Aegis
A Project Change Supervisor

User Guide

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DEDICATIONS

This user guide is dedicated to my wife
Mary Therese Miller
for all her love and support
despite the computers.

And to my grandmother
Jean Florence Pelham
1905 — 1992
Always in our hearts.

This document describes aegis version 2.3
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1. Introduction

The aegis program is a CASE tool with a difference. In the spirit of the UNIX† Operating System, the aegis program is a small component designed to work with other programs.

Many CASE systems attempt to provide everything, from bubble charts to source control to compilers. Users are trapped with the components supplied by the CASE system, and if you don't like one of the components (it may be too limited, for instance), then that is just tough.

In contrast, UNIX provides many components of a CASE system - compilers, editors, dependency tools (such as make), source control (such as SCCS). You may substitute the tool of your choice - gcc, jove, cake, rcs (to name a few) if you don't like the ones supplied with the system.

The aegis program adds to this list with software configuration management (SCM), and consistent with UNIX philosophy, the aegis program does not dictate the choice of any of the other tools (although it may stretch them to their limits).

1.1. What does aegis do?

Just what is software configuration management? This question is sufficiently broad as to require a book in answer. In essence, the aegis program is a project change supervisor. It provides a framework within which a team of developers may work on many changes to a program independently, and the aegis program coordinates integrating these changes back into the master source of the program, with as little disruption as possible. Resolution of contention for source files, a major headache for any project with more than one developer, is one of the aegis program's major functions.

It should be noted that the aegis program is a developer's tool, in the same sense as make or SCCS are developer's tools. It is not a manager's tool - it does not provide progress tracking or help with work allocation.

1.2. Why use aegis?

So why should you use the aegis program? The aegis program uses a particular model of the development of software projects. This model has a master source (or baseline) of a project, consisting of several (possibly several hundred) files, and a team of developers creating changes to be made to this baseline. When a change is complete, it is integrated with the baseline, to become the new baseline. Each change must be atomic and self-contained, no change is allowed to cause the baseline to cease to work. "Working" is defined as passing its own tests. The tests are considered part of the baseline. Aegis provides support for the developer so that an entire copy of the baseline need not be taken to change a few files, only those files which are to be changed need to be copied.

The win in using the aegis program is that there are *O(n)* interactions between developers and the baseline. Contrast this with a master source which is being edited directly by the developers - there is *O(n!)* interactions between developers - this makes adding "just one" more developer a potential disaster.

Another win is that the project baseline always works. Always having a working baseline means that a version is always available for demonstrations, or those "pre-release snapshots" we are always forced to provide.

The above advantages are all very well - for management types. Why should Joe Average Programmer use the aegis program? Recall that SCCS provides file locking, but only for one file at a time. The aegis program provides the file locking, atomically, for the set of files in the change. Recall also that SCCS locks the file the instant you start editing it. This makes popular files a project bottleneck. The aegis program allows concurrent editing, and a resolution mechanism just before the change must be integrated, meaning fewer delays for J.A.Programmer.

† UNIX is a trademark of Bell Laboratories.

1.3. How to use this manual

This manual assumes the reader is already familiar with the UNIX operating system, and with developing software using the UNIX operating system and the tools available; terms such as *RCS* and *SCCS* and *make* (1) are not explained.

There is also the assumption that the reader is familiar with the issues surrounding team development of software; coordination and multiple version issues, for example, are not explained.

This manual is broken into a number of sections.

Chapter 2
: describes how aegis works and some of the reasoning behind the design and implementation of the aegis program. Look here for answers to "Why does it..." questions.

Chapter 3
: is a worked example of how particular users interact with the aegis program. Look here for answers to "How do I..." questions.

Chapter 4
: is a discussion of how aegis interacts with the History Tool, and provides templates and suggestions for history tools known to work with aegis.

Chapter 5
: is a discussion of how aegis interacts with the Dependency Maintenance Tool (DMT), and provides templates and suggestions for DMTs known to work with aegis.

Chapter 6
: is a discussion of how aegis interacts with the Difference Tools, and provides templates and suggestions for difference tools known to work with aegis.

Chapter 7
: describes the project attributes and how the various parameters may be used for particular projects.

Chapter 8
: is a collection of helpful hints on how to use aegis effectively, based on real-world experience. This is of most use when initially placing projects under the supervision of the aegis program.

Appendix A
: is a quick reference for placing an existing project under aegis.

Appendix B
: is a glossary of terms.

1.4. GNU GPL

Aegis is distributed under the terms and conditions of the GNU General Public License. Programs which are developed using Aegis are not automatically subject to the GNU GPL. Only programs which are derivative works based on GNU GPL code are automatically subject to the GNU GPL. We still encourage software authors to distribute their work under terms like those of the GNU GPL, but doing so is not required to use Aegis.

2. How Aegis Works

Before you will be able to exploit aegis fully, you will need to know what aegis does and why.

The aegis program provides a change control mechanism and a repository, a subset of the functionality which CASE vendors call Software Configuration Management (SCM). In order to fit into a software engineering environment, or any place software is written, aegis needs a clearly defined place is the scheme of things.

This chapter describes the model of the software development process embodied in the aegis program, some of the deliberate design decisions made for aegis, some of the things aegis will and wont do for you, and the situations where aegis is most and least useful.

