGI, DEC-Alpha, etc.)
- Windows (3.1x, '95, and NT)

2. How is TestWorks licensed?

On UNIX products, Software Research, Inc. offers LAN-based floating licenses.

On Windows products, Software Research, Inc. offers group licenses, department licenses, and site licenses.

3. What is the TestWorks warranty agreement?

Software Research, Inc. has a standard 30-day warranty. Check your license agreement for complete details and limitations.

4. What are the benefits of keeping my software maintenance contract current?

There are two benefits to keeping your software maintenance contract current:

- Continuous technical support
- The option of receiving upgraded products at no cost

Once your maintenance contract lapses, it is more expensive to restore it than it would be to continue the contract. Maintenance contracts lapse 60 days after the end of prior maintenance.

5. What if I have problems with TestWorks after 30 days?

If you are on maintenance, help is guaranteed. However, if you are not on maintenance, Software Research, Inc. will do its best to help.

2.8 About TestWorks Internal Architecture

1. Why does TestWorks use "C" as its basic command language?

"C" is the language most universally understood by programmers and testers alike, and it is compact and easy to use.

2. Do I have to be highly skilled in "C" programming to use TestWorks?

No. Most of the time it is not necessary to edit scripts, and if it is, the syntax rules are very simple to follow.

3. Why are TestWorks license prices so high?

Compared with other testing products, license fees for TestWorks' products, bundles, and the entire TestWorks Suite are very low on a value per function basis.

TestWorks is the most cost-effective way to automate testing.

4. Why is there a price difference between UNIX and Windows?

Licensing creates the price difference between UNIX and Windows. A single floating license on UNIX can serve 2-4 testers, but on Windows, each tester for each machine needs a license.

5. How difficult is it to install TestWorks

It is easy to install TestWorks.

On theUNIX version there is an `install.stw` that does all the instalation.(If a systems administrator installs TestWorks, "root/superuser" permission may be required.)

On Windows, products are installed using the supplied hands-off installation script.

6. How long does it take to install TestWorks?

If the install script is used, installation takes approximately twenty minutes or less. There are no guarantees if the install script is not used.

7. How much memory do TestWorks products use?

On UNIX, the distribution tapes can range in size from 20 MB to 50 MB, but that includes online documentation and several utilities.

The UNIX products take from 0.5MB to 2MB of RAM to execute.

The Windows products run from 2.5 MB to 5.5 MB depending on the version. They take 250-750 KB to execute.

2.9 Embedded and Cross-Testing

1. What does cross-development and cross-testing mean?

Cross-development means that developing is taking place on one machine (the host) and product runs are taking place on another machine.

Cross-testing is TestWorks' way of supporting cross-development.

2. Does TestWorks test embedded code?

Yes. For cross-development host/target type development, Software Research, Inc. has special kits to test embedded code.

3. How many changes to my code do I have to make for TestWorks to be effective?

None.

The coverage analysis tools work with source code modification, but they make "throw away" versions of your code, then feed that directly to your compiler. You never see the intermediate versions.

4. My question isn't answered above. What should I do?

Send your question to *info@soft.com* and we'll answer it immediately.

2.10 Technical Support

1. What kind of technical support can I expect?

We respond to ALL incoming calls, Emails, FAXes, etc., within 24 hours.

2. Is training available on the TestWorks products?

Standard 2-day, 3-day, 4-day, and 4-1/2 day trainings exist for TestWorks. The length varies with how many products are being learned.

3. Is a demo available?

A "demo disk" is not available, but a trial or evaluation of the fully-functioning TestWorks products can be arranged.

Contact our sales group to arrange a trial/evaluation.

4. Can we evaluate the software in our own environment?

We strongly advocate *in situ* trials/evaluations so that you can see TestWorks working in your environment on your product.

5. What if we are not satisfied after the purchase?

If you are dissatisfied for any reason within the 30-day guarantee period, you can return the product, no questions asked. For longer periods, contact our sales department. Our guideline is that we want satisfied customers, and we will do the best that we can to achieve that goal.

6. Do the TestWorks' tools work across platforms?

When used with caution, TestWorks' tools can work across platforms.

CHAPTER 3

Understanding the User Interface

This chapter summarizes *TestWorks*'s windows, menus and commands. Details of individual commands are described in the relevant chapters of this manual.

3.1 Basic OSF/Motif User Interface

This section demonstrates help menus and pull-down menus. If you are familiar with the basic OSF / Motif graphical user interface (GUI) style, you can go on to Section 2.2.

3.1.1 Help Windows

TestWorks provides on-line information for each of its windows. Click on the **Help** option, to display information relevant to the window you are in.

To access on-line help:

1. Click on the **Help** option. A window like this pops up:

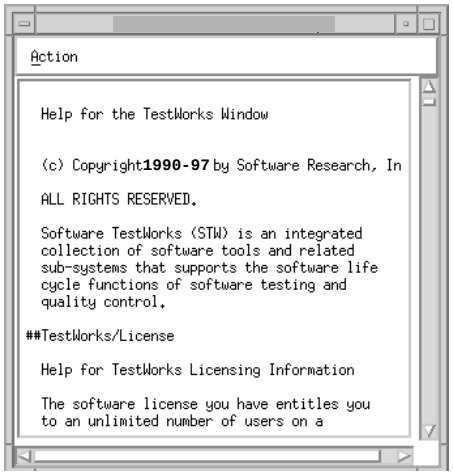


FIGURE 1 Help Window

You can scroll through the text either by clicking on the text and dragging the mouse or by using the vertical and horizontal scroll bars.

2. To search for specific help, click on the **Action** menu and select the **Search** option. The following dialog box pops up:

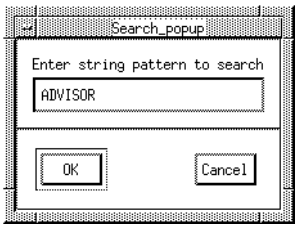


FIGURE 2 Search Dialog Box

3. Click the cursor in the **Enter string pattern to search** field and type in whatever you are looking for.
4. Either click on **OK** or press the **Enter** key.

   If the item is found, then the window will automatically scroll to it.

   Otherwise, the following message box is displayed:

FIGURE 3 "not found" Message

NOTE: If the **Help** window is currently displayed and you call **Help** from a different window, the **Help** display automatically scrolls to the relevant text for the new window.

5. To close the **Help** window, click on the **Action** menu and select the **Exit** option.

3.1.2 Pull-Down Menus

Pull-down menus are located in the menu bar at the top of *TestWorks*'s windows. They often contain several options.

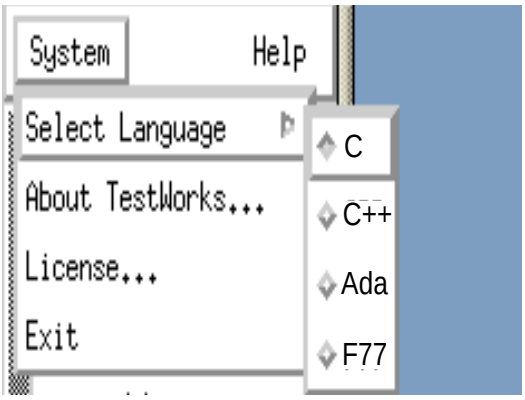


FIGURE 4 Pull-Down Menu

To use pull-down menus and their options, perform the following steps:

1. In the title bar, place the mouse pointer over the menu name.
2. Display the menu's options by holding the left mouse button down.
3. While holding down the left mouse button, slide the mouse pointer to the desired menu option. The menu option is highlighted in reverse shadow.

   NOTE: Three dots to the right of a menu item indicates that selecting the item will display a pop-up window, such as a file selection window. An arrow to the right of the menu indicates that item has a sub-menu (or cascading menu).
4. To activate a command, release the mouse button while the desired item is highlighted. To exit without selecting an item, simply drag the mouse pointer off the menu before releasing the mouse button.
5. To display the sub-menu, slide the mouse pointer over the arrow. You can then select an item on the sub-menu.
6. Release the mouse button while the desired item is highlighted to activate the command. To exit without selecting anything, simply drag the mouse pointer off the menu before releasing the mouse button to not activate anything.

3.2 The TestWorks Window

The **TestWorks** window displays all the commands and menus to operate *TestWorks* including verifying installation, invoking various product lines, using the supplied demos, and viewing the on-line glossary.

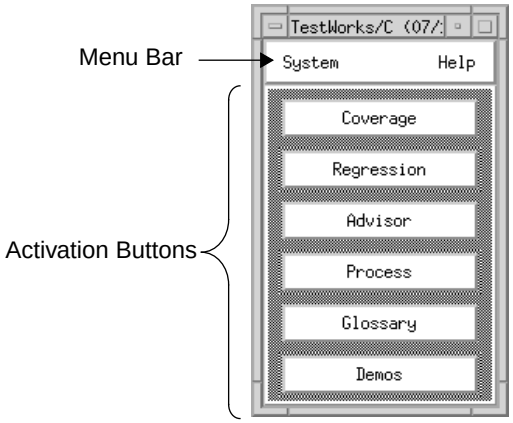


FIGURE 5 TestWorks Window

The window is divided into the following parts:

1. Menu bar.
2. Activation buttons.

3.2.1 Menu Bar

The menu bar spans the length of the top of the **TestWorks** window and contains the following items:

1. **System** menu.
2. **Help** option.

3.2.1.1 System Menu

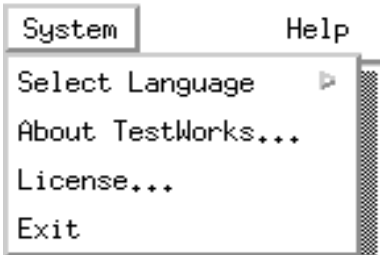


FIGURE 6 System Menu

- **Select Language:** Initiates a sub-menu which allows you to select a language for the *TestWorks/Coverage* and the *TestWorks/Advisor* tools. The default is the C language. Please see Chapter 5 for further information on this sub-menu.
- **About TestWorks:** Invokes a **Help** window that describes the **System** menu's options. Please see Section 4.4 on page 32 for further information.
- **License:** Invokes the **License** window which verifies installation was done correctly. Please see Section 4.3 on page 30 for further information.
- **Exit:** Closes the **TestWorks** window.

3.2.1.2 Help Option

The **Help** option invokes a **Help** window that describes the main features of the **TestWorks** window.

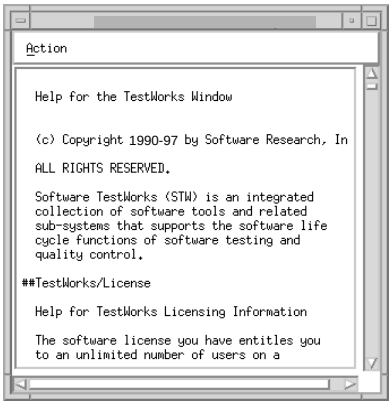


FIGURE 7 Help Window

Using the TestWorks Window

This chapter explains how to use the TestWorks window, its commands and options.

4.1 Invoking the TestWorks Window

You invoke **TestWorks** with the command

stw [-L *lang***]**

The **TestWorks** window pops up.

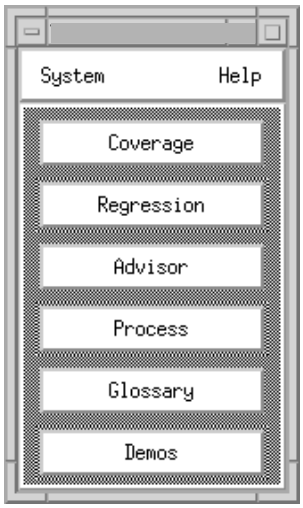


FIGURE 8 TestWorks Window

If it doesn't pop up, it may be because you have not set up your environment correctly. Please refer to the *Installation Instructions* for assistance.

No Options	Invokes the **TestWorks** window for the C language interactively.
-L *lang*	Specifies the language. The following options are supported:

- **-L C** — Supports the C language. This is the default.
- **-L C++** — Supports the C++ language
- **-L Ada** — Supports the Ada language.
- **-L F77** — Supports the FORTAN language.

It's important to specify the language if you plan on working with the language-dependent *STW/Coverage* or *STW/Advisor* tool suites, but is not necessary to specify a language if you want to work with the language-independent *STW/Regression* tool suite.

If you forget to specify the language, you do not have to re-invoke the window. The **System** pull-down menu also allows you to specify the language.

4.2 Selecting the Language

If you invoked the **TestWorks** window for a particular language and want to change it:

1. Click on the **System** pull-down menu.
2. Drag the mouse to the **Select Language** sub-menu.
3. Select the language you want by clicking on the corresponding radio button.
4. The menu bar's language will change to reflect your selection. The menu bar has the following information:

   TestWorks (*language***)** *version date*,

   where *language* represents the language currently selected.

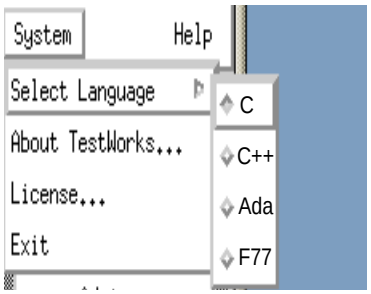


FIGURE 9 Selecting the Language

4.3 Checking Licensing Information

When installation is complete, you can quickly check which products your machine or all machines are licensed for:

1. Click on the **System** pull-down menu.
2. Select **License**.
3. The **License** window pops up.

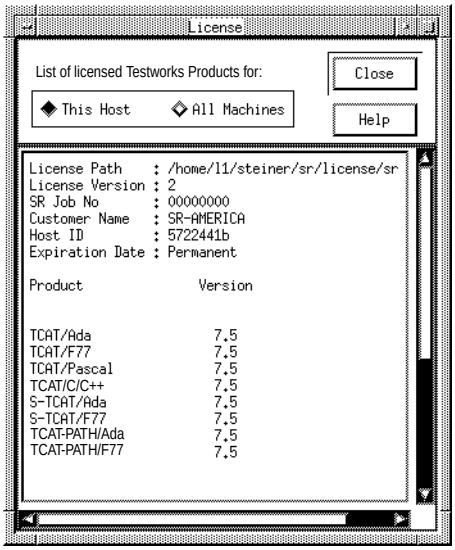


FIGURE 10 License Window

4. If you want to check for your machine only, leave the default **This Host** button on. If you want to check for all the machines that are listed in the *sr.access* file (for node-locked licensing) or *license.dat* (for floating licensing), turn the **All Machines** button on.

   The display lists the following important customer information:

   - **License Path** shows where *sr.access* or *license.dat* is installed.
   - **License Version** shows SR's current licensing version.
   - **SR Job No** is your customer key number. When you have problems and call for support, always identify yourself with the job number your salesperson assigned you.
   - **Host ID** is your machine's `uname -n` or hostid number.
   - **Expiration Date** is the date you license access codes run out. Trials normally allow 30 days of access and purchases have permanent access.
   - **Products** list the product names and version number you are licensed to you. You will only have access to these products.

     If you believe *ANY* of the information is incorrect, please call (415) 957-1441 and ask for technical support. Please also refer to the *Installation Instructions*.

4.4 Using the Menu Buttons

The **TestWorks** window consists of six menu buttons that give you access to the **TestWorks** suite of tools, glossary terms and available demos.

4.4.1 Coverage Button

This button invokes the **STW/Coverage** window, which allows you to initialize:

- *TCAT*
- *TCAT-PATH*
- *T-SCOPE*
- *TCAT C/C++*

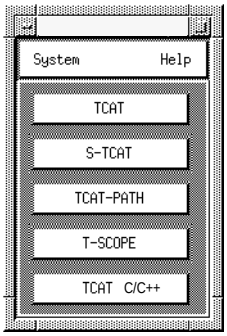


FIGURE 11 STW/Coverage Window

Please refer to the *STW/Coverage User's Guide* for further information on using this window.

4.4.2 Regression Button

This button invokes the **STW/Regression** window, which allows you to initialize:

- *CAPBAK/UNIX*
- *CAPBAK/X*
- *SMARTS*
- *EXDIFF*

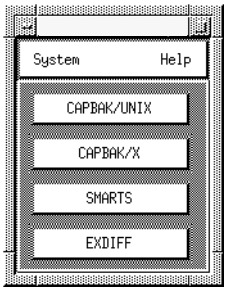


FIGURE 12 STW/Regression Window

Please refer to the *STW/Regression User's Guide* for further information on using this window.

4.4.3 Advisor Button

This button invokes the **STW/Advisor** window, which allows you to initialize:

- *METRIC*
- *STATIC*
- *TDGEN*

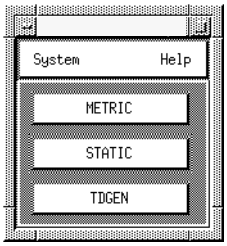


FIGURE 13 STW/Advisor Window

Please refer to the *STW/Advisor User's Guide* for further information on using this window.

4.4.4 Process Button

This button brings up a **Help** window. It describes the different methodologies that **TestWorks**'s products support. For information on using a **Help** window, please refer to Section 3.1.1 on page 21.

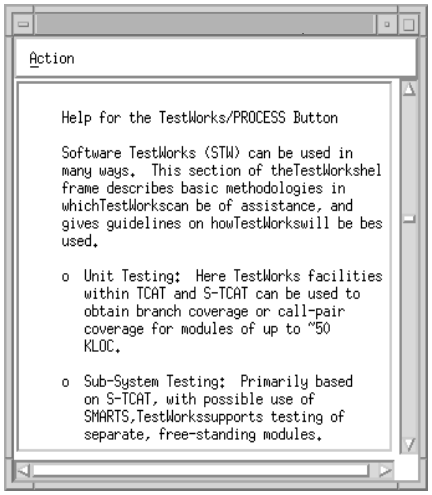


FIGURE 14 Process Help Window

4.4.5 Glossary Button

This button initializes the **Glossary** window (shown below). The glossary includes terms commonly used in the testing and QA industry and important **TestWorks** terminology.The **Glossary** window works just like a **Help** window (see Section 3.1.1 on page 21).

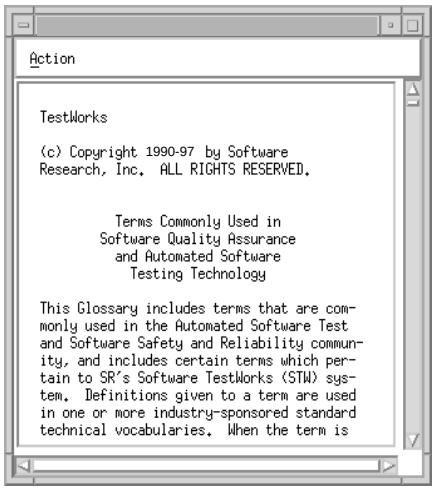


FIGURE 15 Glossary Window

4.4.6 Demos Button

This button invokes the **STW/Demo** window, which identifies the location of supplied demos for: *TestWorks*, *STW/Coverage*, *STW/Regression*, and *STW/Advisor*.

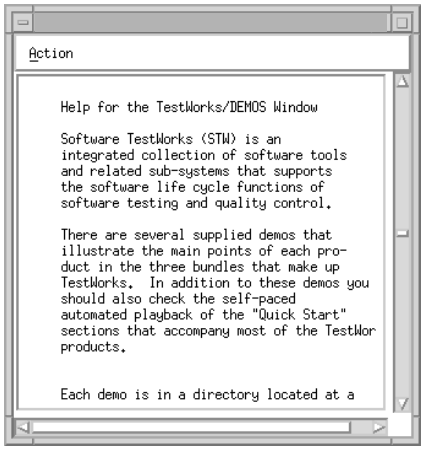


FIGURE 16 STW/Demo Window

CHAPTER 5

A Note About the GUI Resource File

This section tells you where the default settings are located for SR products.

5.1 Locations for Defaults

There exists a file named SR which holds all of the default settings for TestWorks product GUIs. This file may be located in various places:

1. If currently working with OpenWindows under:
   `$OPENHOMEWIN/lib/app-defaults`
2. If currently working with X11, under:
   `usr/lib/X11/app-defaults`
3. In the user's home directory, as either SR or as part of the local `.Xdefaults file.`
4. As SR in the current local directory.

If there are files found in one or all of the above locations, TestWorks's products will read these files in the order presented above. Therefore, any differences in the local SR file will override any settings in either of the `~/app-defaults SR files.`

CHAPTER 6

Glossary

This Glossary includes terms that are commonly used in the Automated Software Test and Software Safety and Reliability community, as well as terms which pertain to SR's TestWorks system. Definitions given to a term are used in one or more industry-sponsored standard technical vocabularies. When the term is specific to SR, the product with which it is most closely associated is named in the definition.

acceptance tests — Formal tests conducted to (1) determine whether or not a system satisfies its acceptance criteria and (2) to enable the customer to determine whether or not to accept a system. This kind of testing is performed with the STW/Regression suite of tools. {Regression}

action statement — A non-decision statement in a program that results in executable code. {Coverage}

activation clause — A clause in the ATS file, composed of a sequence of system commands which perform actions for the test case execution. {SMARTS}

Ada — The DoD standard programming language. Also, Ada9X refers to the 1990's update of this language. {Regression}

alpha testing — Testing of a software product of system conducted at the developer's site by the customer. [Ref. 1]

ALT-M — The CAPBAK/DOS hotkey menu trigger character. {Regression}

ALT-S — The CAPBAK/DOS screen save hotkey character. {Regression}

ancestor node — A node in a directed graph that lies on some path (i.e., sequence of segments) leading to the specified node. {TCAT-PATH}

apg — **A**ll **P**aths **G**enerator. A TCAT-PATH facility which generates equivalence classes that include all program paths from a directed graph. {TCAT-PATH}

arc — In a directed graph, the oriented connection between two nodes. Also called an edge. {Coverage}

archive file — A file containing test trace information in reduced form. {Coverage}

ASCII synchronization — The process by which a playback (e.g. from CAPBAK) holds back execution until a character string is located.

ATS — **Automated Test Script**. A SMARTS user-designed description file which references a test suite. Test cases are referenced in a hierarchical structure and can be supplemented with activation commands, comparison arguments, PASS/FAIL evaluation criteria, and system commands. When SMARTS is run on either an X Window or UNIX system, the ATS is written in SMARTS' Description Language (similar to C language in syntax). The ATS file is written in SMARTS C-Interpreter Language when SMARTS is run on an MS Windows system.