2.1. The Model

The model of the software development process used by aegis evolved and grew with time in a commercial software development environment, and it has continued to be used and developed. Unfortunately, this environment was the largest experienced by the author to date, and consisted of only about forty software engineers working on a single project.[1]

2.1.1. The Baseline

Most CASE systems revolve around a repository: a place where *stuff* is kept. This *stuff* is the raw material that is processed in some way to produce the final product, whatever that may be. This *stuff* is the preferred form for editing or composing or whatever.

In the aegis program, the repository is known as the *baseline* and the units of *stuff* are UNIX files. The aegis program makes no distinction between text and binary files, so both are supported.

The history mechanism which must be included in any repository function is not provided by the aegis program. It is instead provided by some other per-project configurable software, such as RCS. This means that the user may select the history tool most suited to any given project. It also means that aegis is that much smaller to test and maintain. You will not be able to have binary files in your baseline if the history tool of your choice can't cope with them.

The structure of the baseline is dictated by the nature of each project, with some minor exceptions. The aegis program attempts to make as few arbitrary rules as possible. There is one mandatory file in the baseline, and one mandatory directory. The file is called *config*, and contains the per-project configuration information; the directory is called *test*, and contains all of the tests. The contents and structure of the *test* directory are also dictated by aegis. Tests are treated just like any other source file, and are subject to the same process.

The baseline in aegis has one particular attribute: it always works. It is always there to show off to visiting big-wigs, it is always there to grab a copy of and ship a "pre-release snapshot" to some overly anxious customer, it is always there to let upper management "touch and feel" the progress being made towards the next release.

You may claim that "works" is comfortably fuzzy, but it is not. The baseline contains not only the source of a project, but also the tests for a project. Tests are treated just like any other source file, and are subject to the same process. A baseline is defined to "work" if and only if it passes all of its own tests. The aegis program has mandatory testing, to ensure that all changes to the baseline are accompanied by tests, and that those tests have been run and are known to pass. This means that no change to the baseline may result in the baseline ceasing to work[2].

The model may be summarised briefly: it consists of a *baseline* (master source), updated through the agency of an *integrator*, who is in turn fed *changes* by a team of *developers*. These terms will be explained in the following sections. See figure 1 for a picture of how files flow around the system.

The baseline is a set of files including the source files for a projects, and also all derived files (such as generated code, binary files from the compiler, etc), and all of the tests. Tests are treated just like any other source file, and are subject to the same process. All files in the baseline are consistent with each other.

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[1] "Unfortunately," because many real-world projects are far larger, but the author has yet to experience, and understand, the issues and procedures required. (Think of problems, yes; think of real-world solutions, no.)

[2] Well, mostly. It is possible for this restriction to be relaxed if you feel there are special circumstances for a particular change. The danger is that a change will be integrated with the baseline when that change is not actually of acceptable quality.

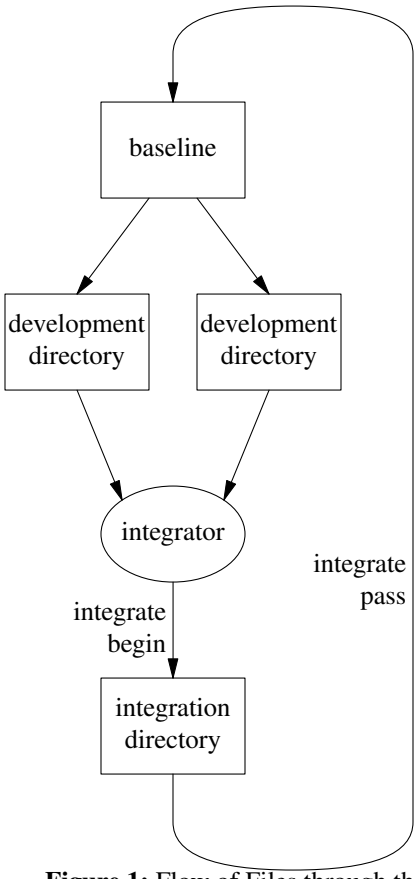

Figure 1: Flow of Files through the Model

Thus the baseline may be considered to be the *closure* of the source files, in mathematical terms. That is, it is the source files and all implications flowing from those source files, such as object files and executables. All files in the baseline are consistent with each other; this means that development builds can take object files from the baseline rather than rebuild them within the development directory.

The baseline is readable by all staff, and usually writable by no-one. When it is necessary to write to the baseline, this is done by aegis, as will be shown below.

In many ways, the baseline may be thought of as a database, and all derived files are projections (views) of the source files. Passing its own tests may be thought of as input validation of fields. This is a powerful concept, and indeed the implementation of the aegis program performs many of the locking and synchronization tasks demanded of a database engine.

All of the files forming this database are text files. This means that they may be repaired with an ordinary text editor, should remedial action be necessary. The format is documented in section 5 of the reference manual. Should you wish to perform some query not yet available in aegis, the files are readily accessible to members of the appropriate UNIX group.

Tests are treated just like any other source file, and are subject to the same process.