AUT — Application-under-test.

automatic flow control — When CAPBAK is being run in terminal emulation record mode, a record of the manual flow control is stored in the keysave file and response file. When CAPBAK is transmitting keys in playback mode the flow control is maintained by using the information saved in these files. See manual flow control. {CAPBAK/UNIX}

Automated Test Script — See **ATS**. {SMARTS}

axis — A subset of the nodes in a digraph used as a basis for digraph display. {Coverage}

back-to-back testing — For software subject to parallel implementation, back-to-back testing is the execution of a test on the software's similar implementations and a comparison of the results.

baseline file — A text or image file created during initial testing. Baseline files provide expected program output for comparison against future test runs. These kinds of files are created during STW/Regression testing. {CAPBAK}

basis paths — The set of non-iterative paths. {TCAT-PATH}

beta-testing — Testing conducted at one or more customer sites by the end-user of a delivered software product or system. This is usually a "friendly" user and the testing is conducted before general release for distribution. {Software Technology Support Center}

black-box testing — See **closed-box testing**. {Regression}

bottom-up testing — Testing starts with lower level units. Each time a new higher- level unit is added to those already tested, driver units must be created for units not yet completed. Again, a set of units may be added to the software system at that time, and for enhancements the software system may be complete before the bottom-up test starts. The test plan must reflect the approach, though. {Coverage}

branch — See **segment.**

branch testing — A test method satisfying coverage criteria that require that (sic) for each decision point, each possible branch be executed at least once. {Software Technology Support Center}

built-in testing — Any hardware or software device which is part of a piece of equipment, a subsystem or system, which is used for the purpose of testing that equipment, subsystem or system.

byte mask — A differencing mask used by EXDIFF that specifies disregarding differences based on byte counts. {EXDIFF}

"C++" — The "C++" object-oriented programming language. The current standard is ANSI C++ and/or AT&T C++. Both are supported by TCAT/C++. {TCAT/C}

"C"	The programming language "C". ANSI standard and K&R "C"are normally grouped as one language. Certain extensions supported by popular "C" compilers are also included as normal "C".
C0 coverage	C0 is the percentage of the total number of statements in a module that are exercised, divided by the total number of statements present in the module. {Coverage}
C1 coverage	The percentage of segments exercised in a test as compared with the total number of segments in a program. {Coverage}
call graph	The function call tree capability of S-TCAT. This utility shows the caller-callee relationship of a program. It helps the user to determine which function calls need to be further tested. {Coverage}
call pair	A connection between two functions in which one function "calls" (references) the other function, in a call tree. {Coverage}
capbak	This command invokes CAPBAK/DOS or CAPBAK/UNIX.
CAPBAK	The test Capture and Playback component of the STW/Regression product set. It has the capability of capturing keystrokes, mouse movements, partial screens, windows, or the whole screen and putting them into a test script language which can be played back later.
capbak	This CAPBAK/UNIX command allows the user to capture keystrokes in a keysave file with or without actually being attached to an application. No response file is created. This provides a way to generate keysave files independent of the user doing anything.
capset	A utility to control CAPBAK/DOS operation from a command line and from the SMARTS ATS file.
CBDIFF	CAPBAK/MSW's image differencing utility. This utility offers general differencing and masking capabilities.

CBVIEW CAPBAK/MSW's image viewing utility.

certification report This report summarizes the total number and percentage of tests that have passed and failed, providing a brief overview of testing status. {SMARTS}

character recognition See **OCR**.

clear-box testing See **glass-box testing**.

closed-box testing A method where the tester views the program as a closed box; i.e. the test is completely unconcerned with the internal behavior and structure of the program. The tester is only interested in finding circumstances in which the program does not behave according to its specifications. Test data are derived solely from these specifications, without taking advantage of knowledge of the internal structure of the program. Also known as **black-box testing**.{Regression}

COBOL The COBOL programming language.

coding rule A rule that specifies a particular way in which a program is to be expressed.

coding style A general measure of the programming nature of a system; abstractly, the way the programming language is used in a real system.

collateral metrics Secondary metrics gathered as an unexpected by-product of the gathering of primary metrics. These may not be needed or even useful, but then again, may prove to be of value later. Consider saving, even if costly. {Software Technology Support Center}

collateral testing Collateral testing is that testing coverage which is achieved indirectly, rather than as the direct object of a test case generation activity. {Coverage}

combinational flow Combinational flow is represented by a sequence of segments, with the property that no segment is repeated within the flow. {Coverage}

command mode This mode allows the user to program the key-save file for conditional execution based on system calls. The other mode of execution is data mode. Command mode is supported by {CAPBAK, CAPBAK/UNIX}

compilers 1. Compilers are included here as a reminder of how much static code checking is done by compilers. These are valuable automatic test tools. {Software Technology Support Center}

2. A computer program that translates instructions, other programs, etc. (from)...a high-level language into a machine language. Webster's New World Dictionary

complexity A relative measurement of the "degree of internal complexity" of a software system, expressed possibly in terms of some algorithmic complexity measure. {METRIC}

complexity report This report lists all of a source code program's encountered procedures and lists Software Science metrics (which are concerned with the "size" of software) and Cyclomatic Complexity measures (which are concerned with the flow of control within the program's code). {METRIC}

component A part of a software system smaller than the entire system but larger than an element.

conditional playback See also **playback programming**. Certain STW components incorporate a language that provides for logical operations to control behavior during test execution; e.g. a SMARTS test can involve use of the `if` or `while` constructs, as can a CAPBAK script.

configuration file A file used to declare start-up time parameter values. Usually suffixed as ***.rc**.

connected digraph A directed graph is connected if there is at least one path from every entry node to terms of all possible sub-trees that can be executed for that program. A TCAT-PATH component used to measure Ct coverage against a path file.

ctcover — A TCAT-PATH utility used to assess Ct coverage.

cumulative coverage — The test coverage attained by a set of test runs. {Coverage}

cumulative report — This report charts branch and / or call-pair coverage for the current test cumulatively, and for each module in the total system. {Coverage}

current position — The current position of the screen's cursor, expressed in x,y coordinates. NOTE x=0, y=0 is the upper left corner of the screen. On some machines this same pixel may be assigned x=1, y=1.

cycle — A sequence of segments that forms a closed loop, so that at least one node is repeated. {Coverage}

cyclomatic number — A number which assesses program complexity according to a program's flow of control. A program's flow of control is based on the number and arrangement of decision statements within the code. The cyclomatic number of a flow-graph can be calculated as follows

e - n + 2

where **n** is the number of nodes in the graph, and **e** is the number of edges or lines connecting each node. {METRIC, TCAT, TCAT-PATH}

data flow graph — A graph of a variable name's uses along a fixed path within a module or software system, expressed in terms of the legal and illegal transitions within the system for the variable. {Coverage}

data sensitivity fault — A fault that causes a failure in response to some particular pattern of data. {Software Technology Support Center}

data mode — In this execution mode for keysave files, text is interpreted as saved keystrokes, to be played back along with timing information which is enclosed in brackets. {CAPBAK, CAPBAK / UNIX}

DD-path — See **segment**.

de-instrumentation — When certain parts of your code have already been tested, you can use TCAT's and S-TCAT's de-instrumentation utilities to exclude those parts from instrumentation. For large programs, this can save time.

debug — After testing has identified a defect, one "debugs" the software by making certain changes that repair the defect. Also see **instrumentation**.

decision-to-decision path — See **logical branch**.

decisional depth — The number of decisions that must take on a particular value prior to arriving at a specified logical branch. "The decisional depth for this logical branch is..." {Coverage}

defect — A difference between program specifications and actual program text of any kind, whether critical or not. What is reported as causing any kind of software problem.

defect analysis — Using defects as data for continuous quality improvement.
{Software Technology Support Center}

defect density — Ratio of the number of defects to program length (a relative number).
{Software Technology Support Center}

deficiency — See **defect**.

delay multiplier — The multiplier used to expand or contract playback rates. {CAPBAK...}

desk checking — A form of manual static analysis, usually performed by the originator. Source code, documentation, etc. is visually checked against standards. It is cheap, effective, and usually underestimated and under-applied. (Maybe if we called it an *individual design review*, it would get more respect. This is where pride in workmanship and individual empowerment are exhibited.)
{Software Technology Support Center}

development test and evaluation (D T & E)

Testing conducted throughout the acquisition process to ensure an effective and supportable system by assisting in design and development and verifying specifications, objectives, and supportability. {Software Technology Support Center}

digraph

Short name for a **directed graph**. This is a graph which displays all of a program's **nodes** and **edges** and their relationships. The **Xdigraph** utility within STW's TCAT and S-TCAT set of tools draws digraphs and has options for displaying them in many different ways.

direct metric

A metric that represents and defines a software quality factor and which is valid by definition, e.g., mean time to software failure for the factor reliability.
{Software Technology Support Center}

dump

A display of some aspect of a computer's execution state, usually the contents of memory, registers, etc. Is used as a diagnostic aid. Some examples are a postmortem dump (taken after a failure), and a snapshot dump (taken during execution).
{Software Technology Support Center}

dynamic analysis

A process of demonstrating a program's properties dynamically, by a series of constructed executions. {Coverage}

dynamic call-tree display

An organic diagram showing modules and their call-pair structure, where the call-pairs are "animated" based on behavior of the instrumented program being tested. {Coverage}

dynamic digraph display

An organic diagram showing the connection between segments in a program, where the segments are "animated"based on behavior of the instrumented program being tested.
{Coverage}

edge

In a directed graph, the oriented connection between two nodes. {Coverage}. See also **digraph**.

emulator — From Webster's, emulate, 'to strive or equal or excel.' Therefore, a machine that strives to equal or exceed the performance characteristics of another, very often through software. Similar to a simulator. Example: Software in a PC that causes it to emulate a data terminal. {Software Technology Support Center}

end-to-end testing — Test activity aimed at proving the correct implementation of a required function at a level where the entire hardware/software chain involved in the execution of the function is available.

entry node — In a program-directed graph, a node which has more than one outway and zero inways. An entry node has an in-degree of zero and a non-zero out-degree. {Coverage}

entry segment — An entry segment, or logical branch is one which has no predecessors, a situation which can occur only at the entrance (i.e., invocation point) of a module. {Coverage}

environment clause — A clause in the ATS file that defines local environment variables that can be used as variables in the activation and evaluation clauses. {SMARTS}

equivalence classes partitioning — This involves identifying a finite set of representative input values that help to minimize the number of necessary test cases. {Software Technology Support Center}

error — A difference between program behavior and specification that renders the program results unacceptable. See **defect.**

error-based testing — Testing where information about programming style, error-prone language constructs, and other programming knowledge is applied to select test data capable of detecting faults, either a specified class of faults or all possible faults. {Software Technology Support Center}

error model — A model used to estimate the number of remaining errors, time to find these errors and similar characteristics of a program. {Software Technology Support Center}

error tolerance — See **robustness**. {Software Technology Support Center}

essential complexity — A measure of the level of 'structuredness' of a program. {Software Technology Support Center}

essential edges — The set of paths that first includes each of the edges only on one of the original set of paths. {TCAT-PATH}

essential logical branch — A logical branch of a program that exists only on one path. Hence, execution of an essential logical branch is required to obtain complete segment (branch) coverage.

essential paths — The set of paths that include one essential edge; that is, an edge that lies on no other path. {TCAT-PATH}

essential segment — A segment of a program that exists on only one path. Hence, execution of an essential segment is required to obtain complete segment (branch) coverage.

evaluation clause — A clause in the ATS file that specifies how to assess the correctness of a test. {SMARTS}

evaluation — The process of examining a system or system component to determine the extent to which specified properties are present. {Software Technology Support Center}

exception report — A METRIC report which identifies source code procedures that exceed a user-defined metric threshold.

EXDIFF — The Extended Differencing System, a component of STW/Regression. EXDIFF compares two files and reports the difference between them, and it ignores differences that lie within a user-defined masked area.

executable statement — A statement in a module which is executable in the sense that it produces object code instructions. A non-executable statement is not the opposite; it may be a declaration. Only comments can be left out without affecting program behavior.

execution history report This report shows how many times individual test cases have been run after they have been passed. This shows if test cases are being run needlessly. Identifies "spinning of the wheels." {Software Technology Support Center}

execution verifier A system to analyze the execution-time behavior of a test object in terms of the level of testing coverage attained.

exit logical branch An exit logical branch is one for which there are no successor logical branches. This occurs only when the consequence of the logical branch is an exit from the module. {Coverage}

exit node In a directed graph, a node which has more than one inway, but has zero outways. An exit node has an out-degree of zero and a non-zero in-degree. {Coverage}

exit structure The exit structure of a program-directed graph is the set of segments which, if executed, lead unalterably to termination of program flow without involving subsequent repetition of any logical branches. {Regression}

explicit predicate A program predicate whose formula is displayed explicitly in the program text. For example, a single conditional always involves an explicit program predicate.

A predicate is implicit when it is not visible in the source code of the program. An example is a program exception, which can occur at any time.

failure The inability of a system or component to perform its required functions within specified performance requirements. A failure may result when a fault is encountered. {Software Technology Support Center}

faithful time recording The capability of CAPBAK to record complete timing information about the CAPBAK session in such a way that it can be played back at identically the same rate it was recorded.

fault An incorrect step, process, or data definition in a computer program. {Software Technology Support Center}

fault-based testing Testing that employs a test data selection strategy designed to generate test data capable of demonstrating the absence of the pre-specified set of faults; typically, frequently-occurring faults. {Software Technology Support Center}

fault dictionary A list of the faults that have occurred in a system and the tests that will detect them. {Software Technology Support Center}

fault masking A condition in which one fault prevents the detection of another. {{Software Technology Support Center}

fault tolerance See **robustness**.

fault tree analysis A form of "safety analysis" that assesses system safety to provide failure statistics and sensitivity analyses that indicate the possible effect of critical failures. {Software Technology Support Center}

feasible path A sequence of logical branches that is logically possible if there is a setting for the input space relative to the first logical branch in the sequence, which permits the sequence to execute. {TCAT-PATH}

flow control When a terminal emulation program establishes communications with a mainframe application, it establishes flow control to prevent characters from being lost. In some cases the mainframe application (or cluster controller) locks out the keyboard. This prevents the user from typing ahead; however, when CAPBAK is being used to record terminal sessions, the user is expected to wait for a response from the mainframe. The user thus imposes manual flow control to prevent data from being lost in cases where the keyboard is not locked.

When CAPBAK is being run in terminal emulation mode, a record of the manual flow control is stored in the keysave and response files. When CAPBAK is transmitting keys in play-

back, flow control is maintained by using this item. {Software Technology Support Center}

full report — A METRIC report which indicates a set of metrics for each of the modules in a given source file.

function call — A reference by one program to another through the use of an independent procedure-call or functional-call method. Each function call is the "tail" of a caller-callee callpair.

function points — A measure of software size. Most appropriate for MIS applications. A product of five defined data components (inputs, outputs, inquiries, files, external interfaces) and 14 weighted environmental characteristics (data comm, performance, reusability, etc.).

Example from *Computer World*, March 8, 1993: A 1,000-line Cobol program would typically have about 10 function points, while a 1,000-line C program would have about eight. {Software Technology Support Center}

functional test cases — A set of test case data sets for software which are derived from structural test cases.

functional specifications — A set of behavioral and performance requirements which, in aggregate, determine the functional properties of a software system.

glass-box testing — A test method where the tester views the internal behavior and structure of the program. In using this strategy, the tester derives test data from an examination of the program's logic without neglecting the requirements in the specification. The goal of this method is to achieve a high test coverage examination of as many of the statements, branches, and paths.

grammar-based test — A testing method that generates test cases from a formal specification of a system or system component. {Software Technology Support Center}

Halstead metric — A measure of the complexity of computer software that is computed as **n * log n** where n is the product of the number of operators and the number of operands in a program. {METRIC}

history report — This SMARTS report shows a summary of all the test history entries stored in the designed test-log file. The display is always relative to a given node (group or test case). {SMARTS}

hit report — This report is used by TCAT, S-TCAT, and TCAT-PATH to identify all of the segments or call-pairs which were exercised in present and past tests. It analyzes both the trace file and archive file. {Coverage}

homogenous redundancy — In fault tolerance, realization of the same function with identical means; for example, use of two identical processors.
{Software Technology Support Center}

hotkey window — When recording or playing back a test session, you can issue commands via function keys (i.e. your **F1** to **F10** keyboard functionkeys).
During a recording session, you can use the function keys to bring up the hotkey window; mark the keysave file; select an image or window to synchronize during playback; save a partial image or window; save the root; and pause, resume or terminate the session.

During playback the function keys let you slow or speed up playback; insert or append new keysave records into a keysave file; pause, resume or terminate a playback session.
{CAPBAK}

ICCCM — The X Window System Protocols for xlib interfaces used by Xt the X-ToolKit.

image synchronization — The process by which a playback is forced to wait until an image is completed. {CAPBAK}

in-degree — In a directed graph, the number of inways for a node. {Coverage}

incompatible segment

Two segments in one program are said to be incompatible if there is no logically feasible execution of the program which will permit both to be executed in the same test.
See also **essential logical branch**.

incremental analysis

The partial analysis of an incomplete product to allow early feedback on its development {Software Technology Support Center}

independent logical branch pair

A pair of logical branches is (sequentially) independent when there are no assignment actions along the first branch. This changes any of the variables used in the predicate of the second statement. {Coverage}

independent verification and validation

Verification and validation performed by an individual or organization that is technically, managerially, and financially independent of the development organization.
{Software Technology Support Center}

infeasible path

1. A logical branch sequence is logically impossible if there is no collection of input data relative to the first branch in the sequence which permits the sequence to execute.
{Coverage}

2. A sequence of program statements that can never be executed.
{Software Technology Support Center}

inherited error

An error that has been carried forward from a previous step in a sequential process.
{Software Technology Support Center}

inspection/review

A process of systematically studying and inspecting programs in order to identify certain types of errors, usually accomplished by human rather than mechanical means.

instrumentation

The first step in analyzing test coverage is to instrument the source code. Instrumentation modifies the source code so that special markers are positioned at every logical branch or call-pair or path. Later, during program execution of the instrumented source code, these

markers will be tracked and counted to provide data for coverage reports. {Coverage}

Integration Testing

Exposes faults during the process of integration of software components or software units and it is specifically aimed at exposing faults in their interactions.

The integration approach could be either bottom-up (using drivers), top-down (using stubs) or a mixture of the two. The bottom-up approach is recommended. {Coverage}

interface

The informational boundary between two software systems, software system components, elements, or modules.

interface testing

Testing conducted to evaluate whether systems or components pass data and control correctly to one another.
{Software Technology Support Center}

invocation point

The invocation point of a module is normally the first statement in the module.

invocation structure

The tree-like hierarchy that contains a link for invocation of one module by another within a software system.

ISO (International Organization for Standardization) 9126

ISO 9126 defines a set of six quality characteristics (functionality, reliability, usability, efficiency, maintainability, and portability) and provides a framework for software quality assessments. ISO 9126 is a product of the ISO/International Electrotechnical Committee/Joint Technical Committee No. 1 Subcommittee on Software Engineering.
{Software Technology Support Center}

iteration level

The level of iteration relative to the invocation of a module. A zero-level iteration characterizes flows with no iteration. A one-level iteration characterizes program flow which involves repetition of a zero-level flow.

junction node — A junction node within a program-directed graph is a node which has an in-degree of two or greater and an out-degree of exactly one. {Coverage}

keycvt — A utility program for keystroke editing. **keycvt** transforms a keysave file into an editable ASCII version. {CAPBAK/UNIX, CAPBAK/DOS}

keypla — This command is used to read a keysave file and emit the characters to the screen. {CAPBAK/UNIX}

keysave file — See **ksv** {Capbak}.

keysave mode — The mode that enables the user to save every keystroke, and the time spent before each is typed in. {CAPBAK/DOS}

ksv — A test script file automatically generated during the CAPBAK's recording session. A keysave file contains a sequence of event statements (including keystrokes, mouse movements and screen captures), which represent user input directed to the AUT. {CAPBAK, CAPBAK/UNIX, CAPBAK/DOS, CAPBAK/MSW}

When a test is played back, the event statements in the keysave file are regenerated and the AUT executes the previously-recorded statements exactly as before.

Kiviat chart — Kiviat charts provide a graphical means to view the impact of multiple metrics on a source code file or multiple files. In its summary report, each metric is represented by an axis and results are plotted with reference to user-definable upper and lower bounds. The Kiviat chart quickly identifies the metrics to focus on for a particular program. {METRIC}

length — Maurice Halstead defined the length of a program to be: **N = N1 + N2**

where **N1** is the total number of operators and **N2** is the total number of operands. This measure is used with METRIC to identify error-prone modules. {METRIC}

lifecycle The period that starts when a software product is conceived and ends when the product is no longer available for use. Test development, execution, and analysis involve the entire lifecycle. {Software Technology Support Center}

line mask An EXDIFF statement that permits masking a line or group of lines.

linear histogram A dynamically-updated linear-style histogram showing accumulating C1 or S1 coverage for a selected module. {Coverage}

logarithmic histogram A dynamically-updated logarithmic-style histogram showing each logical branch or call-pair hit in logarithmic form. {Coverage}

log file 1. A file used by SMARTS to record test history information.

2. An established or default SMARTS file where all test information is automatically accumulated.

logical block See **segment**.

logical trace An execution trace that records only branch or jump instructions. {Software Technology Support Center}

logical units A concept used for synchronization when differencing two files with the EXDIFF system. A logical unit may be a line of text, a page of text, a CAPBAK screen dump, or the keys (or responses) between marker records in a keysave file. {Regression}

loop A sequence of segments in a program that repeats at least one node. See **cycle**.

loopback testing Testing in which signals or data from a test device are output to a system or component, and results are returned to the test device unaltered for measurement or comparison. {Software Technology Support Center}

(M,N)-cycle An M-entry, N-exit cycle in a flowgraph. A program is perfectly structured ("pure-structured") if it is composed of loops that involve only (1,1)-cycles. Most real-world

programs contain many multiexit cycles, however. Some studies show that over 99% of programs are non-pure-structured. {TCAT-PATH}

make file Most often, TCAT, S-TCAT and TCAT-PATH will be used to develop test suites for systems that are created with **make files**. **make files** cut the time of constructing systems, by automating the various steps necessary to build systems, including preprocessing, instrumenting, compiling and linking. All these steps can be written in a **make** file. {Coverage}

makeats A SMARTS utility which, based on minimal information, generates the initial hierarchical test structure for an ATS file, as well as basic source, activation, and evaluation clauses.

manual analysis The process of analyzing a program for conformance to in-house rules of style, format, and content as well as for correctly producing the anticipated output and results. This process is sometimes called code inspection, structured review, or formal inspection.

marker text When CAPBAK/UNIX creates a marker record, it prompts the user for text to place in the marker record. This text is intended to be used for terminal emulator data flow synchronization and special differencing evaluation.

marker trigger key When CAPBAK/UNIX is activated in marker trigger mode, it reads in a set of special keys from the marker trigger file, determining which keys should be used to impose flow control. Flow control is maintained by creating marker records in the keysave and response files.

marker trigger mode When CAPBAK/UNIX is activated in this mode, each time a marker trigger key is pressed, a marker record is recorded in the keysave and response files.

McCabe metric See **cyclomatic number**.

measure To ascertain or appraise by comparing to a standard; to apply a metric.
{Software Technology Support Center}

menu trigger character Alt-M is typed to invoke the CAPBAK/DOS menu at any time.

metric A quantitative measure of the degree to which a system, component, or process possesses a given attribute (Maybe we should think of metrics as the clues to the scene of a crime. Gather them now or lose them forever, and who knows what clues will crack the case?). {Software Technology Support Center}

METRIC The Software Metrics Processor/Generator component of STW/Advisor. METRIC computes several software measures to help you determine the complexity properties of your software.

metric validation The act or process of ensuring that a metric correctly predicts or assesses a quality factor. {Software Technology Support Center}

mkarchive The TCAT utility creates null archive files.

mksarchive The S-TCAT utility creates null archive files. These utilities ensure that the coverage utility reports on all modules on your system whether or not they have been executed. Sometimes, when testing a subsystem, the initial tests do not touch every module in the program. When this occurs, the C1 of S1 measure will start at an artificially high level and, as the tests touch more modules, the C1 or S1 value will decrease. Although no logical branches or call-pairs are being hit, more modules are included in the percentage calculation, so the result value is lower. {Coverage}

module A module is a separately invokable element of a software system. Similar terms are procedure, function, or program.

mouse save file The file of mouse movements (and associated timing information) captured during a CAPBAK/DOS session.

multi-unit test A multi-unit test consists of a unit test of a single module in the presence of other modules. It includes (1) a collection of settings for the input space of the module and all the other

	modules invoked by it and (2) precisely one invocation of the module under test.
mutation testing	A method whereby errors are purposely inserted into a program under test to verify that the test can detect the error. Also known as "error seeding." {Software Technology Support Center}
newly hit report	This report is used for TCAT and S-TCAT and identifies all the segments or call-pairs that are hit in the present test and which were not hit in any prior test.
newly missed report	This report is used for TCAT and S-TCAT and identifies what the current test "lost".
node	1. A position in a program assigned to represent a particular state in the execution space of that program. {Coverage} 2. Group or test case in a test tree. {SMARTS}
node number	A unique node number assigned at various critical places within each module. The node number is used to describe potential and/or actual program flow. {Coverage}
non-executable statement	A declaration or directive within a module which does not produce (during compilation) object code instructions directly.
not hit report	A TCAT or S-TCAT report giving the names of logical branches or call-pairs "not hit" yet by any test.
object under test	See **test object**.
OCR	Optical Character Recognition
operational test and evaluation	The field test, under realistic conditions, of an item or component
operator interface analysis	1. A form of interface analysis that examines the usage of operators applied to data structures. 2. An analysis of the machine-human (operator) interface. {Software Technology Support Center}

(OT&E) to determine effectiveness and suitability, and the evaluation of the results of the tests. {Software Technology Support Center}

out-degree In a directed graph, the number of outways of a node. {Coverage}

output synchronization The process by which a playback (e.g. from CAPBAK) is forced to wait until an expected window opening is completed.

outway In a directed graph, an arc (edge) leaving a node. {Coverage}

P1 Coverage Paragraph coverage, measured by TCAT/COBOL.

partition analysis A program testing-and-verification technique that employs symbolic evaluation to provide common representations of a program's specification and implementation. {Software Technology Support Center}

partition analysis verification The verification process used in partition analysis that attempts to determine the consistency properties that hold between a program specification and its implementation. {Software Technology Support Center}

Pascal The ISO and/or ANSI standard Pascal programming language.

past test report This report lists information from the stored archive file for TCAT and S-TCAT. It summarizes the percentage of logical branches/call-pairs hit in each module listed, giving the C1/S1 value for each module and the program as a whole. {Coverage}

path, path class An ordered sequence of logical branches representing one or more categories of program flow. {Coverage}

path predicate The predicate that describes the legal condition under which a particular sequence of logical branches will be executed. {Coverage}

path testing A test method satisfying coverage criteria that each logical path through the program be tested. Often paths through the program are

grouped into a finite set of classes; one path from each class is tested.
{Software Technology Support Center}

pathcon — A TCAT-PATH utility which generates a path's conditions.

pattern mask — A pattern mask specifies one or more rectangular areas which are to be excluded from image file comparison. (EXDIFF)

perturbation testing — A test path adequacy measurement technique that proposes using the reduction of the space of undetectable faults as a criterion for test path selection and is intended to reveal faults in arithmetic expressions.
{Software Technology Support Center}

playback counter — The time interval between two keystrokes recorded or played back by CAPBAK.

playback delay — Minimum interval between keystrokes at playback time with CAPBAK.

playback mode — The CAPBAK mode that enables the user to play back a file that contains all the keystrokes.

playback programming — A technique in which playback behavior is controlled by the use of various system calls placed in the keysave file. This provides an easy way for a user to playback a keysave file as a script that modifies behavior on the basis of system and environmental factors.
{CAPBAK, CAPBAK/UNIX}

predecessor logical branches — One of many logical branches that precede a specified logical branch in normal (structurally-implied) program flow. {Coverage}

predicate — A logical formula involving variables/constants known to a module.

predicted length — Maurice Halstead theorizes that a well-written program with **n1** unique operators and **n2** unique operands should have a length of

N^ = [n1 x log2(n1)] + [n2 x log2(n2)]

{METRIC}

preview — A CAPBAK utility which simulates keysave file activity. The simulation shows the recording session's mouse movements, button and keyboard activities, and captured images.

program — See **module**.

program digraph — See **digraph**.

program predicate — See **predicate**.

program-sensitive fault — A fault that occurs when a particular sequence of instructions is executed. {Software Technology Support Center}

proof checker — A program that checks formal proofs of program properties for logical correctness. {Software Technology Support Center}

pseudocode — A form of software design in which programming actions are described in a program-like structure; not necessarily executable, but generally held to be humanly readable.

purity ratio — Maurice Halstead suggested that programs which are not the same length as predicted by N^ (see predicted length) are victims of impurities. The purity ratio is the ratio of N^ to N (predicted length/length). This measurement is used by METRIC to determine error-prone parts of code. {METRIC}

qualification — The process ensuring that a given software component, at the end of its development, is compliant with the requirements. The qualification shall be performed with appropriate and defined software components and sub-software systems, before integrating the software to the next-higher level. The techniques for qualification are testing, inspection and reviewing.

quality assurance — A planned and systematic use of metrics to provide adequate confidence that an item or product conforms to established requirements. {Software Technology Support Center}

quick check mode — The CAPBAK and CAPBAK/MSW playback mode that replays a test in order to generate a new set of AUT responses. The new responses,

the actual results, are compared with earlier results; that is, the expected results of the test.

This mode verifies an application's behavior by automatically comparing any currently-captured actual images, windows or ASCII characters with the image, window or characters that were captured and stored as the expected results.

record This command is a program that records keystrokes being entered at a terminal and saves them in a keysave file format. It records and displays the responses from the remote machine, and saves them in a baseline file which can be used to synchronize playback. {CAPBAK/UNIX}

reference analysis A form of static-error analysis that can detect reference anomalies; for example, when a variable is referenced along a program path before it is assigned a value along that path. {Software Technology Support Center}

reference listing report A report produced by TCAT and S-TCAT which shows the coverage level achieved for all modules that are named in the specified reference listing.

regression report This report shows only those tests whose outcomes have changed, thereby identifying bugs which have been fixed or introduced since the last time the test cases were activated. It lists test name, outcome, and activation date. {SMARTS}

regression testing Testing which is performed after making a functional improvement or repair of the software. Its purpose is to determine if the change has regressed other aspects of the software.

As a general principle, software unit tests are fully repeated if a module is modified, and additional tests which expose the removed fault are added to the test set. The software unit will then be re-integrated and integration testing repeated.

resource file

For X Windows applications only, a file that contains a set of pre-determined values for parameters.

response file

CAPBAK captures images from the server and stores them in a response file. This file can be compared against the baseline file. {Regression}

return variable

A return variable is an actual or formal parameter for a module, which is modified within the module.

review

A planned activity during which a work product (strategy, budgets, requirements, design, code, test, support, training, etc.) is reviewed by the author and others involved in an attempt to gain an objective, varied, and complete perspective of the product.

Review is commonly referred to as code review, technical review, walk-through, inspection, etc. Walk-throughs are generally less formal and led by the author, while inspections are more formal and led by a more independent party. {Software Technology Support Center}

robustness

1. The degree to which a system or component can still function in the presence of partial failures or other adverse, invalid, or abnormal conditions.

2. This is a characteristic of a product that enables it to more than meet minimum requirements. Customers really expect more than just minimum requirements, and although "satisfied" with minimum requirements, will look elsewhere next time if not "delighted" by the product. This is more a function of product design than design process.
{Software Technology Support Center}

S-TCAT

The System Test Coverage Analysis Tool of the STW/Coverage tool group. S-TCAT measures the structural completeness of a test suite by reporting on the percentage of function call-pairs exercised.

S0 coverage — The percentage of modules that are invoked at least once during a test or during a set of tests. {S-TCAT}

S1 coverage — The percentage of call-pairs exercised in a test as compared with the total number of call-pairs known in a program. By definition the S1 value for a module which has no call pairs is 100% if the module has been called at least once, and 0% otherwise. {S-TCAT}

scover — An S-TCAT utility used to assess the value of S1 coverage.

screensave file — The file of screen images saved each time a trigger keystroke was hit during a CAPBAK/DOS session.

screensave mode — The CAPBAK/DOS mode that enables the user to save screens exactly as they appear immediately before a trigger key is pressed.

screensave trigger character(s) — Characters that invoke CAPBAK/DOS to save a screen of data, starting from the time the last keystroke was typed prior to when the current trigger was typed.

screensave trigger mode — When screensave trigger mode is on, any time a trigger character is pressed the system records a copy of the current screen contents.

segment — A [logical branch] segment or decision-to-decision path is the set of statements in a module which are executed as a result of the evaluation of some predicate (conditional) within the module. The segment should be thought of as including the outcome of a conditional operation and the subsequent statement execution (up to and including the computation of the value of the next predicate, but not including its evaluation in determining program flow). {Coverage}

segment instrumentation — The process which results in an altered version of a module, logically equivalent to the unmodified module but containing calls to a special data collection subroutine. This subroutine accepts information as to the specific segment

	sequence incurred in an invocation of the module. {Coverage}
semantic error	An error resulting from a misunderstanding of the relationship of symbols or groups of symbols to their meanings in a given language. {Software Technology Support Center}
sensitivity analysis	In safety analysis, it is analysis that assesses the potential impact of a potentially-critical failure on the ability of the system to perform its mission. {Software Technology Support Center}
Shift-PrtSc	This key terminates playback (abnormally) during playback mode, before the end of the session. {CAPBAK/DOS}
simulator	From Webster's, simulate "to create the effect or appearance of." Therefore, a machine that creates the effect or appearance of another. Similar to an emulator. Examples peripheral or network simulators. {Software Technology Support Center}
smarts	This command invokes the ASCII version of SMARTS for UNIX and MS-DOS.
SMARTS	The Software Maintenance and Regression Test System of the STW/Regression tool set. SMARTS reads a user-designed test description file to find out what actions to take for each test or group of tests. This description file, called the Automated Test Script (ATS), is written in SMARTS' description language (similar to C language in syntax). In this file, the user can specify test commands to dispatch and test outcome evaluation methods. At the user's command, SMARTS performs the pre-stated actions, runs a difference check on the outputs against the baseline, and accumulates a detailed record of the test results.
software subsystem	A part of a software system, but one which includes many modules. Intermediate between module and system.

software system — A collection of modules, possibly organized into components and sub-systems, which solves some problem or performs some task.

source clause — A clause in the ATS file that contains comments which may give some explanation to the origin of the test(s) invoked in each particular case. Most commonly, the source clause is used to specify the purpose of a test.The comments in a source clause are displayed by SMARTS when a test case activation is evaluated as a test failure, allowing you to note which files need to be inspected. {SMARTS}

spaghetti code — A program whose control structure is so entangled by a surfeit of GOTO's that its flowgraph resembles a bowl of spaghetti.

statement complexity — A complexity value assigned to each statement which is based on (1) the statement type, and (2) the total length of postfix representations of expressions within the statement (if any). The statement complexity values represent an approximation to potential execution time.

statement testing — Testing designed to execute each statement of a computer program. See **test coverage**. {Software Technology Support Center}

static analysis — The process of analyzing a program without executing it. This may involve a wide range of analyses. The STW / Advisor suite of tools performs static analyses. {STATIC}

static frequency — Forced constant CAPBAK playback rate.

STATIC — The Static Analyzer for C reports on source code errors and inconsistencies that otherwise may go undetected. STATIC does a more detailed check than your compiler, including locating nonportable constructs. It also looks across multiple modules for bugs and so enjoys a perspective that your compiler does not have.

status report — The report presents the most recent information about executed tests. It contains test case name, outcome (pass / fail), activation date, execution time (seconds), and error number. {SMARTS}

stress testing Testing conducted to evaluate a system or component near, at, or beyond the limits of its specified requirements. {Software Technology Support Center}

strong typing Strong typing refers to typedef-based type checking. {STATIC}

stw The command that invokes the GUI for STW.

subtest A part of a test that occurs between passing control to the test object and the return of control to the test environment.

successor logical branch One or more logical branches that (structurally) follow a given logical branch.

successor segment One or more segments that (structurally) follow a given segment. {Coverage}

summary report This report is an accumulated account of the complexity measures for the entire program. {METRIC}

symbolic evaluation A technique of analyzing program behavior without executing the program. This generally results in the generation of a series of formulas that describe the input/output relationships in a software system.

symbolic testing A method of examining the path computation and path condition to ascertain the correctness of a program path. {Software Technology Support Center}

synchronization Synchronization is the process of maintaining coherence between a recording and the resulting system-under-test's responses. During playback of a test script, e.g. with CAPBAK, it is possible, due to many factors, for the playback process to "de-synchronize" with the synthetic input being reproduced by CAPBAK. Synchronization schemes are used to control the playback so that synchronization is not lost. CAPBAK has several ways to prevent loss of synchronization, among them "automatic output synchronization" and "image synchronization".

syntax error

A violation of the structural rules defined for a language.
{Software Technology Support Center}

system testing

Verifies that the total software system satisfies all of its functional, quality attribute and operational requirements in simulated or real hardware environment.

It primarily demonstrates that the software system does fulfill requirements specified in the requirements specification during exposure to the anticipated environmental conditions. All testing objectives relevant to specific requirements should be included during the software system testing. Software system testing is mainly based on covered-box methods. {Coverage}

TCAT-PATH

The Path Test Coverage Analysis Tool of the STW / Coverage tool group. TCAT- PATH measures the thoroughness of your test case coverage by reporting on the paths exercised.

TCAT

The Test Coverage Analysis Tool of the STW / Coverage tool group. TCAT measures the thoroughness of your test case coverage by reporting on the percentage of logical branches exercised.

TDGEN

The Test Data Generator System which is a component of the STW / Advisor product line. TDGEN produces test data files in a user-designed format by replacing variable fields in a template file with random or sequential data values from a values file.

template file

A user-designed TDGEN file which indicates where selected values are to be placed within an existing test file. A template file provides a format for the generation of additional tests.

termination clause

A clause in the ATS file that allows for execution of concurrent processes in order to test the timing of specific test cases and terminate them if necessary. It is executed when a special termination command fails to complete normally. {SMARTS}

test

A [unit] test of a single module consists of (1) a collection of settings for the inputs of the module, and (2) exactly one invocation of the module. A unit test may or may not include the effect of other modules which are invoked by the current testing. The intent of a test is to find faults in the module.

testability

A design characteristic which allows the status (operable, inoperable, or degrade) of a system or any of its subsystems to be confidently determined in a timely fashion. Testability attempts to qualify those attributes of system design which facilitate detection and isolation of faults affecting system performance.

test case

Information about observable states, conditions, events, and data: all the causes (stimuli, inputs) that compel or allow software under test to perform one separately definable and measurable function. It should be possible to identify and track individual test cases. See test failure report.
{Software Technology Support Center}

test coverage measure

1. A measure of the testing coverage achieved as the result of one unit test, usually expressed as a percentage of the number of segments within a module traversed in the test.
{Coverage}

2. The degree to which a given test or set of tests addresses all specified requirements for a given system or component. Components are depth of coverage and breadth of coverage. Test coverage can also refer to code coverage, such as branch and statement test coverage, the results of which will be realized as a metric.
{Software Technology Support Center}

test data set

A specific set of values for variables in the communication space of a module which are used in a test.

test development — The development of anything required to conduct testing. This may include test requirements, strategies, processes, plans, hardware, software, procedures, cases, documentation, and maintenance strategies (essentially, the same or similar efforts as that of any product development, except that usually, but not always, the test products are used by internal customers rather than external. The people involved in the test development effort should use a lifecycle approach; essentially, the same as in the product development effort, and the test products should be treated as assets to be managed rather than expenses to be pared). {Software Technology Support Center}

test failure report — A report containing a unique identifier (ID) for each failure, an ID of the software under test, an ID of the test case, the date and time of the failure, symptoms of the failure, and a classification of the failure (criticality, priority, etc.). {Software Technology Support Center}

test harness — A tool that supports automated testing of a module or small group of modules.

test object — The central object on which testing attention is focused. Also known as **object under tes**t.

test path — A test path is a specific (sequence) set of segments which is traversed as the result of a unit test operation on a set of testcase data. A module can have many test paths. {Coverage}

test procedure — The formal or informal procedure that will be followed to execute the test in question. This is usually a written document that will allow others to carry out the test with a minimum of training and confusion. There will be a separate test procedure for each case, which will be noted in the test plan. {Software Technology Support Center}

test purpose — The free-text description of the purpose of a test, normally included in the source clause of an ATS file that is processed by SMARTS.

test readiness review

In *Technical Review and Audits For Systems, Equipments, and Computer Software*, the test readiness review comes after the critical design review and before the functional configuration audit. By default, one test readiness review is conducted for each CSCI. This is to verify that the item is ready for formal testing and approval.
{Software Technology Support Center}

test status report

Shows metrics for work products and work processes. Shows quantity for information at a glance; e.g. total test cases, total run, total passed. Generally, shows little or nothing about quality of tests. {Software Technology Support Center}

test stub

A test stub is a module simulating the operations of another module invoked within a test. The test stub can replace the real module for testing purposes.

test target

The current module (system testing) or the current segment (unit testing) upon which testing effort is focused.

test target selector

A function which identifies a recommended next testing target.

testing techniques

Can be used in order to obtain a structured and efficient testing which covers the testing objectives during the different phases in the software life cycle.

top-down testing

The testing starts with the main program, which becomes the test harness. The subordinated units are added as they are completed, and testing continues. Stubs must be created for units not yet completed.

This strategy results in re-testing of higher level units when more lower level units are added. The adding of new units one by one should not be taken too literally. Sometimes a collection of units will be included simultaneously, and the whole set will serve as test harness for each unit test. Each unit is tested according to a unit test plan, with a top-down strategy.

trace file — A file containing the most recent test run of trace coverage information. {Coverage}

trigger key — These are user-defined keys that CAPBAK/DOS uses to record screens or to write marker records to the keysave file.

true-time recording — The capability of CAPBAK to record complete timing information about the CAPBAK session in such a way that it can be played back at the same rate it was recorded.

T-SCOPE — The Test Data Observation and Analysis System provides dynamic visualization of test attainment during unit testing and system integration. It is a companion tool for TCAT, S-TCAT and TCAT-PATH.

unconstrained paths — The set of edges that will imply execution of other edges in the program. {TCAT-PATH}

unit test — See **test**.

Unit Testing — This procedure is meant to expose faults in each software unit as soon as the unit is available, regardless of its interaction with other units. The unit is exercised against its detailed design, and by ensuring that a defined logic coverage is performed.

Informal tests on module level which will be done by the software development team are necessary to check that the coded software modules reflect the requirements and design for that module. Clear-box (glass-box) oriented testing, in combination with at least one closed-box method, is used.

unreachability — A statement (or segment) is unreachable if there is no logically obtainable set of input-space settings which can cause the statement (or segment) to be traversed.

validation — The evaluation at the end of the development process to ensure compliance with software requirements. The techniques for validation are testing, inspection and reviewing.

values file — A user-designed TDGEN file which indicates the actual test values, test value ranges or test value generation rules for the creation of additional test files.

verification — The process of determining whether or not the products of a given phase of the software development cycle meet the implementation steps, and can be traced to the objectives established during the previous phase. The techniques for verification are testing, inspection and reviewing.

vertex — See **node**.

white-box testing — See **glass-box testing**.

Xcalltree — An S-TCAT and TCAT utility which displays a software system's caller-callee dependence structure (may be called **Xcgpic** in older versions of TestWorks).

Xcapbak — This command invokes the GUI version of CAPBAK/X. See also **Xrecord, Xplabak,** and **Xdemo.**

Xdemo — A variation of **Xplabak** that does not require access to licensing, but does check to assure that the keysave file played back has been processed by **Xdemo.key**.

Xdemo.key — A command that is part of the CAPBAK/X package that authorizes a keysave file for playback by **Xdemo**.

Xdigraph — A TCAT or TCAT-PATH utility used to create a picture of a directed graph (may be called **Xdigpic** in older versions of STW.)

Xexdiff — The EXDIFF command to perform a pixel-by-pixel comparison of two saved images.

Xkiviat — The command to invoke the Kiviat chart generator that is supplied with the METRIC product.

Xmask — The EXDIFF command to mask out regions. This is useful whenever there are differences between two files that are completely inconsequential, such as a date, header, footer, or path name.

Xplabak — A CAPBAK/X command which reads a keysave file and plays back the captured keystrokes, mouse movements and images.

Xrecord — A CAPBAK/X command which allows you to record keystrokes, screen captures, and mouse movements and save them to a keysave file.

Xsmarts — The command to invoke the GUI version of SMARTS.

Xstatic — The command to invoke the STATIC component of the TestWorks system.

Xtcat — The command to invoke the GUI version of TCAT.

Xtcatpath — The command to invoke the GUI version of TCAT-PATH.

Xtdgen — The command to invoke the TDGEN system within the STW package.

Xtscope — The command to invoke the GUI for T-SCOPE.

CHAPTER 7

The TestWorks Index

A Quantitative Quality Index for Your Application

7.1 Abstract

Assessing the relative quality of a software system is a complex but important matter in software engineering. To make rational decisions about complex software requires an approach that combines analysis of product properties with analysis of the underlying software construction process. A weighted, figure of merit, software quality index — The TestWorks Index™ — offers an attractive approach because it takes into account software quality metrics, process assessments, and practical considerations.