2.1.2. The Change Mechanism

Any changes to the baseline are made by atomic increments, known (unoriginally) as "changes". A change is a collection of files to be added to, modified in, or deleted from, the baseline. These files must all be so altered simultaneously for the baseline to continue to "work".[3]

For example, if the calling interface to a function were changed in one file, all calls to that function in any other file must also change for the baseline to continue to work. All of the files must be changed simultaneously, and thus must all be included in the one change. Other files which would logically be included in such an change include the reference manual entry for the function, the design document relating to that area of functionality, the relevant user documentation, tests would have to be included for the functionality, and existing tests may need to be revised.

Changes must be accompanied by tests. These tests will either establish that a bug has been fixed (in the case of a bug fix) or will establish that new functionality works (in the case of an enhancement).

Tests are shell scripts, and as such are capable of testing anything which has functionality accessable from the command line. The ability to run background processes allows even client-server models to be tested. Tests are thus text files, and are treated as source files; they may be modified by the same process as any other source file. Tests usually need to be revised as a project grows and adapts to changing requirements, or to be extended as functionality is extended. Tests can even be deleted if the functionality they tests has been deleted; tests are deleted by the same process as any other source file.

[3] Whether to allow several logically independent changes to be included in the one change is a policy decision for individual projects to make, and is not dictated by the aegis program. It is a responsibility of reviewers to ensure that all new and changed functionality is tested and documented.

2.1.3. Change States

As a change is developed using aegis, it passes through six states. Many aegis commands relate to transitions between these states, and aegis performs any validation at these times.

The six states of a change are described as follows, although the various state transitions, and their conditions, will be described later.

2.1.3.1. Awaiting Development

A change is in this state after it has been created, but before it has been assigned to a developer. This state can't be skipped: a change can't be immediately assigned to a developer by an administrator, because this disempowers the staff.

The aegis program is not a progress tracking tool, nor is it a work scheduling tool; plenty of both already exist.

2.1.3.2. Being Developed

A change is in this state after it has been assigned to a developer, by the developer. This is the coal face: all development is carried out in this state. Files can be edited in no other state, this particularly means that only developers can develop, reviewers and integrators only have the power to veto a change. Staff roles will be described more fully in a later section.

To advance to the next state, the change must build successfully, it must have tests, and it must pass those tests.[4]

The new tests must also *fail* against the baseline; this is to establish that tests for bug-fixes actually reproduce the bug and then demonstrate that it is gone. New functionality added by a change will naturally fail when tested in the old baseline, because it is not there.

When these conditions are met, the aegis program marks all of the changes files as locked, simultaneously. If any one of them is already locked, you can't leave the *being developed* state, because the file is part of a change which is somewhere between *being reviewed* and *being integrated* .

If any one of them is out-of-date with respect to the baseline, the lock is not taken, either. Locking the files at this state transition means that popular files may be modified simultaneously in many changes, but that only differences to the latest version are ever submitted for integration. The aegis program provides a mechanism, described later, for bringing out-of-date files in changes up-to-date without losing the edits made by the developer.

2.1.3.3. Being Reviewed

A change is in this state after a developer has indicated that development is complete. The change is inspected, usually by a second party (or parties), to ensure that it matches the what it is meant to be doing, and meets other project or company standards you may have.

The style of review, and who may review, is not dictated by the aegis program. A number of alternative have been observed:

• You may have a single person who coordinates review panels of, say, 4 peers, with this coordinator the only person allowed to sign-off review passes or fails.

• You may allow any of the developers to review any other developer's changes.

• You may require that only senior staff, familiar with large portions of the code, be allowed to review.

The aegis program enforces that a developer may not review their own code. This ensures that at least one person other than the developer has scrutinized the code, and eliminates a rather obvious conflict of interest. It is possible to turn this requirement off on a per-project basis, but this is only desirable for projects with a one person team (or maybe two). The aegis program has no way of knowing that the user passing a review has actually looked at, and understood, the code.

The reviewer knows certain things about a change for it to reach this state: it has passed all of the conditions required to reach this state. The change compiles, it has tests and it passes those tests, and the changes are to the current version of the baseline. The reviewer may thus concentrate on issues of completeness, implementation, and standards - to name only a few.

2.1.3.4. Awaiting Integration

A change is in this state after a reviewer has indicated that a change is acceptable to the reviewer(s). This is essentially a queue, as there may be many developers, but only one integration

[4] It is possible for these testing requirements to be waived on either a per-project or per-change basis. How is described in a later section. The power to waive this requirement is not automatically granted to developers, as experience has shown that it is usually abused.

may proceed at any one time.

The issue of one integration at a time is a philosophical one: all of the changes in the queue are physically independent; because of the *Develop End* locking rules they do not have intersecting sets of files. The problem comes when one change would break another, in these cases the integrator needs to know which to bounce and which to accept. Integrating one change at a time greatly simplifies this, and enforces the "only change one thing at a time" maxim, occasionally at the expense of integrator throughput.

2.1.3.5. Being Integrated

A change is in this state when the integration of the change back into the baseline is commenced. A (logical) copy of the baseline is taken, and the change is applied to that copy. In this state, the change is compiled and tested once again.

The additional compilation has two purposes: it ensures that the successful compile performed by the developer was not a fluke of the developer's environment, and it also allows the baseline to be the closure of the sources files. That is, all of the implications flowing from the source files, such as object files and linked programs or libraries. It is not possible for aegis to know which files these are in the development directory, because aegis is decoupled from the build mechanism (this will discussed later).