7.2 Introduction

This paper addresses a common problem in software development: How good is the quality of a specific software application? How do I know it? How can I make decisions about it? (For example, should it be released yet?) How can I estimate what to do next on my product based on where I am now?

The approach to this problem is to assess the quality of a particular application by weighing the answers to questions that address BOTH the properties of the application itself and the characteristics of the process used to produce it.

7.3 Quality Process Assessment Methods

The SEI CMM and the ISO-9000 type quality process models are based on examining the process that produces the product. This approach is based on the well-documented fact that a better industrial process tends to produce a better product, and that continual incremental improvements to that process tend to lead to continual incremental improvements in its product. This simple method can account for spectacular quality — and consumer acceptance — gains.

While this technique is clearly valid in general terms, sometimes good processes produce bad products and bad processes produce good products. This happens annoyingly often in software products, perhaps because some of the intermediate elements of the process can be very difficult to measure.

So Quality Process Models accept such exceptions, focusing on the main point: Improving the process improves the product. And the exceptions are anomalies.

7.4 Product Methods

The Product Analysis approach, often called the metrics approach or the static analysis approach, takes the opposite tack: look at the final product only, and base decisions about its quality on what is actually there, regardless of how it got there. After all, the final source code itself completely determines what an application can do. Regardless of how it was produced, regardless of the methodology or tools or process used to make it, the actual quality of a software product is determined directly by its own internal, intrinsic properties.

So, even if it is junky, spaghetti code hacked together by rank amateurs, if it works well then it works well. Who needs a fancy software process, anyway?

Simply put, quality is determined in the contest of the marketplace.

Of course, given that quality is implicit in the as-built product, we still have to find a way to measure it if we want some measure of control over the result. To measure the quality of an application by its structural properties or content, we use software metrics (e.g., cyclomatic complexity, size metrics — there are hundreds of possible metrics).

Yet we know from experience that sometimes applications with very poor software quality metrics, e.g., with **E(n)** in the 100's and Halstead weights in the 1,000,000's, are perfectly good, perfectly reliable code and don't have any field problems. At the same time, some products that are high-scoring by every metric one can find are complete disasters.

Automated static analysis tries to mechanize code inspection methods, but most implementations tend to find far too many things wrong. Long lists of product features that are "dangerous" but not "fatal" suggest not that a product will fail in the field, but that the builders don't mind living on the edge.

For example, if you always fixed everything that /bin/lint said ought to be fixed, assuming you could afford to do that, your software quality would be sure to go up, but there would be no guarantee that your delivered functionality would change for the better. It might change for the worse! You could be spending money to improve the product and changing it for the worse.

The paradox is that just having measurable high-quality code that meets small-scale and large-scale quality guidelines is no more a measure of field product success than having a perfect manufacturing process that is building a "Monday Morning Car."

7.5 Process/Application Assessments

A combined process / application assessment is a way out of this mess. A software manager needs to take into account the following factors: HOW a product was built; WHAT its characteristics are; and WHY better quality is important; and what the producers and their management — the team — FEEL about how good the team / product combination is.

A multi-faceted assessment method can be fooled too, of course, but its strength is that it focuses on perceived quality-key aspects of both process assessment and product assessment.

- HOW a product was built is addressed by questioning whether certain basic quality-oriented processes are used in its construction. For example: Was coverage analysis done? What coverage metrics, and how thoroughly? (How well was it tested?) Was automated regression done? How thoroughly? (How well was it tested?)
- WHAT its characteristics are is addressed by identifying certain basic metrics that pertain to its actual functional content. For example: What is the average **E(n)** for functions? (How complex is the code?) What is the calltree aspect ratio? (How is the code shaped?)
- WHY better quality is important is, simply put, an assessment of how critical the product is to the producers. If product quality isn't important, then quality shouldn't be of any concern. But if a product is intended for a life-critical application, and therefore has to have very high quality, then the need for quality has to be taken into account.
- HOW the team FEELS about the product they've built affects a lot of things — and will be controversial to measure. The very best software development efforts have often been fielded by dedicated, talented, teams who believe in their work.

7.6 The Methodology

The TestWorks Index™ is a balanced, weighted, experience-determined estimate of selected factors and uses a combination of estimates, measurements, and process-characterizations to come up with a quality figure that can be used — within a single organization — to compare products. The TestWorks Index™ is the average score obtained on a simple question list, where specific quantitative responses based on current engineering experience assign "points". The more points scored, the better the product. The average point count (the total points scored divided by number of questions) is the TestWorks Index™.

In engineering this has been called a "Figure of Merit (FOM)" and the notion of using FOMs has a long tradition of use in comparing complex things. From assessing competitive proposals (which are scored according to weighted averages), to determining plant efficiency, engineers take the practical approach even when it is known there is no theoretical solution.

Some benefits the TestWorks Index™ offers in assessing *your* products are:

- You can compare two products from your production shop in a quantitative way.
- You can adjust the point values, if you like, to match your own experience. Or you can add quality-related factors if you like (but you can't take them away or you may destroy the integrity of the index).
- You can use the evidence internally for your own purposes. You don't have to expose yourself to SEI or ISO-9000 audit processes.
- You CAN have or seek a high SEI rating or obtain ISO-9000 approval. The TestWorks Index™ assesses product / producer / process quality in a way that combines many of the features of these two important quality-related standards.
- You can use The TestWorks Index™ now, with data that you probably already have available, to come up with meaningful comparative estimates.
- By adopting The TestWorks Index™ you create an internal culture in which achieving practical goals for a software product becomes a common goal. You might even say that the product had been "TestWorked" to a certain level in your advertising.

7.6.1 Caveats

If you read this, you may get the impression that this is a foil to encourage users to buy the TestWorks™ product line. True, you may want to use some TestWorks™ products in your software production line to make sure you obtain a better TestWorks Index™ score. But you could use our competitors' products as well. The TestWorks Index™ is NOT tied use of TestWorks™ products.

7.6.2 How It Works

The TestWorks Index works as shown on the following chart. The factors on the chart are metrics that you can measure, or are assessments you can make, in a straightforward way. Detailed explanations of the terms follow the chart.

As you read the explanations, think of a specific project that you're working on, and try to calculate its The TestWorks Index™ score as you go along.

TestWorks™ PRODUCT QUALITY INDEX™ — DEFINITION AND EXPLANATION

This table shows how to compute the TestWorks Product Quality Index™ — the "TestWorks Index." The index gives an organization the chance to assess how well their internal software quality process is actually used on a particular product level and to compare their indicated product quality against current likely industry standards.

Each factor in the TestWorks Index is evaluated so that a simple point — scored between 0 and 100 — can be assigned depending on the answers. The overall TestWorks Index is the arithmetic average of the individual scores on each factor (you add them up and divide by the number of factors used).

WORKSHEET TestWorks Index™ EVALUATION FACTOR	50 Points	60 Points	70 Points	80 Points	90 Points	100 Points	My Score
F1 Cumulative C1 (Branch Coverage) Value for All Tests	>25%	>40%	>60%	>85%	>90%	>95%	
F2 Cumulative S1 (Callpair Coverage) Value for All Tests	>50%	>65%	>80%	90%	95%	98%	
F3 Percent of Functions with E(n) < 20	<25%	>25%	>50%	>75%	>90%	>95%	
F4 Percent of Functions with Clean Static Analysis	<20%	>20%	>30%	>40%	>50%	>60%	
F5 Last PASS / FAIL Percentage	>25%	<25%	>50%	>75%	>90%	>95%	
F6 Total Number of Test Cases / KLOC	>10	<10	>15	>20	>30	>40	
F7 Calling Tree Aspect Ratio (Width/Height)	>1.0	<1.25	<1.5	<1.75	<2.0	>2.0	
F8 Current Number of OPEN Defects / KLOC	>5	<5	<3	<2	<1	<0.5	
F9 Path Coverage Performed for % of Functions	<1%	>2%	>5%	>10%	>15%	>25%	
F10 Cost Impact / Defect:	>$100K	>$50K	>$25K	>$10K	>$1K	<$1K	
Total Points	—>	—>	—>	—>	—>	—>	

7.7 Index Criteria

Not just any list of scored questions should quality as a valid comparative index. To qualify as an effective indicator some constraints have to be put on The TestWorks Index™ or its home-brewed derivatives to make sure that it isn't manipulated to favor a particular process or product feature or quality assurance approach. The constraints that make sense are the following:

- There can be no more than 10 (ten) factors. This keeps the arithmetic simple (managers need this, technical people think).
- At least half of the criteria must be completely quantitative, objective, measurable, repeatable; i.e. not subject to any kind of judgment **[Q]**.
- At least three of them have to deal with something about the static (non-dynamic) characteristics of the product **[S]**.
- At least three of the criteria have to somehow involve actual tests of (experiments on, examinations of, executions of) the as-built software product — you can't design quality into a product without *some* kind of checking, and you can't score high on the index without something that works and does something **[T]**.
- At least three of the factors have to deal with something about the dynamic behavior of the product, how it actually works when you run it **[B]**.
- At least one of them have to deal with something about how the product was put together, i.e., about the process used in constructing it **[P]**.
- At least one of the factors has to deal with a measure of the quality "need" imposed from some outside force, e.g. the cost of repairing a defect in the field or the life-criticality of the application **[$]**.
- Some of the factors can address several of these criteria: they don't have to be unique to each area.
- No more than one of the qualifying factors can be a "wild card" and need not meet any of the above criteria (The error will be still no worse than 10%).
- At least eight of the ten factors have to have some non-zero value. (You can leave out two if you have to!).

7.8 Explanation Of Terms

Here are short explanations of the above indicated measures. (The keys **[B, S, T, P, $]** are explained on the preceding page.)

F1 *Cumulative C1 (Branch Coverage) Value for All Tests* **[B, S, Q]**

This is the total C1 value achieved for this product on all tests. E.g. as measured by TCAT. Note that statement coverage is NOT usable because it understands results by half or more. Statement coverage is accepted as inadequate.

F2 *Cumulative S1 (Callpair Coverage) Value for All Tests [***B, S, Q]**

This is the total C1 value achieved for this product on all tests. E.g. as measured by TCAT. Note that we are counting the connects between caller and callee, not just whether a function was ever called (which is called module testing). Module testing is accepted as inadequate.

F3 *Percent of Functions with* ***[E(n)*** *< 20* **[S, Q]**

This measures the structural complexity for all functions or modules or methods in the current application. Experience shows that the cyclomatic complexity **E(n)** = E - N + 2 > 20 implies a "complex function" — not necessarily bad, but a potentially troublesome problem if a high percentage of the individual functions has this value. Though not necessarily harmful too high a percentage of "too complex" functions can be a serious warning sign of trouble ahead.

F4 *Percent of Functions with Clean Static Analysis* **[S, Q]**

Static analysis finds a broad class of defects that may cause trouble in the future. Many errors found by static analysis are non-critical, but too many static analysis detections is an indicator of poor quality. The measurement made here requires that a certain percentage of functions be subjected to some form of static analysis.

F5 *Last PASS / FAIL Percentage* **[B, P, Q]**

This is the total number of tests that PASS vs. the total number of tests available, as would be measured by the test controller, e.g. SMARTS. Tests PASS if they run as expected, and produce output close enough (as determined by the programmable differencer) to the baseline to be acceptable.

F6 *Total Number of Test Cases / KLOC* **[T, Q]**

This is a measure of the degree to which you have thoroughly tested the software relative to its size measured in 1000's of lines of code (KLOC). Most software is very poorly tested, so it may not take a great many tests to score high on this measure.

F7 *Call Tree Aspect Ratio* **[S, Q]**

This is a measure of the "verticalness" of the call-tree of the package, with packages that have a less vertical structure (and thus more independently testable) viewed as superior. The vertical height is the maximum depth calling tree (this is shown in Xcalltree / WINcalltree), and the horizontal width is the largest number of functions on any level in the tree. If the tree has multiple roots (as it will likely have in most modern applications) then the average values for all possible roots is taken.

F8 *Current Number of OPEN Defects / KLOC* **[T, J]**

No software product / project is perfect; this metric indicates how many defects per KLOC are open that are critical. An open defect typically means it is reported, reproduced, but unresolved with no work-around available to the user.

F9 *Path Coverage Performed for% of Functions* **[P, J]**

For almost all packages some critical functions or modules require full path coverage, but not all. This measures the percentage of all functions for which some form of path coverage has been performed. Remember, path coverage is NOT the same as branch coverage; path coverage would be measured by something like TCAT-PATH.

F10 *Cost Impact / Defect* **[$, J]**

This is an indication of how critical a serious software defect might be, expressed in monetary terms, i.e. in terms of the direct cost of any defect. Note that the scale used tends to take points *away* for the most-critical kinds of projects; this is done so that the more critical projects receive the greatest attention. Any product which is "life critical" gets 0 points.

7.9 Examples

Here's how the The TestWorks Index™ works when applied to some (admittedly, 100% fictitious) example projects.

Quick-And-Dirty Order Tracker

This project was done by one programmer and involved putting together an order tracking system for his company. Done in C and using an ASCII interface to a standard library of C++ functions...

Here's a summary of the scores that resulted:

```
Cumulative C1 (Branch Coverage) Value for All Tests  25
Cumulative S1 (Callpair Coverage) Value for All Tests70
Percent of Functions with E(n) < 20                  50
Percent of Functions with Clean Static Analysis      50
Last PASS / FAIL Percentage                          80
Total Number of Test Cases / KLOC                    50
Calling Tree Aspect Ratio (Width/Height)             60
Current Number of OPEN Defects / KLOC                50
Path Coverage Performed for % of Functions           50
Cost Impact / Defect:                                100
TOTAL POINTS SCORED                                  535

TestWorks Quality Index                             53.5
```

Test Tool Vendor's Coverage Analyzer

This coverage analyzer, a very popular one, is a sophisticated compiler-based product...

```
Cumulative C1 (Branch Coverage) Value for All Tests  70
Cumulative S1 (Callpair Coverage) Value for All Tests85
Percent of Functions with E(n) < 20                  80
Percent of Functions with Clean Static Analysis      60
Last PASS / FAIL Percentage                          50
Total Number of Test Cases / KLOC                    80
Calling Tree Aspect Ratio (Width/Height)             60
Current Number of OPEN Defects / KLOC                95
Path Coverage Performed for % of Functions           50
Cost Impact / Defect:                                80

TOTAL POINTS SCORED                                  710

TestWorks Quality Index                              71
```

Bedside Cardiac Monitor

Think of this as a life-critical application...

```
Cumulative C1 (Branch Coverage) Value for All Tests  100
Cumulative S1 (Callpair Coverage) Value for All Tests100
Percent of Functions with E(n) < 20                   80
Percent of Functions with Clean Static Analysis       80
Last PASS / FAIL Percentage                           90
Total Number of Test Cases / KLOC                     85
Calling Tree Aspect Ratio (Width/Height)              60
Current Number of OPEN Defects / KLOC                  95
Path Coverage Performed for % of Functions            60
Cost Impact / Defect:                                 50

TOTAL POINTS SCORED                                   800

TestWorks Quality Index                               80
```

7.10 Connecting To Reality

The hard part comes when trying to connect with reality. The main question everyone asks is, ``**How reliable will my application be in the field?**''

As students of software quality know very well, this is a very deep question to which there are few definitive or even suggestive answers. Instead, about the best we can do is associate a particular process's TestWorks Index score with a likely estimate of reliability based on judgment and experience.

An initial experimental *estimate* of this is done in the attached chart.

Time will tell whether the numbers are too high or too low. Time will tell if the reliability values correspond to the SEI/CMM levels, or if the achieved reliability is too low or too high. And, time will tell whether that application of relatively simple quality filters will achieve, or won't achieve, the expected effect often enough to be relied upon.

But in any case, making the attempt to tie these essential ingredients together is totally essential.

TestWorks™ — PRODUCT APPLICATION PROFILE

This table shows the components of TestWorks and how they are applied in an increasingly sophisticated sequence of quality processes, all calibrated with the TestWorks Index™ minimum value. For comparison, the corresponding CMM value is shown as a range (because of uncertainties in the CMM definitions).

PROCESS LEVEL	ADVISOR	PLANNING	REGRESSION	COVERAGE	PROBABLE DETECTION EFFICIENCY
Introductory Process TestWorks Index: > 40 (CMM Level 0-1)			CAPBAK/Lite	TCAT/Lite	10%-40%, 2 filters
Basic Process TestWorks Index: > 50 (CMM Level 1)		Manual	CAPBAK/Standard	TCAT/Lite	25%-50%, 2.5 filters
Standard Process TestWorks Index: > 60 (CMM Level 1-2)	METRIC	SMARTS	CAPBAK/Standard	TCAT/Standard	50%-90%, 3+ filters
Advanced Process TestWorks Index: > 70 (CMM Level 2-3)	METRIC	Informal	CAPBAK/Professional	TCAT/Professional	75%-90%, 4 filters
Critical Process TestWorks Index: > 80 (CMM Level 3-4)	STW/Advisor	Semi-Formal Specification-based	STW/Regression	STW/Coverage	80%-95%, 5 filters
Life-Critical Process TestWorks Index: > 90 (CMM Level 4-5)	STW/Advisor	Formal Specification-Based	STW/Regression	STW/Coverage	90%95%, 5 filters

TestWorking Motifburger

In this comprehensive application note, the entire suite of Software Research testing tools explores the sample application, MotifBurger.

8.1 Sample Application: Motifburger

Motifburger is a sample GUI application distributed along with the OSF/Motif X windowing system. Motifburger lets you summon a menu that gives you choices among various possible combinations of hamburger meals.

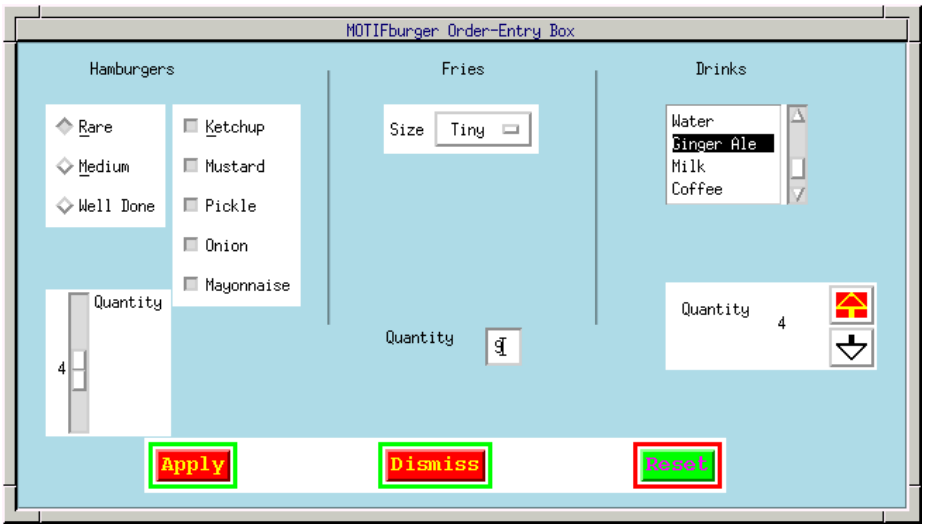


FIGURE 17 Motifburger's Order-Entry Box

The following Application Note shows results from TestWorks's comprehensive treatment of Motifburger.

- **STATIC**™, TestWorks' static analyzer for C, displaying customized bug detection reports on Motifburger's code based on static analysis of Motifburger
- **METRIC**™, TestWorks' software metrics processor and generator, displaying graphical and tabular reports based on metrical analysis of Motifburger's code
- **CAPBAK/X**™, TestWorks' capture / playback tool for the X Window System, recording tests of Motifburger in TrueTime and ObjectMode and capturing baseline images for comparison against later tests
- **SMARTS**™, TestWorks' software maintenance and regression test system, running a hierarchy of tests of Motifburger and displaying current and cumulative results
- **EXDIFF**™, TestWorks' extended file differencing system, performing both graphical file comparison and comparison of captured ASCII strings
- **TCAT**™, TestWork's test coverage analysis tool, displaying its analysis of test coverage of Motifburger in graphical displays, including call-trees that show the caller-callee structure of the program, directed graphs that show the control-flow structure of program modules, and coverage charts that display numerical results of the amount of coverage provided by a given test
- **XVIRTUAL**™, TestWorks' X11 virtual display system for X Windows, simulating multiple-user tests of Motifburger
- **TDGEN**™, TestWorks' test data generator, generating random input for multiple tests of Motifburger

8.2 STATIC Analysis of MotifBurger

STATIC processes a source code file or files and automatically generates customized reports covering more than 300 possible syntactical, warning and informational messages. It performs a more detailed check than a compiler does, looking at an entire program to find inconsistencies across the modules that comprise an application.

STATIC's reports are easy to customize, because the messages it includes in its reports are enabled or disabled according to the tester's preference using the following option groups:

- Control options enable and disable messages individually or in groups by symbol names or by type differences
- Flag options handle data types and syntax errors
- Size options set the sizes of various scalars (`short`, `int`) for a target machine
- Compiler options can disregard nonstandard constructs.