To advance to the next state, the integration copy must have been compiled, and the tests included in the change must have been run and passed.

The integrator also has the power of veto. A change may fail an integration because it fails to build or fails tests, and also just because the integrator says so. This allows the *being integrated* state to be another review state, if desired. The *being integrated* state is also the place to monitor the quality of reviews and reviewers.

Should a faulty change manage to reach this point, it is to be hoped that the integration process, and the integrator's sharp eyes, will detect it.

While most of this task is automated, this step is necessary to ensure that some strange quirk of the developer's environment was not responsible for the change reaching this stage. The change is built once more, and tested once more. If a change fails to build or test, it is returned to the developer for further work; the integrator may also choose to fail it for other reasons. If the integrator passes that change, the integrated version becomes the new baseline.

2.1.3.6. Completed

A change reaches this state when integration is complete. The (logical) copy of the baseline used during integration has replaced the previous copy of the baseline, and the file histories have been updated. Once in this state, a change may never leave it, unlike all other states.

If you wish to remove a change which is in this state from the baseline, you will have to submit another change.

2.1.4. The Software Engineers

The model of software development used by aegis has four different roles for software engineers to fill. These four roles may be overlapping sets of people, or be distinct, as appropriate for your project.

2.1.4.1. Developer

This is the coal-face. This role is where almost everything is done. This is the only role allowed to edit a source file of a project.

Most staff will be developers. There is nothing stopping a developer from also being an administrator, except for the possible conflict of interests with respect to testing exemptions.

A developer may edit many of the attributes of a change while it is being developed. This is mostly useful to update the description of the change to say why it was done and what was actually done. A developer may not grant testing exemptions (but they may be relinquished).

2.1.4.2. Reviewer

The role of the reviewer is to check a developer's work. This review may consist of a peer examining the code, or it may be handled by a single member of staff setting up and scheduling multi-person review panels. The aegis program does not mandate what style of review, it only requires that a reviewer pass or fail each change. If it passes, an integrator will handle it next, otherwise it is returned to the developer for further work.

In a large team, the reviewers are usually selected from the more senior members of the team, because of their depth of experience at spotting problems, but also because this is an opportunity for more senior members of staff to coach juniors on the finer points of the art.

The aegis programs makes some of the reviewer's task easier, because the reviewer knows several specific things about a change before it comes up for review: it builds, it has tests, and they have run successfully. There is also optional (per project) additional conditions imposed at the end of development, such as line length limits, or anything else which is automatically testable. The aegis program also provides a difference listing to the reviewer, so that each and every edit, to each and every file, can be pointed out to the reviewer.

There is nothing stopping a reviewer from being either an administrator or a developer. The aegis program specifically prevents a developer from reviewing his own work, to avoid conflicts of interest. (It is possible for this restriction to be waived, but that only makes sense for one person projects.)

It will occasionally be necessary to arbitrate between a developer and a reviewer. The appropriate person to do this would have line responsibility above both staff involved. Thus it is desirable that supervisors/managers not be reviewers, except in very small teams.

2.1.4.3. Integrator

The role of the integrator is to take a change which has already been reviewed and integrate it with the baseline, to form a new baseline. The integrator is thus the last line of defence for the baseline.

There is nothing preventing an administrator from being an administrator, a developer or a reviewer. The aegis program specifically prevents a developer or reviewer from integrating his own work, eliminating any conflict of interests. (It is possible for this restriction to be waived, but that only makes sense for one and two person projects.)

It will occasionally be necessary to arbitrate between an integrator and a reviewer and/or a developer. The appropriate person to do this would have line responsibility above all of the staff involved. Thus it is desirable that supervisors/mangers not be integrators, except in very small teams.

The baseline is readable by all developers, but not writable. All updates of the baseline to reflect changes produced by developers are performed through the agency of the integrator.

2.1.4.4. Administrator

The project administrator has the following duties:

• Create new changes. These may be the result of some customer bug reporting mechanism, it may be the result of new functionality being requested.

• Grant testing exemptions. By default, aegis insists that all changes be accompanied by tests. The project administrator may grant case-by-case exemptions, or a project-wide exemption.

• Add or remove staff. The four roles described in this section may be assigned to, or removed from, specific UNIX logins by the project administrator.

• Edit project attributes. There are many attributes attached to a project, only a project administrator may alter them.

• Edit change attributes. There are many attributes attached to a change, only a project administrator may alter all of them.

A project usually has only one or two administrators at any one time.

2.1.5. The Change Process

This section will examine the progression of a change through the six change states. Most of the attention will be given to the conditions which must be met in order to progress from one state to the next, as this is where the software development model employed by aegis is most often expressed.

See figure 2 for a picture of how all of the states and transitions fit together.

2.1.5.1. New Change

A project administrator creates a change. This change will consist mostly of a description at this time. The project administrator is not able (through aegis) to assign it to a specific developer.

The change is awaiting development; it is in the awaiting development state.

2.1.5.2. New Change Undo

It is possible to abandon a change if it is in the *awaiting development* state. All record of the change, including its description, will be deleted.

It is called *new change undo* to emphasize the state it must be in to delete it.