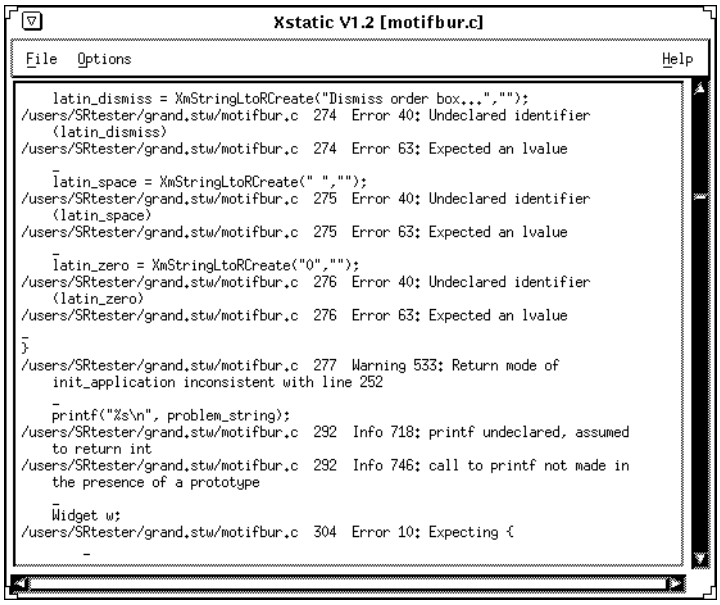


FIGURE 18 Static Displaying Report on Motifburger's Source Code

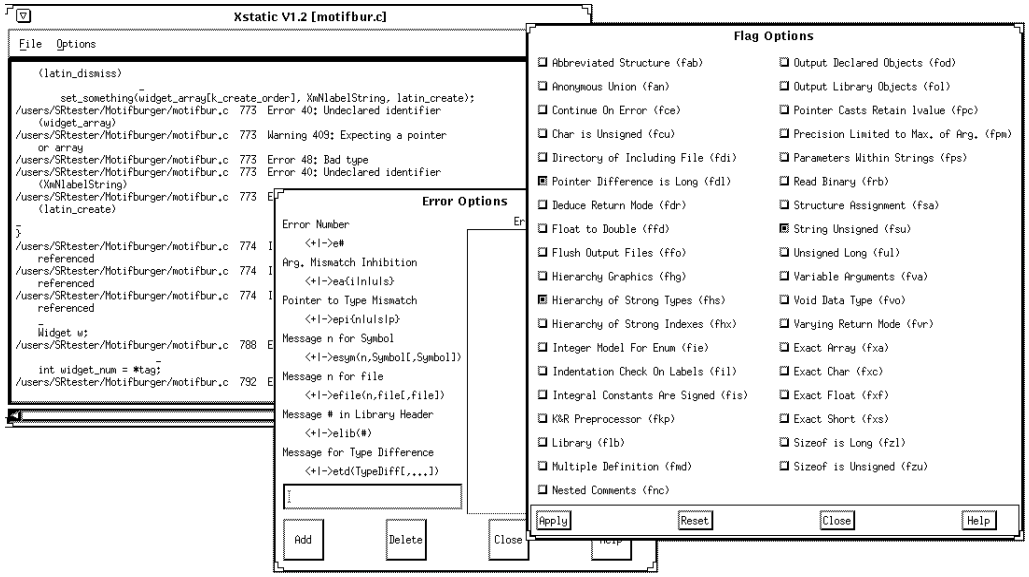


FIGURE 19 Static's Flag and Error Options

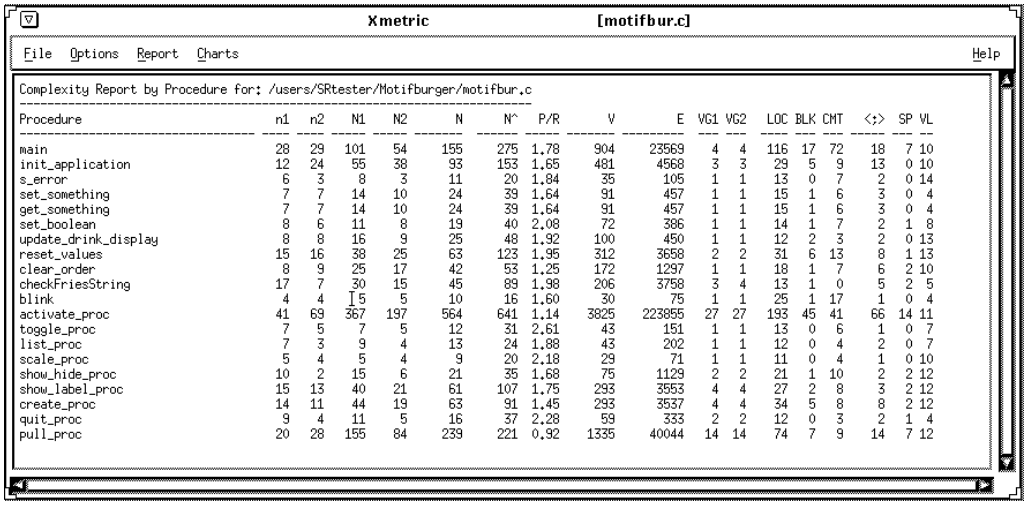
Figure 19 shows the compilations messages from STATIC for the Motifburger source code (left). Inspection can be modified by flag settings (right) and by directory / file / pointer specifications (center). STATIC supports multiple C compilers.

8.3 METRIC Analysis of MotifBurger

METRIC, TestWorks' software metrics processor / generator, here automatically computes several metrics for Motifburger, including Halstead Software Science metrics that measure data complexity in routines, Cyclomatic Complexity metrics that measure logic complexity in routines, and size metrics, such as number of lines, comments and executable statements. **METRIC** identifies which program modules are the most complex, so that informed decisions can be made about the allocation of testing resources. These software measurements are reported in the following configurable, easy-to-read reports and charts:

- **Full** reports display a set of metrics for each of the modules in a given source file.
- **Summary** reports provide metrics for the program as a whole.
- **Exception** reports list instances in which the code exceeds user-defined metric thresholds.
- **Kiviat** charts graphically plot metric results from the Summary report. Each metric is represented by an axis, and results are plotted with reference to user-definable upper and lower bounds.

Figure 20 is the complexity report view of Motifburger generated by **METRIC**. Shown are complexity indices for each of Motifburger's functions and procedures. **METRIC** supports C / C++, Ada, and Fortran.



Procedure	n1	n2	N1	N2	N	N^	P/R	V	E	VG1	VG2	LOC	BLK	CMT	<:>	SP	VL
main	28	29	101	54	155	275	1.78	904	23569	4	4	116	17	72	18	7	10
init_application	12	24	55	38	93	153	1.65	481	4568	3	3	29	5	9	13	0	10
s_error	6	3	8	3	11	20	1.84	35	105	1	1	13	0	7	2	0	14
set_something	7	7	14	10	24	39	1.64	91	457	1	1	15	1	6	3	0	4
get_something	7	7	14	10	24	39	1.64	91	457	1	1	15	1	6	3	0	4
set_boolean	8	6	11	8	19	40	2.08	72	386	1	1	14	1	7	2	1	8
update_drink_display	8	8	16	9	25	48	1.92	100	450	1	1	12	2	3	2	0	13
reset_values	15	16	38	25	63	123	1.95	312	3658	2	2	31	6	13	8	1	13
clear_order	8	9	25	17	42	53	1.25	172	1297	1	1	18	1	7	6	2	10
checkFriesString	17	7	30	15	45	89	1.98	206	3758	3	4	13	1	0	5	2	5
blink	4	4	5	5	10	16	1.60	30	75	1	1	25	1	17	1	0	4
activate_proc	41	69	367	197	564	641	1.14	3825	223855	27	27	193	45	41	66	14	11
toggle_proc	7	5	7	5	12	31	2.61	43	151	1	1	13	0	6	1	0	7
list_proc	7	3	9	4	13	24	1.88	43	202	1	1	12	0	4	2	0	7
scale_proc	5	4	5	4	9	20	2.18	29	71	1	1	11	0	4	1	0	10
show_hide_proc	10	2	15	6	21	35	1.68	75	1129	2	2	21	1	10	2	2	12
show_label_proc	15	13	40	21	61	107	1.75	293	3553	4	4	27	2	8	3	2	12
create_proc	14	11	44	19	63	91	1.45	293	3537	4	4	34	5	8	8	2	12
quit_proc	9	4	11	5	16	37	2.28	59	333	2	2	12	0	3	2	1	4
pull_proc	20	28	155	84	239	221	0.92	1335	40044	14	14	74	7	9	14	7	12

FIGURE 20 Metric Displaying Software Measurements of Motifburger

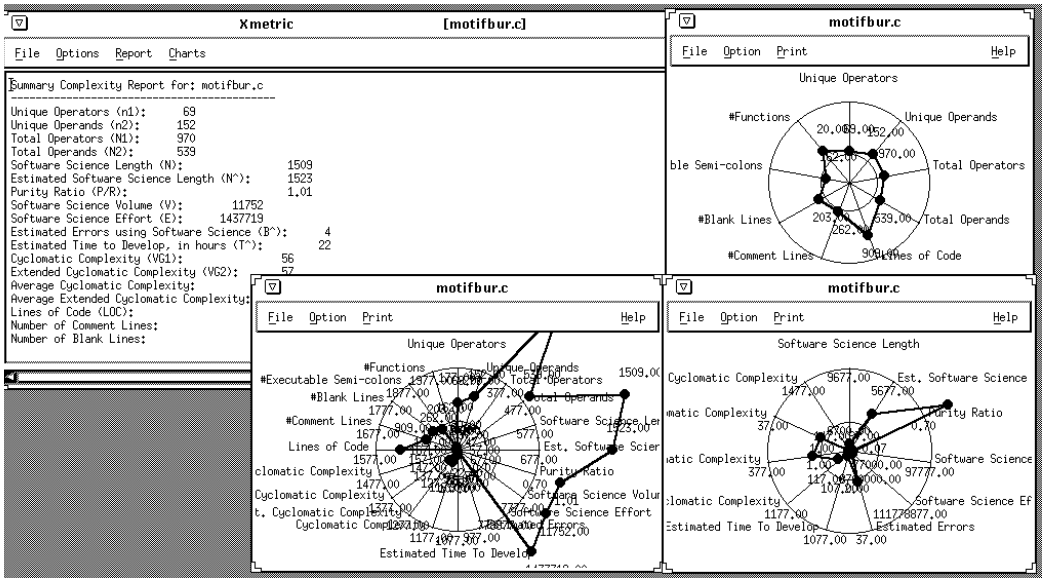


FIGURE 21 Kiviat Charts: Graphical Plotting of Motifburger's Code Metric Values

Figure 21 shows the summary report view of Motifburger's complexity, together with Kiviat graphs types I through III (counterclockwise from top right). Kiviat reports allow quick, accurate assessments of the complexity of an application's code relative to user-definable bounds.

The **Kiviat** charts display metric results from the Summary report. Each metric is represented by an axis, and results are plotted with reference to user-definable upper and lower bounds. Because Kiviat charts indicate whether source code falls above or below set metric values, they serve as an invaluable means of quickly viewing the metrics to focus on for a particular program.

Note: For more detailed Metric reports: (See Section 8.10 on page 117.)

8.4 CAPBAK/X: Recording Motifburger

CAPBAK/X™ is TestWorks' capture / playback tool for regression testing in the X Window System.

CAPBAK/X lets programmers record tests of an application. These recorded tests can be played back to determine whether subsequent modifications to the application have changed the application's functionality. **CAPBAK/X** records keystrokes, mouse movements, captured bitmap images, widget (object) actions, and extracted ASCII characters, and writes them into a test script. Snapshots of screen images and character strings taken during the recording are taken again during playbacks, and these snapshots can be minutely compared using **EXDIFF, TestWorks**' file comparison utility.

As a program plays back recorded test script file, keyboard, mouse and widget events are shown together with the running script, allowing the user to relate an event to the recorded test script code that actuates it. The user can also directly edit the recorded test script.

CAPBAK/X's virtual display capability allows tests to run in the background. This capability can be used to invoke a single application multiple times on the same workstation, allowing for load testing in a client / server environment.

CAPBAK / X records in two complementary modes, TrueTime and Object-Mode.

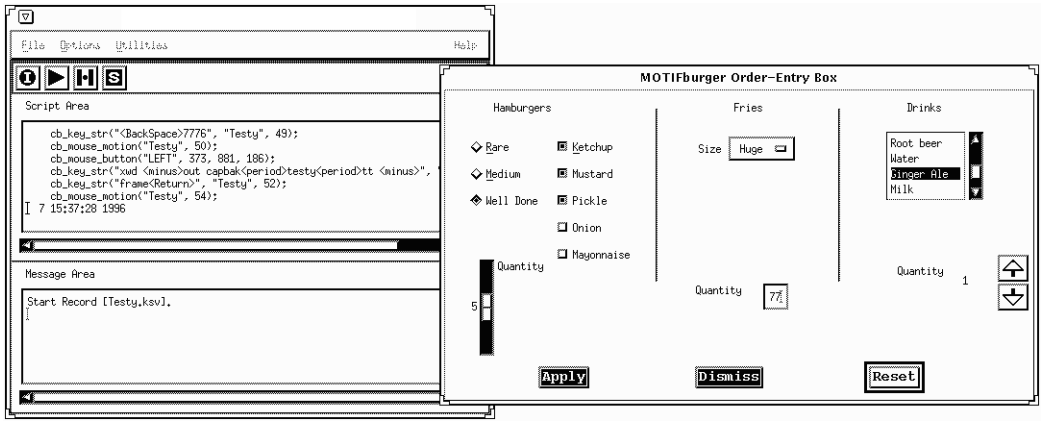


FIGURE 22 CAPBAK/X Recording Motifburger in TrueTime Mode

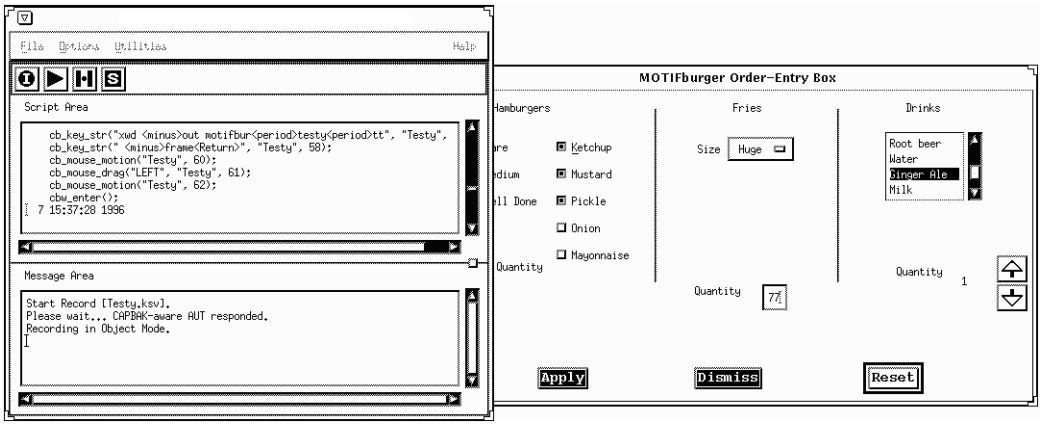


FIGURE 23 CAPBAK/X Recording Motifburger in ObjectMode

- *TrueTime* — Automatically records keyboard and mouse activity into an ASCII-format test script and plays back bit-mapped user input exactly as recorded.
- *ObjectMode* — Records and plays back actual widget (object) calls, regardless of their screen location, color, size, or other setup.

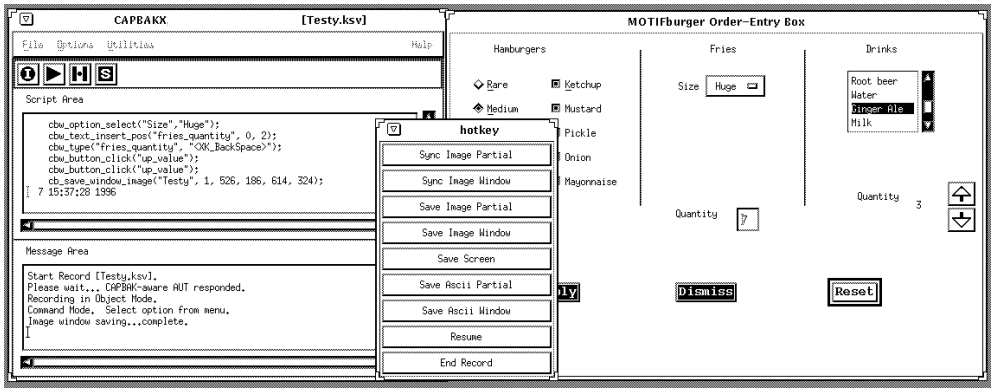


FIGURE 24 CAPBAK/X Capturing a Baseline Image During an ObjectMode Recording Session

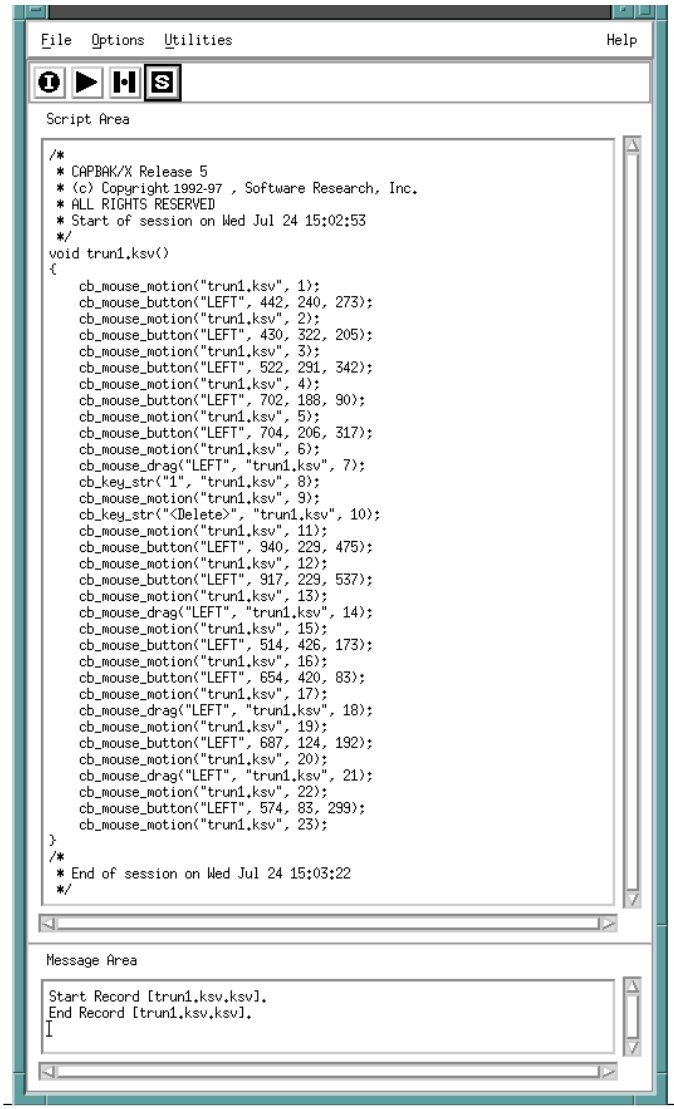


FIGURE 25 Script Window for Motifburger test run

Figure 25 on page 103 shows a script window for the Motifburger test run. Segments can be edited or appended to other sessions. Additional options are available to facilitate a more efficient playback, such as removal of extraneous mouse movements (Mouse Compression option in the Edit Keysave File menu).

Note: For sample scripts, see Section 8.11.

8.5 SMARTS and Motifburger

SMARTS, the TestWorks software maintenance and regression test system, is a tool for building and running test scripts, organizing the tests into a hierarchical tree, automatically executing all or a subset of tests, and generating reports based on the test results.

SMARTS reads a user-designed Automated Test Script (ATS) (see Appendix). The hierarchically organized tests can be supplemented with test activation commands, comparison arguments and pass/fail evaluation methods. The ATS can also be augmented with system calls to tools, such as the **STW/Regression** tool **CAPBAK**/X, which replays captured user sessions. The ATS automatically generates a directory listing of tests, providing a means of interactively executing the test script or viewing results of previous runs.

All **SMARTS** commands are context-sensitive. Test execution and reporting is based on the selection of a test or a group of tests, from the displayed ATS test tree hierarchy. **SMARTS** performs the stated actions, runs a difference check on the outputs against the baseline, and accumulates a detailed record of the test results.

Using the **STW/Regression** comparison system **EXDIFF**, differencing capabilities can be extended to ignore specified character strings and text line differences in ASCII files and masked areas in image files.

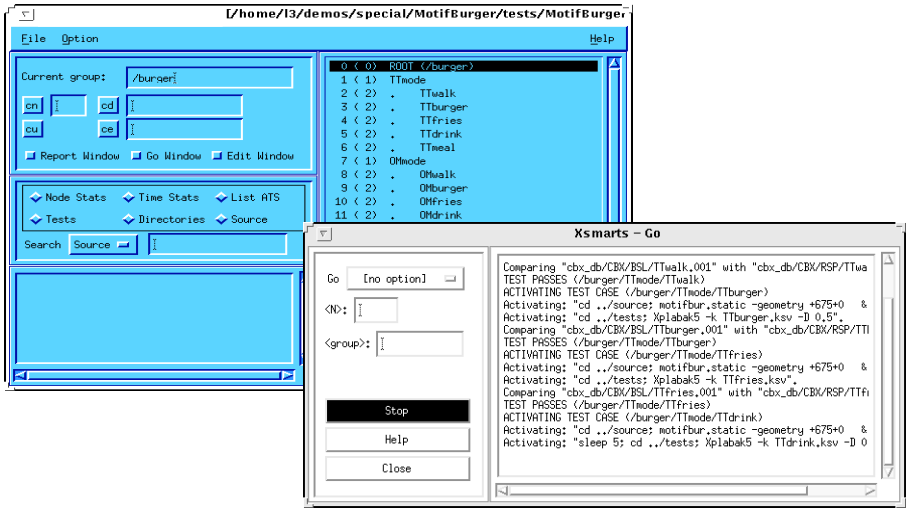


FIGURE 26 SMARTS Automatically Executing a Motifburger Test Script,

Four reports can be generated from test outcomes:

- The **Status** report lists the most recent test execution outcomes.
- The **Regression** report lists only those tests whose outcome has changed, identifying bugs which have been fixed or introduced since previous test activation.
- The **History** report includes current and past test results for every test executed.
- The **Certification** report summarizes the total number and percentage of tests that have passed and failed, providing an overview of testing status.

SMARTS facilitates the testing process by providing an effective means of automatically determining discrepancies and monitoring the effects of regression testing.

An appendix to this Application Note contains sample ATS files for testing Motifburger using **CAPBAK**.

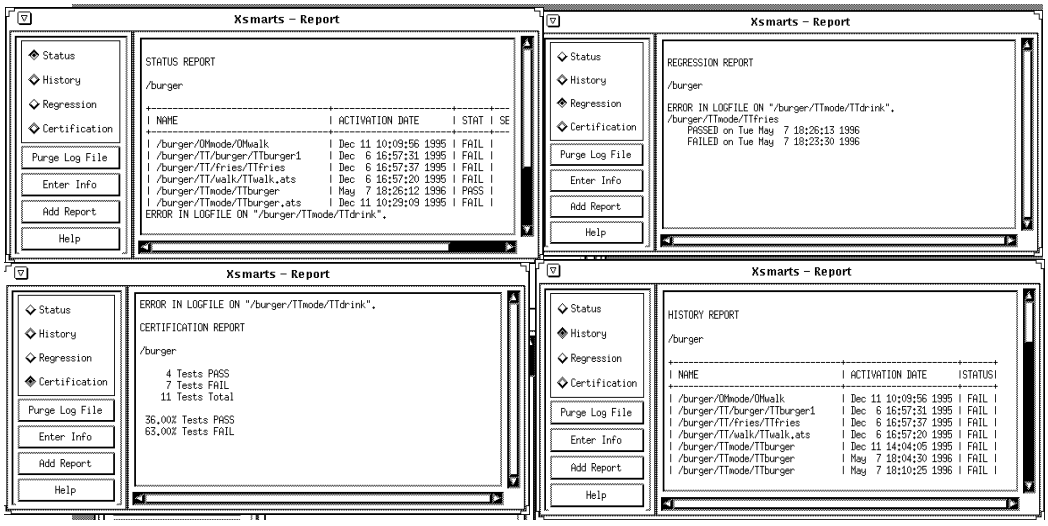


FIGURE 27 Reports Generated by SMARTS from Motifburger

Note: For illustrations of several SMARTS files, see Section 8.12 on page 124

8.6 EXDIFF and Motifburger

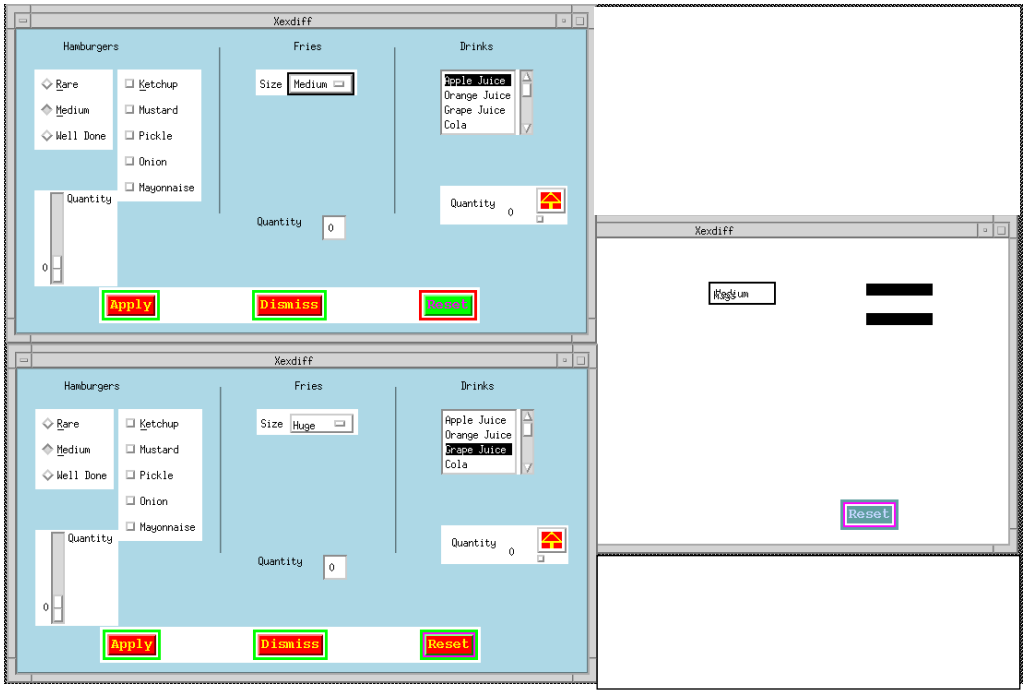


FIGURE 28 Xexdiff Showing Graphic Differences Between an Initial Motifburger Menu and an Improperly Reset Result

The EXDIFF extended file differencing system is a test evaluation tool that extends commonly available file differencing facilities. Its masking options let you specify areas within ASCII or image files to be ignored during the differencing process.

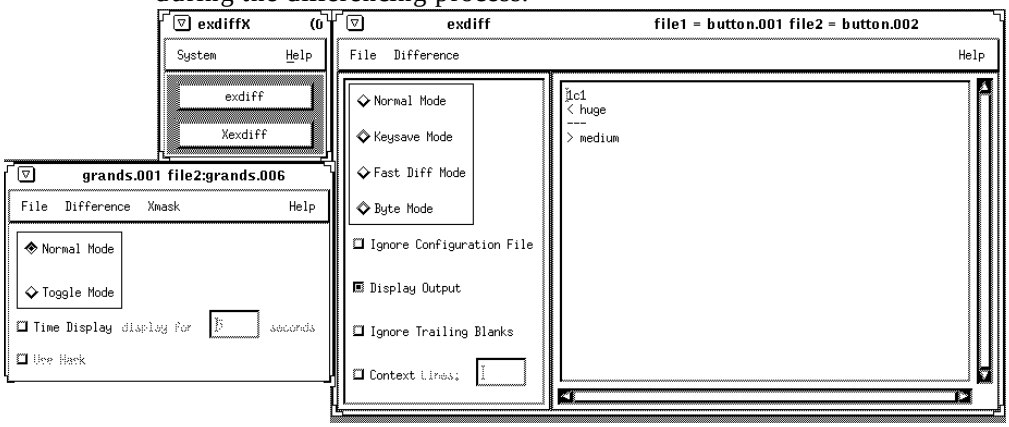


FIGURE 29 Exdiff Showing Differences Between Two OCR-Extracted ASCII Images from Motifburger Bitmap Display

8.7 Xvirtual and Motifburger

Xvirtual allows a virtual mode of test session playback that will produce the *effect* of an actual playback using a display that is kept only in memory and not displayed on the screen. All of the timing, image save actions, and other activities of a playback session are identical to a session run on the actual display screen. During virtual testing, all system calls to the actual screen display are disabled. The calls are simulated as demands on RAM, mimicking all system responses and performance.

The virtual display server (**X11virtual**) and its associated control programs (**xvinit** and **xvmon**) permit a tester to run a large number of parallel, independently controlled playback sessions on a single system. In effect, you can generate realistic system loading for performance measurement purposes as well as for testing.

The *Virtual Display* feature of **CAPBAK/X** permits extension of single-user tests to a multi-user context. This makes it possible for **CAPBAK/X** to measure performance of a system as it responds to the load imposed by two or more users. Each such *Virtual Session* includes a complete execution environment – with many options and features – and each can be controlled and monitored from a central display.

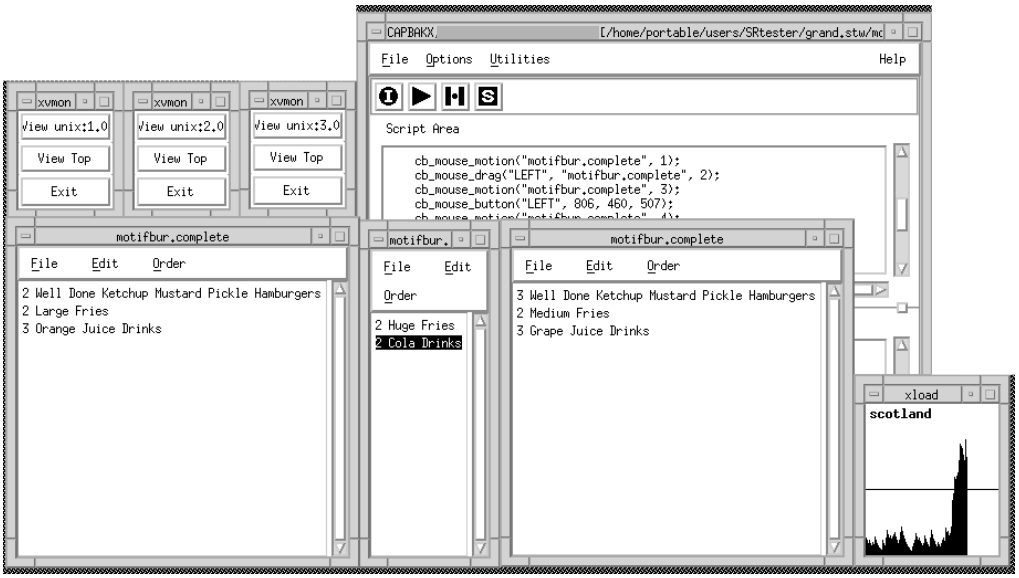


FIGURE 30 Xvirtual Simulating Three Simultaneous Tests of Motifburger. Note rising Xloads.

8.8 TCAT C/C++ and Motifburger

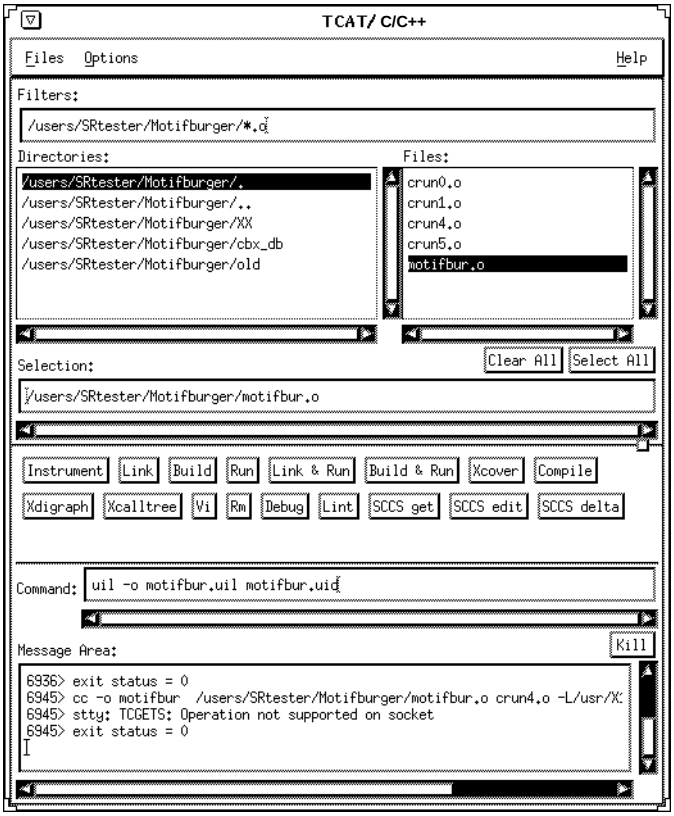


FIGURE 31 TCAT's Main Control Panel

TCAT, TestWorks' test coverage analysis tool, uses a new consolidated C and C++ instrumentor to measure logical path and branch completeness at the individual function level (C1), and to determine at the system level(S1) if all of the interfaces have been exercised.

TCAT measures how many times logical branches have been exercised for both True and False conditions using its *C1* metric. The *S1* measurement expresses test effectiveness as the percentage of function-calls (every function, not just one per function) exercised in a program by a set of tests, relative to the number of such function-calls in the system. *S1* identifies system interface errors by tracing exercises of the system's caller-callee relationships. **TCAT** instruments the program, placing markers at each logical branch and function-call. When test cases have been run against the instrumented code, the *C1* and *S1* metrics collect

data on the markers and store it in a trace file, from which **TCAT** extracts information to create tabular coverage reports showing which code is untested or frequently tested, and which test cases duplicate coverage. **TCAT** also creates an archive file that stores all cumulative test information.

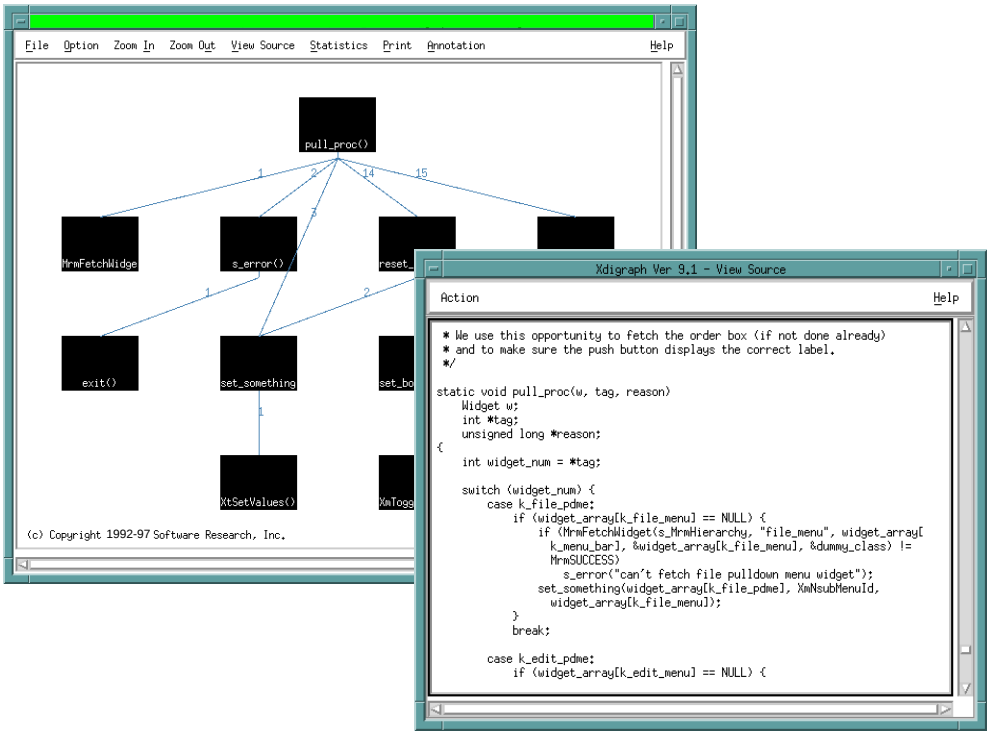


FIGURE 32 TCAT Calltree Graph of the Caller-Callee Structure of Motifburger Showing the Source Code Associated with One of Its Nodes

Instrumentation creates directed graphs and call trees that depict a module's control-flow structure and the caller-callee structure of a program, respectively. Figure 32 shows a calltree of Motifburger's `pull_proc()`. Each nodal element is active and can be selected to initialize its related digraph or source code view. Statistical and graphical annotation is also available.

The directed graphs allow the user to view a logical branch's level of coverage with **TCAT**'s unique annotation feature, and then to display and highlight the source code for that logical branch. The directed graphs can

be used to identify unexercised code and to study the architecture of a module to aid in re-designing new test cases for unexercised branches. Call-trees aid the user in understanding code by organizing and identifying a program's modules and connecting function-calls in a hierarchy.

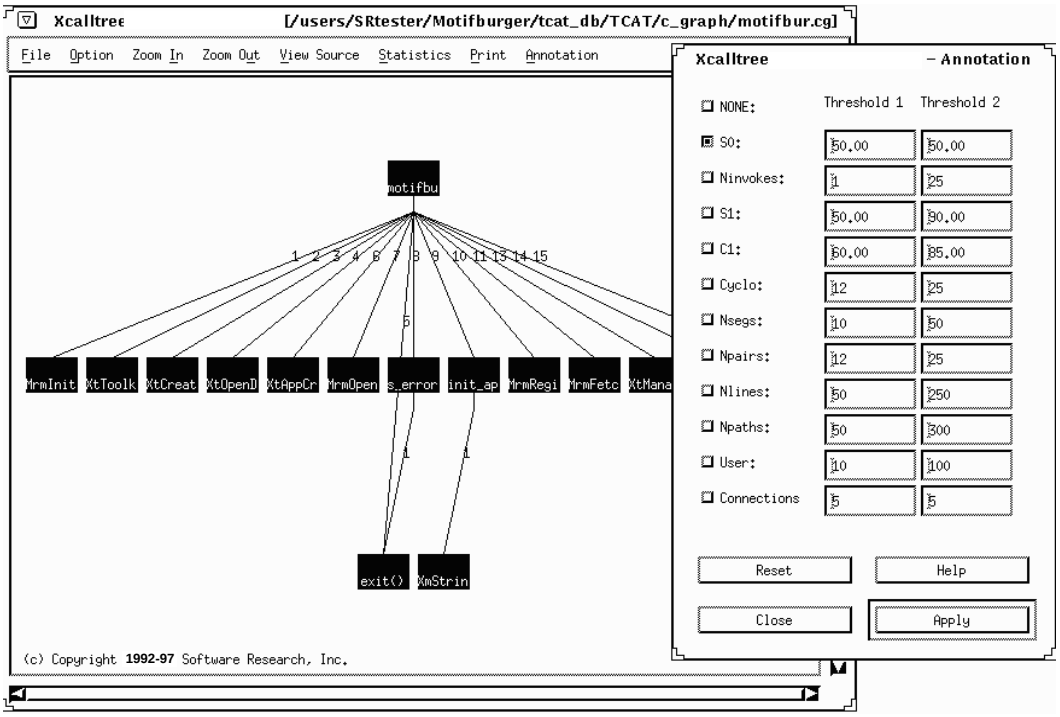


FIGURE 33 Setting the Annotation Thresholds for TCAT Calltree Graph of Motifburger

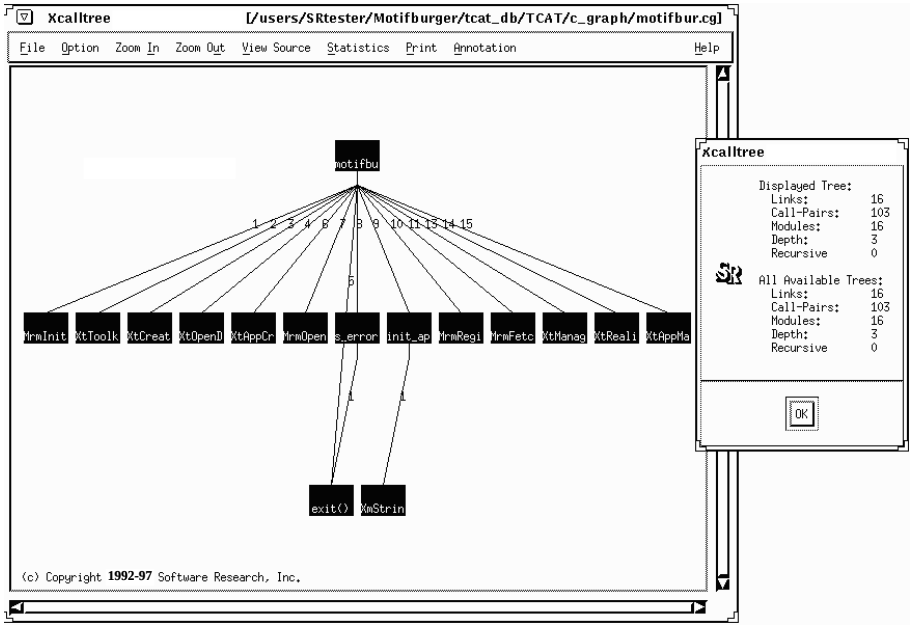


FIGURE 34 Statistical Report on TCAT Calltree Graph of Motifburger

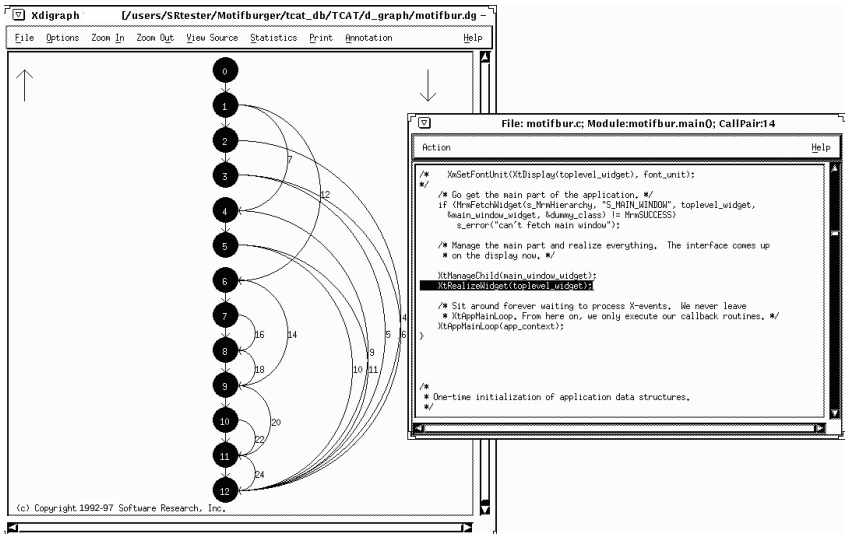


FIGURE 35 TCAT Digraph Showing Control-Flow Structure of Motifburger and Displaying the Source Code

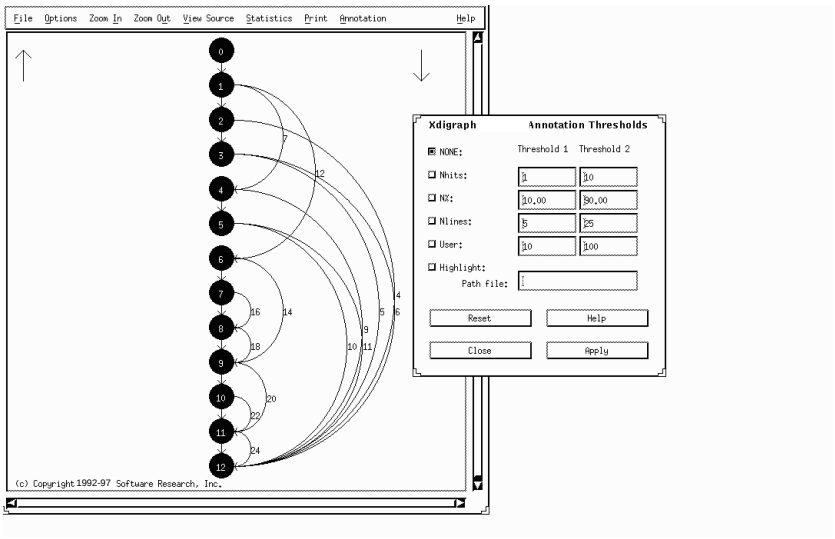


FIGURE 36 Setting the Annotation Thresholds for TCAT Digraph of Motifburger

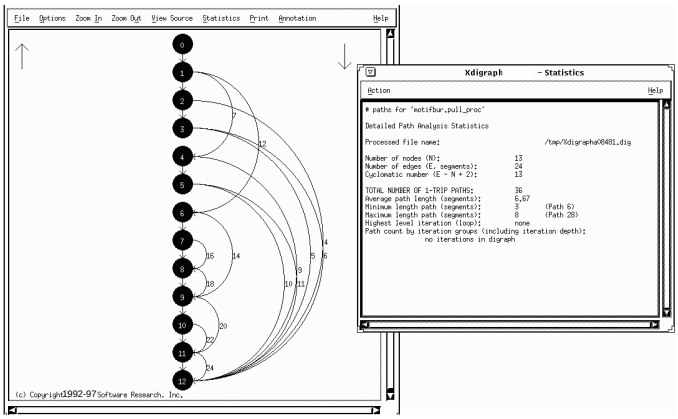


FIGURE 37 Statistical Report on TCAT Digraph of Motifburger

Figure 37 shows the digraph of Motifburger's `pul_proc()`. Graphics elements are not active, though they are linked to their respective source code and statistical report views. Views of Motifburger's calltree are restricted to one node at a time. Additional options are available to change graphics elements and display features to user's preferences, as well as to set annotation features to the diagram.