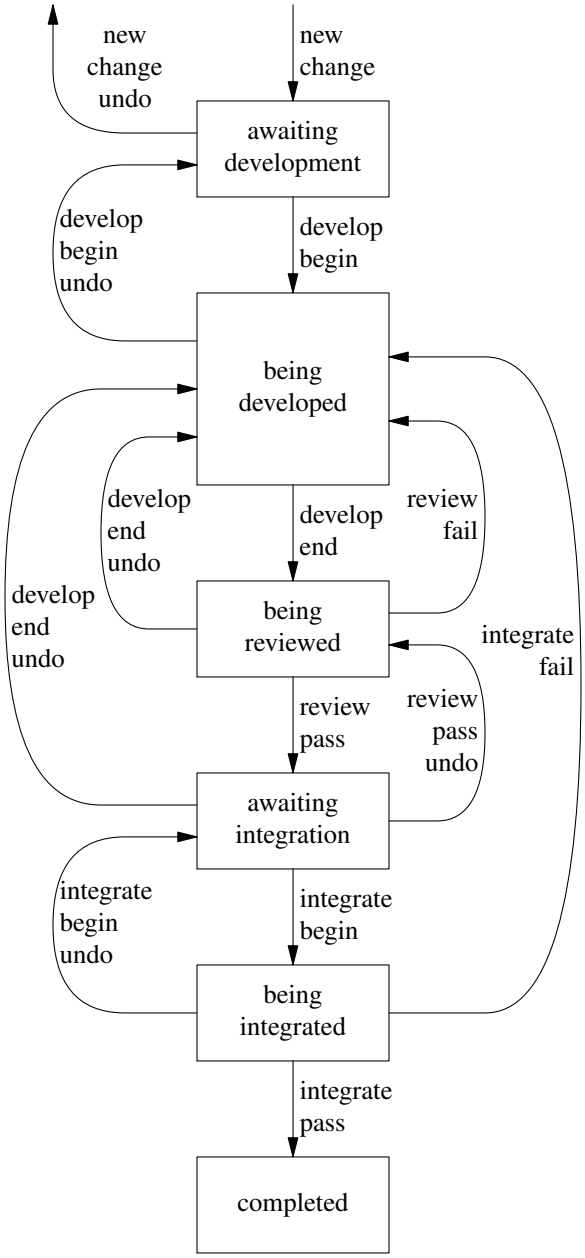

Figure 2: Change States and Transitions

2.1.5.3. Develop Begin

A developer, for whatever reason, scans the list of changes awaiting development. Having selected a change, the developer then assigns that change to herself.

The change is now being developed; it is in the being developed state.

A number of aegis commands only work in this state, including commands to include files and tests in the change (be they new files to be added to the baseline, files in the baseline to be modified, or files to be deleted from the baseline), commands to build the change, commands to test the change, and commands to difference the change.

The process of taking sources files, the preferred form for editing of a project, and transforming them, through various manipulations and translations, into a "finished" product is known as building. In the UNIX world this usually means things like compiling and linking a program, but as fancy graphical programs become more widespread, the source files could a binary output from a graphical Entity-Relationship-Diagram editor, which would then be run through a database schema generator.

The process of testing a change has three aspects. The most intuitive is that a test must be run to determine of the functionality works. The second requirement is that the test be run against the baseline and fail; this is to ensure that bugs are not just fixed, but reproduced as well. The third requirement is optional: all or some of the tests already in the baseline may also be run. Tests consist of UNIX shell scripts - anything that can be done in a shell script can be tested.

In preparation for review, a change is differenced. This usually consists of automatically comparing the present contents of the baseline with what the change proposes to do to the baseline, on a file-by-file basis. The results of the difference, such as UNIX *diff -c* output, is kept in a difference file, for examination by the reviewer(s). The benefit of this procedure is that reviewers may examine these file to see every change the developer made, rather than only the obvious ones. The differencing commands are per-project configurable, and other validations, such as line length restrictions, may also be imposed at this time.

To leave this state, the change must have source files, it must have tests, it must have built successfully, it must have passed all its own tests, and it must have been differenced.

2.1.5.4. Develop Begin Undo

It is possible to return a change from the being developed state to the awaiting development state if it has no source files and has no tests. This is usually desired if a developer selected the wrong change by mistake.

2.1.5.5. Develop End

When the conditions for the end of development have been met (the change must have source files, it must have tests, it must have built successfully, it must have passed all its own tests, and it must have been differenced) the developer may cause the change to leave the being developed state and enter the being reviewed state. The aegis program will check to see that all the conditions are met at this time. There is no history kept of unsuccessful develop end attempts.

2.1.5.6. Develop End Undo

There are many times when a developer thinks that a change is completed, and goes hunting for a reviewer. Half way down the hall, she thinks of something that should have been included.

It is possible for a developer to rescind a *Develop End* to allow further work on a change. No reason need be given. This request may be issued to a change in either the *being reviewed* or *awaiting integration* states.

2.1.5.7. Review Pass

This event is used to notify aegis that the change has been examined, by a method unspecified as discussed above, and has been found to be acceptable.

2.1.5.8. Review Pass Undo

The reviewer of a change may rescind a *Review Pass* while the change remains in the *awaiting integration* state. No reason must be supplied. The change will be returned to the *being reviewed* state.

2.1.5.9. Review Fail

This event is used to notify aegis that the change has been examined, by a method unspecified as discussed above, and has been found to be unacceptable.

A file containing a brief summary of the problems must be given, and will be included in the change's history.

The change will be returned to the *being developed* state for further work.

It is not the responsibility of any reviewer to fix a defective change.

2.1.5.10. Integrate Begin

This command is used to commence integration of a change into the project baseline.

Whether a physical copy of the baseline is used, or a logical copy using hard links, is controlled by the project configuration file. The change is then applied to this copy.

The integrator must then issue build and test commands as appropriate. This is not automated as some integrator tasks may be required in and around these commands.

2.1.5.11. Integrate Begin Undo

This command is used to return a change to the integration queue, with out prejudice. No reason need be given.

This is usually done when a particularly important change is in the queue, and the current integration is expected to take a long time.

2.1.5.12. Integrate Pass

This command is used to notify aegis that the change being integrated is acceptable.

The current baseline is replaced with the integration copy, and the history is updated.

2.1.5.13. Integrate Fail

This command is used to notify aegis that an integration is unacceptable, usually because it failed to build or test in some way, or sometimes because the integrator found a deficiency.

A file containing a *brief* summary of the problems must be given, and the summary will be included in the change's history.

The change will be returned to the *being developed* state for further work. The integration copy of the baseline is deleted, leaving the original baseline unchanged.

It is not the responsibility of any integrator to fix a defective change, or even diagnose what the defect may be.

2.2. Philosophy

The philosophy is simple, and that makes some of the implementation complex. When a change is in the *being developed* state, the aegis program is a developer's tool. Its purpose is to make it as easy for a developer to develop changes as possible. When a change leaves (or attempts to leave) the *being developed* state, the aegis program is protecting the project baseline, and does not exist to make the developer happy. The aegis program attempts to adhere to the UNIX minimalist philosophy. Least unnecessary output, least command line length, least dependence on 3rd party tools. No overlap in functionality of other tools.

2.2.1. Development

During the development of a change, the aegis program exists to help the developer. It helps him navigate around his change and the project, it copies file for him, and keeps track of the versions. It can even tell him what changes he has made.

2.2.2. Post Development

When a change has left the "being developed" state, or when it is attempting to leave that state, the aegis program ceases to attempt to help the developer and proceeds to defend the project baseline. The model used by aegis states that "the baseline always works", and aegis attempts to guarantee this.

2.2.3. Minimalism

The idea of minimalism is to help the user out. It is the intention that the aegis program can work out unstated command line options for itself, in cases where it is "safe" to do so. This means a number of defaulting mechanisms, all designed to help the user.

2.2.4. Overlap

It was very tempting while writing the aegis program to have it grow and cover source control and dependency maintenance roles. Unfortunately, this would have meant that the user would have been trapped with whatever the aegis program provided, and the aegis program is already plenty big. To add this functionality would have diverted effort, resulting in an inferior result. It would also have violated the underlying UNIX philosophy.

2.2.5. Design Goals

A number of specific ideas molded the shape of the aegis program. These include:

The UNIX philosophy of writing small tools for specific tasks with little or no overlap. Tools should be written with the expectation of use in pipes or scripts, or other combinations.

• Stay out of the way. If it is possible to let a project do whatever it likes, write the code to let it. It is not possible to anticipate even a fraction of the applications of a software tool.

• People. The staff using aegis should be in charge of the development process. They should not feel that some machine is giving them orders.

• Users aren't psychic. Feedback must be clear, accurate and appropriate.

2.3. Security

Access to project data is controlled by the UNIX group mechanism. The group may be selected as suitable for your project, as may the umask.

All work done by developers (build, difference, etc) is all with a default group of the project's group, irrespective of the user's default group. Directories (when BSD semantics are available) are all created so that their contents default to the correct group. This ensures that reviewers and integrators are able to examine the change.

Other UNIX users not in the project's group may be excluded, or not, by the appropriate setting of the project umask. This umask is used by all aegis actions, assuring appropriate default behaviour.

A second aspect of security is to ensure that developers are unable to deliberately deceive aegis. At develop end, all files in the development directory are marked read only, aegis notes the time stamps on the files. Should the files be tampered with at any later date, aegis will notice. If a change is returned to the *being developed* state, the files are marked writable again.

2.4. Scalability

How big can a project get before aegis chokes? There are a huge number of variables in this question.

The most obvious bottleneck is the integrator. An artificial "big project" example: Assume that the average integration takes an hour to build and test. A full-time integrator could be expected to get 7 or 8 of these done per day (this was the observed average on one project the author was involved in). Assume that the average time for a developer to develop a change is two weeks; a figure recommended by many text books as These two assumptions mean that for this "big project" aegis can cope with 70 to 80 developers, before integrations become a bottleneck.

The more serious bottle neck is the dependency maintenance tool. Seventy developers can churn out a staggering volume of code. It takes a very long time to wade through the file times and the rules, just to find the one or two files which changed. This can easily push the integrate build time past the one hour mark. Developers also become very vocal when build times are this long.

2.5. When (not) to use Aegis

The aegis program is not a silver bullet; it will not solve all of your problems. Aegis is suitable for some kinds of projects, useful for others, and useless for a few.