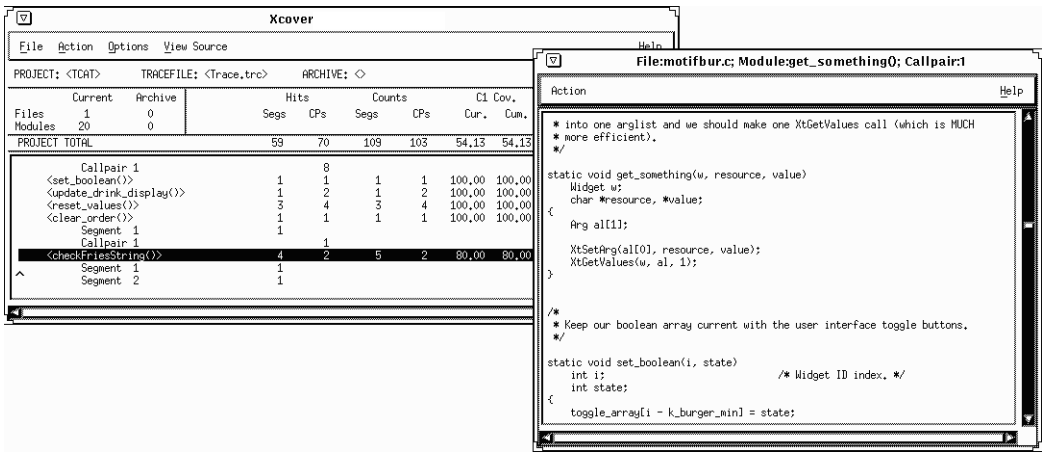


FIGURE 38 TCAT Tabular Coverage Report on Motifburger, and Motifburger Source Code

Figure 38 shows the coverage report for Motifburger generated by **Xcover**. Each call node can be selected to expand the listing to show segment information. Source code can be viewed by selecting View Source.

Note: See Section 8.13 on page 126,for more details.

8.9 TDGEN and Motifburger

TestWork's test data generator, **TDGEN**, can take an existing test script and substitute new data values to create additional tests, increasing the size of a test suite to exercise the program-under-test more fully.

TDGEN produces an input test data file based on the following user-created files:

- A template file describes how selected test data values are to be placed in a typical test file through data descriptors. This file provides an outline of the eventual output file.
- A values file indicates the actual test values, test value ranges or test value generation rules for each data descriptor.

According to user specifications, such as sequential or random generation, **TDGEN** replaces the template file's data descriptors with the value file's actual values. The descriptors in the template file are denoted by a special syntax; all other text, except comments, is reproduced verbatim.

TDGEN behaves as an intelligent macro processor. The user either creates new test data files or configures existing test scripts to substitute different data items for selected fields. With **TDGEN**, tens or hundreds of additional tests can be created in a short amount of time.

TEMPLATES FILE

VALUES FILE

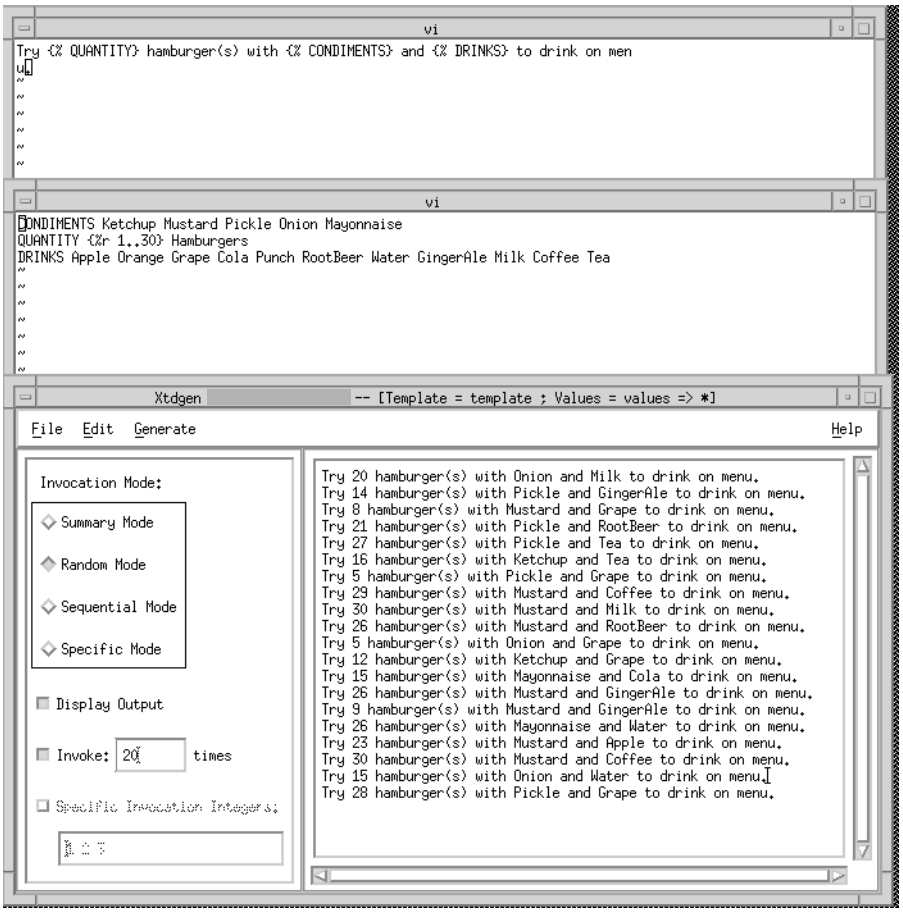


FIGURE 39 TDGEN Randomly Generating Test Data for Motifburger Tests from Input Template and Values Files

Note: For more details, see Section 8.14 on page 133.

8.10 Metric Files

8.10.1 Metric Summary Complexity Report

```
7/29/96
UX-METRIC (C) Version 2.20
Summary Complexity Report for: /tmp/Xmetrica03260.rpt
------------------------------------------------------
Unique Operators (n1):      64
Unique Operands (n2):      137
Total Operators (N1):      852
Total Operands (N2):       462

Software Science Length (N):                1314
Estimated Software Science Length (N^):     1356
Purity Ratio (P/R):                         1.03

Software Science Volume (V):        10053
Software Science Effort (E):      1084895

Estimated Errors using Software Science (B^):      3
Estimated Time to Develop, in hours (T^):         17

Cyclomatic Complexity (VG1):               53
Extended Cyclomatic Complexity (VG2):      53
Average Cyclomatic Complexity:              2
Average Extended Cyclomatic Complexity:     2

Lines of Code (LOC):                      847
Number of Comment Lines:                  238
Number of Blank Lines:                    197
Number of Executable Semi-colons (<;>):   143
Number of Procedures/Functions:            18
```

Example 1 METRIC Summary Complexity Report

8.10.2 Metric Complexity Report by Procedure

```
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                                Page:  1

UX-METRIC (C) Version 2.20

Complexity Report by Procedure for: /home/COV/motifbur.c

---------------------------------------------------------------------
Procedure                  n1   n2    N1    N2       N      N^   P/R       V         E
VG1 VG2   LOC BLK CMT   <;>  SP VL
---------------------------------- ---- ---- ----- ----- -------  ------ ----- ----
--- ---------  --- ---  ---- --- --- ----- --- --

main                        28   29   101    54     155     275  1.78     904     23569
4   4   116  17  72    18   7 10

init_application            12   24    55    38      93     153  1.65     481      4568
3   3    29   5   9    13   0 10

s_error                      6    3     8     3      11      20  1.84      35       105
1   1    13   0   7     2   0 14

set_something                7    7    14    10      24      39  1.64      91       457
1   1    15   1   6     3   0  4

get_something                7    7    14    10      24      39  1.64      91       457
1   1    15   1   6     3   0  4

set_boolean                  8    6    11     8      19      40  2.08      72       386
1   1    14   1   7     2   1  8

update_drink_display         8    8    16     9      25      48  1.92     100       450
1   1    12   2   3     2   0 13

reset_values                15   16    38    25      63     123  1.95     312      3658
2   2    31   6  13     8   1 13

clear_order                  8    9    25    17      42      53  1.25     172      1297
1   1    18   1   7     6   2 10

activate_proc               37   57   284   140     424     525  1.24    2779    126280
26  26   169  41  34    53  11 11

toggle_proc                  7    5     7     5      12      31  2.61      43       151
1   1    13   0   6     1   0  7

list_proc                    7    3     9     4      13      24  1.88      43       202
1   1    12   0   4     2   0  7

scale_proc                   5    4     5     4       9      20  2.18      29        71
1   1    11   0   4     1   0 10

show_hide_proc              10    2    15     6      21      35  1.68      75      1129
2   2    21   1  10     2   2 12

show_label_proc             15   13    40    21      61     107  1.75     293      3553
4   4    27   2   8     3   2 12

create_proc                 14   11    44    19      63      91  1.45     293      3537
4   4    34   5   8     8   2 12

quit_proc                    9    4    11     5      16      37  2.28      59       333
2   2    12   0   3     2   1  4

pull_proc                   20   28   155    84     239     221  0.92    1335     40044
14  14    74   7   9    14   7 12
```

Example 2 METRIC Complexity Report by Procedure

8.10.3 Metric Exceptions report

```
7/29/96                                                          Page:  1
UX-METRIC (C) Version 2.20
Exception Report for Procedures in /home/COV/motifbur.c
-----------------------------------------------------------------------

Exception(s) for Procedure: main
  ** At 116 lines, this procedure is larger
     than the standard of 60 lines

Exception(s) for Procedure: activate_proc
  ** At 169 lines, this procedure is larger
     than the standard of 60 lines
  ** At 53 semicolons, this procedure is larger
     than the standard of 50 semicolons
  ** With an Extended Cyclomatic Complexity of 26
     this procedure exceeds the standard of 15
  ** With an Average Maximum Span of Reference of 11
     this procedure exceeds the standard of 10

Exception(s) for Procedure: pull_proc
  ** At 74 lines, this procedure is larger
     than the standard of 60 lines
```

Example 3 METRIC Exceptions Report

8.11 CAPBAK/X Keysave Files

8.11.1 for TrueTime Test of Motifburger

```
/*
 * CAPBAK/X Release 5
 * (c) Copyright 1992-94, Software Research, Inc.
 * ALL RIGHTS RESERVED
 * Start of session on Wed Jul 31 10:39:22 1996
 */
void TTburger()
{
    cb_mouse_motion("TTburger", 1);
    cb_mouse_button("LEFT", 928, 47, 169);
    cb_mouse_motion("TTburger", 2);
    cb_mouse_button("LEFT", 928, 67, 229);
    cb_sync_win_activate("MOTIFburger Order-Entry Box", 522, 27, 619, 328);
    cb_mouse_motion("TTburger", 3);
    cb_mouse_button("LEFT", 654, 169, 186);
    cb_mouse_motion("TTburger", 4);
    cb_mouse_button("LEFT", 565, 245, 346);
    cb_save_window_image("TTburger", 1, 522, 27, 619, 328);
    cb_mouse_motion("TTburger", 7);
    cb_mouse_drag("LEFT", "TTburger", 8);
    cb_mouse_motion("TTburger", 9);
    cb_mouse_drag("LEFT", "TTburger", 10);
    cb_mouse_motion("TTburger", 11);
    cb_mouse_button("LEFT", 945, 48, 402);
    cb_mouse_motion("TTburger", 12);
    cb_mouse_button("LEFT", 934, 112, 372);
    cb_mouse_motion("TTburger", 13);
    cb_mouse_button("LEFT", 831, 41, 233);
    cb_mouse_motion("TTburger", 14);
    cb_mouse_button("LEFT", 825, 65, 743);
}
/*
 * End of session on Wed Jul 31 10:39:42 1996
 */
TTburger();    /* RUN */
```

Example 1 CAPBAK/X Keysave File for a TrueTimeTest of Motifburger

8.11.2 CAPBAK/X KeysaveFile for an ObjectMode Test of Motifburger

```
/*
 * CAPBAK/X Release 5
 * (c) Copyright 1992-94, Software Research, Inc.
 * ALL RIGHTS RESERVED
 * Start of session on Wed Jul 31 07:57:04 1996
 */
void OMburger()
{
    cb_mouse_motion("OMburger", 1);
    cb_key_down("<Control_L>", 235);
    cbw_enter();
    cbw_set_window("motifbur");
    cbw_menu_select("Order");
    cbw_submenu_select("m_show_control_button");
    cb_sync_win_activate("MOTIFburger Order-Entry Box", 522, 27, 619,
328);
    cbw_set_window("MOTIFburger Order-Entry Box");
    cbw_button_set("Mustard", "ON");
    cbw_button_set("Well Done", "ON");
    cbw_scale_set("Quantity", 1);
    cbw_scale_set("Quantity", 2);
    cbw_button_click("Apply");
    cb_save_window_image("OMburger", 1, 522, 27, 619, 328);
    cbw_button_click("Dismiss");
    cbw_set_window("motifbur");
    cbw_menu_select("Order");
    cbw_submenu_select("Submit Order");
    cbw_menu_select("File");
    cbw_submenu_select("Quit");
    cbw_exit();
}
/*
 * End of session on Wed Jul 31 07:57:31 1996
 */
OMburger();    /* RUN */
```

Example 2 CAPBAK/X KeysaveFile for an ObjectMode Test of Motifburger

8.12 SMARTS Files

8.12.1 SMARTS Main TrueTime ATS File for Motifburger

```
/* This Automated Test Script is read by SMARTS to run the
following Testplan for MotifBurger.

TrueTime Mode Tests:
walk Opens application; drives menues, closes app.
burger Opens app, orders burgers only, closes app.
fries Opens app, orders N fries only, closes app.
drink Opens app, orders drinks only, closes app.
meal Opens app, orders burgers + fries + drinks only, closes app.

ObjectMode Tests:
walk    same...
burger
fries
drink
meal
*/
define group burger{
/*    #include “setup.ats”   */
    define group TTmode{
#include “TTwalk.ats”
        #include “TTburger.ats”
#include “TTfries.ats”
#include “TTdrink.ats”
#include “TTmeal.ats”
    }
    define group OMmode{
#include “OMwalk.ats”
#include “OMburger.ats”
#include “OMfries.ats”
#include “OMdrink.ats”
#include “OMmeal.ats”
    }
/*    #include “teardown.ats”  */
```

Example 1 }SMARTS Main TrueTime ATS File for Motifburger

8.12.2 SMARTS ATS File for An ObjectMode Test of Motifburger

```
define case OMburger
{
source
“This walks around the Motifburger menus.”;
activation
“cd ../source; motifbur.static -geometry +800+10 &”,
/*“/home/l3/demos/special/Morgan-Stantley/Motifburger/source/motifbur.static -
geometry +800+0 &”, “sleep 1”,  */
“Xplabak5 -k OMburger.ksv”;
evaluation with baseline
“cbx_db/CBX/BSL/TTburger.001” vs. “cbx_db/CBX/RSP/TTburger.001”;
}
```

Example 2 SMARTS Burger ObjectMode ATS File

8.12.3 SMARTS ATS File for A TrueTime Test of Motifburger

```
define case TTburger
{
source
“This test orders a burger.”;
activation
“cd ../COV; motifbur -geometry +800+10 &”,
“sleep 1”,
“cd ../tests; Xplabak5 -k TTburger.ksv -D 0.5”,
“mv ../COV/Trace.trc ../COV/mb_TTburger.trc”;
evaluation with baseline
“cbx_db/CBX/BSL/TTburger.001” vs. “cbx_db/CBX/RSP/TTburger.001”;
}
```

Example 3 SMARTS Burger TrueTime ATS File

8.12.4 SMARTS Logfile

```
# LOGFILE created: Fri Jul 26 08:19:34 1996
/search/match/ln1match.test 838394374 1     0
/search/match/ln1match.test 838394375 FAIL     1
/search/match/ln2match.test 838394375 1     0
/search/match/ln2match.test 838394375 FAIL     1
/search/match/smallstr.test 838394375 1     0
/search/match/smallstr.test 838394375 FAIL     1
/search/match/largestr.test 838394375 1     0
/search/match/largestr.test 838394375 FAIL     1
/search/nomatch/smstring.test 838394375 1     0
/search/nomatch/smstring.test 838394375 FAIL     1
/search/nomatch/mdstring.test 838394376 1     0
/search/nomatch/mdstring.test 838394376 FAIL     1
/search/nomatch/lgstring.test 838394376 1     0
/search/nomatch/lgstring.test 838394376 FAIL     1
/search/error/nofile.test 838394376 1     0
/search/error/nofile.test 838394376 FAIL     1
/search/error/fewargs.test 838394376 1     0
/search/error/fewargs.test 838394376 FAIL     1
/search/error/manyargs.test 838394376 1     0
/search/error/manyargs.test 838394376 FAIL     1
```

Example 4 SMARTS Logfile

8.12.5 SMARTS Archive File

```
#Format 3.0
# Profile for project ‘TCAT’:
p TCAT 18 17
n motifbur.main() 0 168 7 15
n motifbur.init_application() 1 84 5 6
n motifbur.s_error() 2 84 1 1
n motifbur.set_something() 3 84 1 1
n motifbur.get_something() 4 84 1 1
n motifbur.set_boolean() 5 84 1 1
n motifbur.update_drink_display() 6 84 1 2
n motifbur.reset_values() 7 84 3 4
n motifbur.clear_order() 8 84 1 1
```

```
n motifbur.activate_proc() 9 84 35 35
n motifbur.toggle_proc() 10 84 1 0
n motifbur.list_proc() 11 84 1 2
n motifbur.scale_proc() 12 84 1 0
n motifbur.show_hide_proc() 13 84 3 3
n motifbur.show_label_proc() 14 84 7 5
n motifbur.create_proc() 15 84 5 3
n motifbur.quit_proc() 16 84 3 1
n motifbur.pull_proc() 17 84 24 17
# End of profile for project 'TCAT'.
s 0 1 5
s 0 3 5
s 0 5 5
s 0 6 5
c 0 1 5
c 0 2 5
c 0 3 5
c 0 4 5
c 0 6 5
c 0 7 5
c 0 9 5
c 0 10 5
c 0 11 5
c 0 12 5
s 1 1 5
s 1 2 195
s 1 3 5
s 1 4 40
s 1 5 5
c 1 1 5
c 1 2 5
c 1 3 5
c 1 4 5
c 1 5 5
c 1 6 5
s 2 1 5
c 2 1 5
```