The most difficult thing about the aegis program is that it takes management buy-in. It takes effort to convince many people that the model used by aegis has benefits, and you need management backing you up when some person comes along with a way of developing software "without the extra work" imposed by the model used by aegis program.

There is extra up-front work: writing tests. The win is that the tests hang around forever, catching minor and major slips before they become embarrassing "features" in a released product. Prevention is cheaper than cure in this case, the tests save work down the track.

All of the "extra work" of writing tests is a long-term win, where old problems never again reappear. All of the "extra work" of reviewing changes means that another pair of eyes sights the code and finds potential problems before they manifest themselves in shipped product. All of the "extra work" of integration ensures that the baseline always works, and is always self-consistent. All of the "extra work" of having a baseline and separate development directories allows multiple parallel development, with no inter-developer interference; and the baseline always works, it is never in an "in-between" state. In each case, not doing this "extra work" is a false economy.

The existence of these tests, though, is what determines which projects are most suited to aegis and which are not. It should be noted that suitability is a continuous scale, not black-and-white. With effort and resources, almost anything fits.

2.5.1. Projects for which Aegis is Most Suitable

Projects most suited to supervision by aegis are straight programs. What the non-systems-programmers out there call "tools" and sometimes "applications". These are programs which take a pile of input, chew on it, and emit a pile of output. The tests can then compare actual outputs with expected outputs.

As an example, you could be writing a *sed*(1) look-alike, a public domain clone of the UNIX sed utility. You could write tests which exercise every feature (insertion, deletion, etc.) and generate the expected output with the real UNIX sed. You write the code, and run the tests; you can immediately see if the output matches expectations.

This is a simple example. More complex examples exist, such as aegis itself. The aegis program is used to supervise its own development. Tests consist of sequences of commands and expected results are tested for.

Other types of software have been developed using aegis: compilers and interpreters, client-server model software, magnetic tape utilities, graphics software such as a ray-tracer. The range is vast, but it is not all types of software.

2.5.2. Projects for which Aegis is Useful

For many years there have been full-screen applications on text terminals. In more recent times there is increasing use of graphical interfaces.

In developing these types of programs it is still possible to use aegis, but several options need to be explored.

2.5.2.1. Testing Via Emulators

There are screen emulators for both full-screen text and X11 available. Using these emulators, it is possible to test the user interface, and test via the user interface. As yet, the author knows on no freely available emulators suitable for testing via aegis. If you find one, please let me know.

2.5.2.2. Limited Testing

You may choose to use aegis simply for its ability to provide controlled access to a large source. You still get the history and change mechanisms, the baseline model, the enforced review. You simply don't test all changes, because figuring out what is on the screen, and testing it against expectations, is too hard.

If the program has a command line interface, in addition to the full-screen or GUI interface, the functionality accessible from the command line may be tested using aegis.

It is possible that "limited testing" actually means "no testing", if you have no functionality accessible from the command line.

2.5.2.3. Testing Mode

Another alternative is to provide hooks into your program allowing you to substitute a file for user input, and to be able to trigger the dump of a "screen image". The simulated user input can

then be fed to the program, and the screen dump (in some terminal-independent form) can be compared against expectations.

This is easier for full-screen applications, than for X11 applications. You need to judge the cost-benefit trade-off. Cost of development, cost of storage space for X11 images, cost of *not* testing.

2.5.2.4. Manual Tests

The aegis program provides a manual test facility. It was originally intended for programs which required some physical action from a user, such as "unplug ethernet cable now" or "mount tape XG356B now". It can also be used to have a user confirm that some on-screen activity has happened.

The problem with manual tests is that they simply don't happen. It is far more pleasant to say "run the automatic tests" and go for a cup of coffee, than to wait while the computer thinks of mindless things to ask you to do. This is human nature: if it can be automated, it is more likely to happen.

2.5.3. Projects for which Aegis is Least Suitable

Another class of software is things like operating system kernels and firmware; things which are "stand alone". This isolated nature makes it the most difficult to test: to test it you want to provide physical input and watch the physical output. By its very nature, it is hard to put into a shell script, and thus hard to write an aegis test for.

2.5.3.1. Operating Systems

It is not impossible, just that few of us have the resources to do it. You need to have a test system and a testing system: the test system has all of its input and outputs connected to the outputs and inputs of the testing system. That is, the testing system controls and drives the test system, and watches what happens.

For example, many operating system vendors test their products by using computers connected to each serial line to simulate "user input". The system can be rebooted this way, and using dual-ported disks allows different versions of a kernel to be tried, or other test conditions created.

For software houses which write kernels, or device drivers for kernels, or some other kernel work, this is bad news: the aegis program is probably not for you. It is possible, but there may be more cost-effective development strategies. Of course, you could always use the rest of aegis, and ignore the testing part.

2.5.3.2. Firmware

Firmware is a similar deal: you need some way to download the code to be tested into the test system, and write-protect it to simulate ROM, and have the necessary hardware to drive the inputs and watch the outputs.

As you can see, this is generally not available to run-of-the-mill software houses, but then they rarely write firmware, either. Those that do write firmware usually have the download capabilities, and some kind of remote operation facility.

2.6. Further Work

The aegis program is far from finished. A number of features are known to be lacking.

At the date of this writing, aegis is being actively supported and improved.