Example 5 SMARTS Archive File

8.13 TCAT Files

8.13.1 TCAT Calltree File

```
motifbur.main() MrmInitialize() 1 0 /home/COV/motifbur.c 189 0 0 1
motifbur.main() XtToolkitInitialize() 2 0 /home/COV/motifbur.c 196 0 0 1
motifbur.main() XtCreateApplicationContext() 3 0 /home/COV/motifbur.c 198 0 0 1
motifbur.main() XtOpenDisplay() 4 0 /home/COV/motifbur.c 199 0 0 1
motifbur.main() exit() 5 0 /home/COV/motifbur.c 202 0 0 2
motifbur.main() XtAppCreateShell() 6 0 /home/COV/motifbur.c 208 0 0 3
motifbur.main() MrmOpenHierarchy() 7 0 /home/COV/motifbur.c 213 0 0 3
motifbur.main() s_error() 8 0 /home/COV/motifbur.c 218 0 0 4
motifbur.main() init_application() 9 0 /home/COV/motifbur.c 220 0 0 5
motifbur.main() MrmRegisterNames() 10 0 /home/COV/motifbur.c 224 0 0 5
motifbur.main() MrmFetchWidget() 11 0 /home/COV/motifbur.c 230 0 0 5
motifbur.main() s_error() 12 0 /home/COV/motifbur.c 232 0 0 6
motifbur.main() XtManageChild() 13 0 /home/COV/motifbur.c 237 0 0 7
motifbur.main() XtRealizeWidget() 14 0 /home/COV/motifbur.c 238 0 0 7
motifbur.main() XtAppMainLoop() 15 0 /home/COV/motifbur.c 242 0 0 7
motifbur.init_application() XmStringLtoRCreate() 1 1 /home/COV/motifbur.c 269 0 0 5
motifbur.init_application() XmStringLtoRCreate() 2 1 /home/COV/motifbur.c 270 0 0 5
motifbur.init_application() XmStringLtoRCreate() 3 1 /home/COV/motifbur.c 273 0 0 5
motifbur.init_application() XmStringLtoRCreate() 4 1 /home/COV/motifbur.c 274 0 0 5
motifbur.init_application() XmStringLtoRCreate() 5 1 /home/COV/motifbur.c 275 0 0 5
motifbur.init_application() XmStringLtoRCreate() 6 1 /home/COV/motifbur.c 276 0 0 5
motifbur.s_error() exit() 1 2 /home/COV/motifbur.c 292 0 0 1
motifbur.set_something() XtSetValues() 1 3 /home/COV/motifbur.c 310 0 0 1
motifbur.get_something() XtGetValues() 1 4 /home/COV/motifbur.c 328 0 0 1
motifbur.set_boolean() XmToggleButtonSetState() 1 5 /home/COV/motifbur.c 342 0 0 1
motifbur.update_drink_display() sprintf() 1 6 /home/COV/motifbur.c 358 0 0 1
motifbur.update_drink_display() set_something() 2 6 /home/COV/motifbur.c 359 0 0 1
motifbur.reset_values() set_boolean() 1 7 /home/COV/motifbur.c 391 0 0 2
motifbur.reset_values() set_something() 2 7 /home/COV/motifbur.c 395 0 0 3
motifbur.reset_values() XmTextSetString() 3 7 /home/COV/motifbur.c 400 0 0 3
motifbur.reset_values() set_something() 4 7 /home/COV/motifbur.c 403 0 0 3
motifbur.clear_order() XtSetValues() 1 8 /home/COV/motifbur.c 427 0 0 1
motifbur.activate_proc() MrmFetchWidget() 1 9 /home/COV/motifbur.c 457 0 0 3
motifbur.activate_proc() s_error() 2 9 /home/COV/motifbur.c 459 0 0 5
motifbur.activate_proc() XtManageChild() 3 9 /home/COV/motifbur.c 464 0 0 4
motifbur.activate_proc() clear_order() 4 9 /home/COV/motifbur.c 471 0 0 7
motifbur.activate_proc() clear_order() 5 9 /home/COV/motifbur.c 477 0 0 8
motifbur.activate_proc() XtUnmanageChild() 6 9 /home/COV/motifbur.c 484 0 0 9
motifbur.activate_proc() reset_values() 7 9 /home/COV/motifbur.c 489 0 0 10
motifbur.activate_proc() printf() 8 9 /home/COV/motifbur.c 493 0 0 11
```

```
motifbur.activate_proc() printf() 9 9 /home/COV/motifbur.c 497 0 0 12
motifbur.activate_proc() printf() 10 9 /home/COV/motifbur.c 501 0 0 13
motifbur.activate_proc() printf() 11 9 /home/COV/motifbur.c 505 0 0 14
motifbur.activate_proc() sprintf() 12 9 /home/COV/motifbur.c 514 0 0 16
motifbur.activate_proc() XmStringLtoRCreate() 13 9 /home/COV/motifbur.c 515 0 0 16
motifbur.activate_proc() get_something() 14 9 /home/COV/motifbur.c 523 0 0 20
motifbur.activate_proc() XmStringConcat() 15 9 /home/COV/motifbur.c 524 0 0 20
motifbur.activate_proc() XmStringConcat() 16 9 /home/COV/motifbur.c 525 0 0 20
motifbur.activate_proc() XmStringConcat() 17 9 /home/COV/motifbur.c 529 0 0 19
motifbur.activate_proc() XmListAddItem() 18 9 /home/COV/motifbur.c 531 0 0 19
motifbur.activate_proc() XmTextGetString() 19 9 /home/COV/motifbur.c 537 0 0 17
motifbur.activate_proc() sscanf() 20 9 /home/COV/motifbur.c 538 0 0 17
motifbur.activate_proc() sprintf() 21 9 /home/COV/motifbur.c 543 0 0 22
motifbur.activate_proc() XmStringLtoRCreate() 22 9 /home/COV/motifbur.c 544 0 0 22
motifbur.activate_proc() XmStringConcat() 23 9 /home/COV/motifbur.c 547 0 0 22
motifbur.activate_proc() XmStringConcat() 24 9 /home/COV/motifbur.c 548 0 0 22
motifbur.activate_proc() XmStringConcat() 25 9 /home/COV/motifbur.c 551 0 0 22
motifbur.activate_proc() XmListAddItem() 26 9 /home/COV/motifbur.c 553 0 0 22
motifbur.activate_proc() sprintf() 27 9 /home/COV/motifbur.c 559 0 0 24
motifbur.activate_proc() XmStringLtoRCreate() 28 9 /home/COV/motifbur.c 560 0 0 24
motifbur.activate_proc() XmStringConcat() 29 9 /home/COV/motifbur.c 563 0 0 24
motifbur.activate_proc() XmStringConcat() 30 9 /home/COV/motifbur.c 564 0 0 24
motifbur.activate_proc() XmStringConcat() 31 9 /home/COV/motifbur.c 568 0 0 24
motifbur.activate_proc() XmListAddItem() 32 9 /home/COV/motifbur.c 570 0 0 24
motifbur.activate_proc() get_something() 33 9 /home/COV/motifbur.c 582 0 0 30
motifbur.activate_proc() update_drink_display() 34 9 /home/COV/motifbur.c 589 0 0 31
motifbur.activate_proc() update_drink_display() 35 9 /home/COV/motifbur.c 597 0 0 34
motifbur.list_proc() XtFree() 1 11 /home/COV/motifbur.c 636 0 0 1
motifbur.list_proc() XmStringCopy() 2 11 /home/COV/motifbur.c 637 0 0 1
motifbur.show_hide_proc() XtIsManaged() 1 13 /home/COV/motifbur.c 677 0 0 1
motifbur.show_hide_proc() XtUnmanageChild() 2 13 /home/COV/motifbur.c 679 0 0 2
motifbur.show_hide_proc() XtManageChild() 3 13 /home/COV/motifbur.c 681 0 0 3
motifbur.show_label_proc() MrmFetchWidget() 1 14 /home/COV/motifbur.c 699 0 0 2
motifbur.show_label_proc() s_error() 2 14 /home/COV/motifbur.c 701 0 0 4
motifbur.show_label_proc() XtIsManaged() 3 14 /home/COV/motifbur.c 708 0 0 3
motifbur.show_label_proc() set_something() 4 14 /home/COV/motifbur.c 709 0 0 6
motifbur.show_label_proc() set_something() 5 14 /home/COV/motifbur.c 711 0 0 7
motifbur.create_proc() get_something() 1 15 /home/COV/motifbur.c 740 0 0 2
motifbur.create_proc() get_something() 2 15 /home/COV/motifbur.c 744 0 0 3
motifbur.create_proc() get_something() 3 15 /home/COV/motifbur.c 748 0 0 4
motifbur.quit_proc() exit() 1 16 /home/COV/motifbur.c 768 0 0 2
motifbur.pull_proc() MrmFetchWidget() 1 17 /home/COV/motifbur.c 791 0 0 3
motifbur.pull_proc() s_error() 2 17 /home/COV/motifbur.c 794 0 0 5
motifbur.pull_proc() set_something() 3 17 /home/COV/motifbur.c 795 0 0 6
```

```
motifbur.pull_proc() MrmFetchWidget() 4 17 /home/COV/motifbur.c 802 0 0 8
motifbur.pull_proc() s_error() 5 17 /home/COV/motifbur.c 805 0 0 10
motifbur.pull_proc() set_something() 6 17 /home/COV/motifbur.c 806 0 0 11
motifbur.pull_proc() MrmFetchWidget() 7 17 /home/COV/motifbur.c 813 0 0 13
motifbur.pull_proc() s_error() 8 17 /home/COV/motifbur.c 816 0 0 15
motifbur.pull_proc() set_something() 9 17 /home/COV/motifbur.c 817 0 0 16
motifbur.pull_proc() MrmFetchWidget() 10 17 /home/COV/motifbur.c 819 0 1 16
motifbur.pull_proc() s_error() 11 17 /home/COV/motifbur.c 822 0 0 17
motifbur.pull_proc() MrmFetchWidget() 12 17 /home/COV/motifbur.c 829 0 0 19
motifbur.pull_proc() s_error() 13 17 /home/COV/motifbur.c 835 0 0 21
motifbur.pull_proc() reset_values() 14 17 /home/COV/motifbur.c 836 0 0 20
motifbur.pull_proc() XtIsManaged() 15 17 /home/COV/motifbur.c 837 0 0 20
motifbur.pull_proc() set_something() 16 17 /home/COV/motifbur.c 838 0 0 23
motifbur.pull_proc() set_something() 17 17 /home/COV/motifbur.c 841 0 0 24
```

Example 1 TCAT Calltree File

8.13.2 TCAT Directed Graph File

```
motifbur.main() MrmInitialize() 1 0 /home/COV/motifbur.c 189 0 0 1
motifbur.main() XtToolkitInitialize() 2 0 /home/COV/motifbur.c 196 0 0 1
motifbur.main() XtCreateApplicationContext() 3 0 /home/COV/motifbur.c 198 0 0 1
motifbur.main() XtOpenDisplay() 4 0 /home/COV/motifbur.c 199 0 0 1
motifbur.main() exit() 5 0 /home/COV/motifbur.c 202 0 0 2
motifbur.main() XtAppCreateShell() 6 0 /home/COV/motifbur.c 208 0 0 3
motifbur.main() MrmOpenHierarchy() 7 0 /home/COV/motifbur.c 213 0 0 3
motifbur.main() s_error() 8 0 /home/COV/motifbur.c 218 0 0 4
motifbur.main() init_application() 9 0 /home/COV/motifbur.c 220 0 0 5
motifbur.main() MrmRegisterNames() 10 0 /home/COV/motifbur.c 224 0 0 5
motifbur.main() MrmFetchWidget() 11 0 /home/COV/motifbur.c 230 0 0 5
motifbur.main() s_error() 12 0 /home/COV/motifbur.c 232 0 0 6
motifbur.main() XtManageChild() 13 0 /home/COV/motifbur.c 237 0 0 7
motifbur.main() XtRealizeWidget() 14 0 /home/COV/motifbur.c 238 0 0 7
motifbur.main() XtAppMainLoop() 15 0 /home/COV/motifbur.c 242 0 0 7
motifbur.init_application() XmStringLtoRCreate() 1 1 /home/COV/motifbur.c 269 0 0 5
motifbur.init_application() XmStringLtoRCreate() 2 1 /home/COV/motifbur.c 270 0 0 5
motifbur.init_application() XmStringLtoRCreate() 3 1 /home/COV/motifbur.c 273 0 0 5
motifbur.init_application() XmStringLtoRCreate() 4 1 /home/COV/motifbur.c 274 0 0 5
motifbur.init_application() XmStringLtoRCreate() 5 1 /home/COV/motifbur.c 275 0 0 5
motifbur.init_application() XmStringLtoRCreate() 6 1 /home/COV/motifbur.c 276 0 0 5
motifbur.s_error() exit() 1 2 /home/COV/motifbur.c 292 0 0 1
motifbur.set_something() XtSetValues() 1 3 /home/COV/motifbur.c 310 0 0 1
motifbur.get_something() XtGetValues() 1 4 /home/COV/motifbur.c 328 0 0 1
```

```
motifbur.set_boolean() XmToggleButtonSetState() 1 5 /home/COV/motifbur.c 342 0 0 1
motifbur.update_drink_display() sprintf() 1 6 /home/COV/motifbur.c 358 0 0 1
motifbur.update_drink_display() set_something() 2 6 /home/COV/motifbur.c 359 0 0 1
motifbur.reset_values() set_boolean() 1 7 /home/COV/motifbur.c 391 0 0 2
motifbur.reset_values() set_something() 2 7 /home/COV/motifbur.c 395 0 0 3
motifbur.reset_values() XmTextSetString() 3 7 /home/COV/motifbur.c 400 0 0 3
motifbur.reset_values() set_something() 4 7 /home/COV/motifbur.c 403 0 0 3
motifbur.clear_order() XtSetValues() 1 8 /home/COV/motifbur.c 427 0 0 1
motifbur.activate_proc() MrmFetchWidget() 1 9 /home/COV/motifbur.c 457 0 0 3
motifbur.activate_proc() s_error() 2 9 /home/COV/motifbur.c 459 0 0 5
motifbur.activate_proc() XtManageChild() 3 9 /home/COV/motifbur.c 464 0 0 4
motifbur.activate_proc() clear_order() 4 9 /home/COV/motifbur.c 471 0 0 7
motifbur.activate_proc() clear_order() 5 9 /home/COV/motifbur.c 477 0 0 8
motifbur.activate_proc() XtUnmanageChild() 6 9 /home/COV/motifbur.c 484 0 0 9
motifbur.activate_proc() reset_values() 7 9 /home/COV/motifbur.c 489 0 0 10
motifbur.activate_proc() printf() 8 9 /home/COV/motifbur.c 493 0 0 11
motifbur.activate_proc() printf() 9 9 /home/COV/motifbur.c 497 0 0 12
motifbur.activate_proc() printf() 10 9 /home/COV/motifbur.c 501 0 0 13
motifbur.activate_proc() printf() 11 9 /home/COV/motifbur.c 505 0 0 14
motifbur.activate_proc() sprintf() 12 9 /home/COV/motifbur.c 514 0 0 16
motifbur.activate_proc() XmStringLtoRCreate() 13 9 /home/COV/motifbur.c 515 0 0 16
motifbur.activate_proc() get_something() 14 9 /home/COV/motifbur.c 523 0 0 20
motifbur.activate_proc() XmStringConcat() 15 9 /home/COV/motifbur.c 524 0 0 20
motifbur.activate_proc() XmStringConcat() 16 9 /home/COV/motifbur.c 525 0 0 20
motifbur.activate_proc() XmStringConcat() 17 9 /home/COV/motifbur.c 529 0 0 19
motifbur.activate_proc() XmListAddItem() 18 9 /home/COV/motifbur.c 531 0 0 19
motifbur.activate_proc() XmTextGetString() 19 9 /home/COV/motifbur.c 537 0 0 17
motifbur.activate_proc() sscanf() 20 9 /home/COV/motifbur.c 538 0 0 17
motifbur.activate_proc() sprintf() 21 9 /home/COV/motifbur.c 543 0 0 22
motifbur.activate_proc() XmStringLtoRCreate() 22 9 /home/COV/motifbur.c 544 0 0 22
motifbur.activate_proc() XmStringConcat() 23 9 /home/COV/motifbur.c 547 0 0 22
motifbur.activate_proc() XmStringConcat() 24 9 /home/COV/motifbur.c 548 0 0 22
motifbur.activate_proc() XmStringConcat() 25 9 /home/COV/motifbur.c 551 0 0 22
motifbur.activate_proc() XmListAddItem() 26 9 /home/COV/motifbur.c 553 0 0 22
motifbur.activate_proc() sprintf() 27 9 /home/COV/motifbur.c 559 0 0 24
motifbur.activate_proc() XmStringLtoRCreate() 28 9 /home/COV/motifbur.c 560 0 0 24
motifbur.activate_proc() XmStringConcat() 29 9 /home/COV/motifbur.c 563 0 0 24
motifbur.activate_proc() XmStringConcat() 30 9 /home/COV/motifbur.c 564 0 0 24
motifbur.activate_proc() XmStringConcat() 31 9 /home/COV/motifbur.c 568 0 0 24
motifbur.activate_proc() XmListAddItem() 32 9 /home/COV/motifbur.c 570 0 0 24
motifbur.activate_proc() get_something() 33 9 /home/COV/motifbur.c 582 0 0 30
motifbur.activate_proc() update_drink_display() 34 9 /home/COV/motifbur.c 589 0 0 31
motifbur.activate_proc() update_drink_display() 35 9 /home/COV/motifbur.c 597 0 0 34
motifbur.list_proc() XtFree() 1 11 /home/COV/motifbur.c 636 0 0 1
```

```
motifbur.list_proc() XmStringCopy() 2 11 /home/COV/motifbur.c 637 0 0 1
motifbur.show_hide_proc() XtIsManaged() 1 13 /home/COV/motifbur.c 677 0 0 1
motifbur.show_hide_proc() XtUnmanageChild() 2 13 /home/COV/motifbur.c 679 0 0 2
motifbur.show_hide_proc() XtManageChild() 3 13 /home/COV/motifbur.c 681 0 0 3
motifbur.show_label_proc() MrmFetchWidget() 1 14 /home/COV/motifbur.c 699 0 0 2
motifbur.show_label_proc() s_error() 2 14 /home/COV/motifbur.c 701 0 0 4
motifbur.show_label_proc() XtIsManaged() 3 14 /home/COV/motifbur.c 708 0 0 3
motifbur.show_label_proc() set_something() 4 14 /home/COV/motifbur.c 709 0 0 6
motifbur.show_label_proc() set_something() 5 14 /home/COV/motifbur.c 711 0 0 7
motifbur.create_proc() get_something() 1 15 /home/COV/motifbur.c 740 0 0 2
motifbur.create_proc() get_something() 2 15 /home/COV/motifbur.c 744 0 0 3
motifbur.create_proc() get_something() 3 15 /home/COV/motifbur.c 748 0 0 4
motifbur.quit_proc() exit() 1 16 /home/COV/motifbur.c 768 0 0 2
motifbur.pull_proc() MrmFetchWidget() 1 17 /home/COV/motifbur.c 791 0 0 3
motifbur.pull_proc() s_error() 2 17 /home/COV/motifbur.c 794 0 0 5
motifbur.pull_proc() set_something() 3 17 /home/COV/motifbur.c 795 0 0 6
motifbur.pull_proc() MrmFetchWidget() 4 17 /home/COV/motifbur.c 802 0 0 8
motifbur.pull_proc() s_error() 5 17 /home/COV/motifbur.c 805 0 0 10
motifbur.pull_proc() set_something() 6 17 /home/COV/motifbur.c 806 0 0 11
motifbur.pull_proc() MrmFetchWidget() 7 17 /home/COV/motifbur.c 813 0 0 13
motifbur.pull_proc() s_error() 8 17 /home/COV/motifbur.c 816 0 0 15
motifbur.pull_proc() set_something() 9 17 /home/COV/motifbur.c 817 0 0 16
motifbur.pull_proc() MrmFetchWidget() 10 17 /home/COV/motifbur.c 819 0 1 16
motifbur.pull_proc() s_error() 11 17 /home/COV/motifbur.c 822 0 0 17
motifbur.pull_proc() MrmFetchWidget() 12 17 /home/COV/motifbur.c 829 0 0 19
motifbur.pull_proc() s_error() 13 17 /home/COV/motifbur.c 835 0 0 21
motifbur.pull_proc() reset_values() 14 17 /home/COV/motifbur.c 836 0 0 20
motifbur.pull_proc() XtIsManaged() 15 17 /home/COV/motifbur.c 837 0 0 20
motifbur.pull_proc() set_something() 16 17 /home/COV/motifbur.c 838 0 0 23
motifbur.pull_proc() set_something() 17 17 /home/COV/motifbur.c 841 0 0 24
```

Example 2 TCAT Directed Graph File

8.13.3 TCAT MDF File

```
TCAT 18 17
motifbur.main() 0 168 7 15
motifbur.init_application() 1 84 5 6
motifbur.s_error() 2 84 1 1
motifbur.set_something() 3 84 1 1
motifbur.get_something() 4 84 1 1
motifbur.set_boolean() 5 84 1 1
motifbur.update_drink_display() 6 84 1 2
motifbur.reset_values() 7 84 3 4
motifbur.clear_order() 8 84 1 1
motifbur.activate_proc() 9 84 35 35
motifbur.toggle_proc() 10 84 1 0
motifbur.list_proc() 11 84 1 2
motifbur.scale_proc() 12 84 1 0
motifbur.show_hide_proc() 13 84 3 3
motifbur.show_label_proc() 14 84 7 5
motifbur.create_proc() 15 84 5 3
motifbur.quit_proc() 16 84 3 1
motifbur.pull_proc() 17 84 24 17
```

Example 3 TCAT MDF File

8.13.4 TCAT Trace File

```
#Format 3.0
# Profile for project 'TCAT':
p TCAT 18 17
n motifbur.main() 0 168 7 15
n motifbur.init_application() 1 84 5 6
n motifbur.s_error() 2 84 1 1
n motifbur.set_something() 3 84 1 1
n motifbur.get_something() 4 84 1 1
n motifbur.set_boolean() 5 84 1 1
n motifbur.update_drink_display() 6 84 1 2
n motifbur.reset_values() 7 84 3 4
n motifbur.clear_order() 8 84 1 1
n motifbur.activate_proc() 9 84 35 35
n motifbur.toggle_proc() 10 84 1 0
n motifbur.list_proc() 11 84 1 2
n motifbur.scale_proc() 12 84 1 0
```

```
n motifbur.show_hide_proc() 13 84 3 3
n motifbur.show_label_proc() 14 84 7 5
n motifbur.create_proc() 15 84 5 3
n motifbur.quit_proc() 16 84 3 1
n motifbur.pull_proc() 17 84 24 17
# End of profile for project ‘TCAT’.
s 0 1 1
s 0 3 1
s 0 5 1
s 0 6 1
c 0 1 1
c 0 2 1
c 0 3 1
c 0 4 1
c 0 6 1
c 0 7 1
c 0 9 1
c 0 10 1
c 0 11 1
c 0 12 1
s 1 1 1
s 1 2 39
s 1 3 1
s 1 4 8
s 1 5 1
c 1 1 1
c 1 2 1
c 1 3 1
c 1 4 1
c 1 5 1
c 1 6 1
s 2 1 1
c 2 1 1
```

Example 4 TCAT Trace File

8.14 TDGEN Files

8.14.1 TDGEN Summary Mode Test Data File

```
------------------------------------------------------------------------
      No. Table Cumulative Total
Field Entries   Combinations
------------------------------------------------------------------------
% CONDIMENTS          55
% QUANTITY            31155
% DRINKS              111705
------------------------------------------------------------------------
```

Example 1 TDGEN Summary Mode Test Data File

8.14.2 TDGEN Random Mode Test Data File

```
Try 14 hamburger(s) with Onion and Tea to drink on menu
Try 23 hamburger(s) with Ketchup and Punch to drink on menu
Try 26 hamburger(s) with Pickle and Punch to drink on menu
Try 23 hamburger(s) with Pickle and GingerAle to drink on menu
Try 10 hamburger(s) with Mustard and Tea to drink on menu
Try 7 hamburger(s) with Onion and Water to drink on menu
Try 28 hamburger(s) with Mustard and Cola to drink on menu
Try 14 hamburger(s) with Onion and GingerAle to drink on menu
Try 17 hamburger(s) with Mustard and Tea to drink on menu
Try 14 hamburger(s) with Onion and Water to drink on menu
Try 10 hamburger(s) with Ketchup and Coffee to drink on menu
Try 22 hamburger(s) with Pickle and RootBeer to drink on menu
Try 23 hamburger(s) with Ketchup and GingerAle to drink on menu
Try 26 hamburger(s) with Ketchup and Milk to drink on menu
Try 16 hamburger(s) with Mustard and Apple to drink on menu
Try 14 hamburger(s) with Mustard and Punch to drink on menu
Try 6 hamburger(s) with Onion and RootBeer to drink on menu
Try 26 hamburger(s) with Mustard and Apple to drink on menu
Try 15 hamburger(s) with Ketchup and Milk to drink on menu
Try 23 hamburger(s) with Mayonnaise and Water to drink on menu
```

Example 2 TDGEN Random Mode Test Data File

8.14.3 TDGEN Sequential Mode Test Data File

```
Try 1 hamburger(s) with Ketchup and Apple to drink on menu
Try 2 hamburger(s) with Ketchup and Apple to drink on menu
Try 3 hamburger(s) with Ketchup and Apple to drink on menu
Try 4 hamburger(s) with Ketchup and Apple to drink on menu
Try 5 hamburger(s) with Ketchup and Apple to drink on menu
Try 6 hamburger(s) with Ketchup and Apple to drink on menu
Try 7 hamburger(s) with Ketchup and Apple to drink on menu
Try 8 hamburger(s) with Ketchup and Apple to drink on menu
Try 9 hamburger(s) with Ketchup and Apple to drink on menu
Try 10 hamburger(s) with Ketchup and Apple to drink on menu
Try 11 hamburger(s) with Ketchup and Apple to drink on menu
Try 12 hamburger(s) with Ketchup and Apple to drink on menu
Try 13 hamburger(s) with Ketchup and Apple to drink on menu
Try 14 hamburger(s) with Ketchup and Apple to drink on menu
Try 15 hamburger(s) with Ketchup and Apple to drink on menu
Try 16 hamburger(s) with Ketchup and Apple to drink on menu
Try 17 hamburger(s) with Ketchup and Apple to drink on menu
Try 18 hamburger(s) with Ketchup and Apple to drink on menu
Try 19 hamburger(s) with Ketchup and Apple to drink on menu
Try 20 hamburger(s) with Ketchup and Apple to drink on menu
```

Example 3 TDGEN Sequential Mode Test Data File

8.14.4 TDGEN Specific Mode Test Data File

```
Try 21 hamburger(s) with Ketchup and Apple to drink on menu
```

Example 4 TDGEN Specific Mode Test Data File

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