2.6.1. Hierarchy of Projects

It would be nice if there was some way to use one projects as a sort of "super change" to a "super project", so that large teams (say 1000 people) could work as lots of small teams (say 100 people). As a small team gets their chunk ready, using the facilities provided to-date by aegis, the small team's baseline is treated as a change to be made to the large team baseline.

This idea can be extended quite naturally to any depth of layering.

The desired semantics, let alone the implementation details, can not begin without more experience to show (and fix) the warts on the existing functionality.

After reading *Transaction Oriented Configuration Management: A Case Study* Peter Fieler, Grace Downey, CMU/SEI-90-TR-23, this is not a new idea. It also provies some ideas for how to do branching sensably.

2.6.2. Code Coverage Tool

It would be very helpful if a code coverage tool could be used to analyze tests included with changes to ensure that the tests actually exercised the lines of code changed in the change.

Another use of the code coverage tool would be to select regression tests based on the object files recompiled by a change, and those regression tests which exercise those files.

While there is freeware C code coverage tool available, based on GNU C, the interfacing and semantics still need more thought.

2.6.3. Branching

The aegis program does not provide support for branching in the history files. The semantics of the baseline, the source files and their closure, would appear to imply that a baseline is required for every leaf in the history tree.

Branching is provided in this way with the *new release* functionality. An entire new project is derived from an existing project, including another baseline. The history, however, is severed from the original project, precluding automatic merging by aegis at a later date. It also precludes having a single change to be applied to more than one branch.

Should better semantics become available, or a better algorithmic approach, this is certainly one area of aegis which could be improved.

2.6.4. Virtual File System

There is almost sufficient information in the aegis data base to create a virtual file system, overlaying the development directory atop the baseline[5]. This could be implemented similarly to automounters, intercepting file system operations by pretending to be an NFS server. Many commercial CASE products provide such a facility.

Such a virtual file system has a number of advantages: you don't need such a capable DMT, for starters; it only needs the dynamic include dependencies, and does not need a search path[6]. Second, many horrible and dumb compilers, notably FORTRAN and "fourth" GLs, don't have adequate include semantics; overlaying the two directories make this much easier to deal with[7]. Many graphical tools, such as bubble chart drawers, etc, when they do actually have include files, have no command line specifiable search path.

The disadvantage is that this adds significant complexity to an already large program. Also, implementation is limited to NFS capable systems, or would have to be rewritten for a variety of other systems. The semantics of interactions between the daemon and other aegis commands, while clearly specifiable, are challenging to implement. Performance could also be a significant factor.

The question is "is it really necessary?" If the job can be done without it, does the effort of writing such a beast result in significant productivity gains?

The addition of the *create_symlinks_before_build* fielf to the project *config* file has greatly reduced the need for this functionality. However, it does not provide copy-on-write semantics, nor automatic *aecp* functionality; which a virtual file system could do.

---

[5] Reminiscent of Sun's TFS, but not the same.

[6] Discussed in the *Dependency Maintenance Tool* chapter.

[7] There are other ways, discussed in the *Tips and Traps* chapter.

3. The Change Development Cycle

As a change to a project is developed using aegis, it passes through several states. Each state is characterised by different quality requirements, different sets of applicable aegis commands, and different responsibilities for the people involved.

These people may be divided into four categories: developers, reviewers, integrators and administrators. Each has different responsibilities, duties and permissions; although one person may belong to more than one category, depending on how a project is administered.

This chapter looks at each of these categories, by way of an example project undergoing its first four changes. This example will be examined from the perspective of each category of people in the following sections.

There are six hypothetical users in the example: the developers are Pat, Jan and Sam; the reviewers are Robyn and Jan; the integrator is Isa; and the administrator is Alex[8]. There need not have been this many people involved, but it keeps things slightly cleaner for this example.

The project is called "example". It implements a very simple calculator. Many features important to a quality product are missing, checking for divide-by-zero for example. These have been omitted for brevity.

[8] The names are deliberately gender-neutral. Finding such a name starting with "I" is not easy!

3.1. The Developer

The developer role is the coal face. This is where new software is written, and bugs are fixed. This example shows only the addition of new functionality, but usually as modifications of existing code, similar to bug-fixing activity.

3.1.1. The First Change

While the units of change, unoriginally, are called "changes", this also applies to the start of a project - a change to nothing, if you like. The developer of this first change will be Pat.

First, Pat has been told by the project administrator that the change has been created. How Alex created this change will be detailed in the "Administrator" section, later in this chapter. Pat then acquires the change and starts work.

```
pat% aedb -l -p example
Project "example"
List of Changes

Change  State           Description
------- -------         -------------
   1    awaiting_       Create initial skeleton.
        development
pat% aedb example 1
aegis: project "example": change 1: development directory "/u/pat/
        example.001"
aegis: project "example": change 1: user "pat" has begun development
pat% aecd
aegis: project "example": change 1: /u/pat/example.001
pat%
```

At this point aegis has created a development directory for the change and Pat has changed directory to the development directory[9].

Five files will be created by this change.

```
pat% aenf config Howto.cook gram.y lex.l main.c
aegis: project "example": change 1: file "Howto.cook" added
aegis: project "example": change 1: file "config" added
aegis: project "example": change 1: file "gram.y" added
aegis: project "example": change 1: file "lex.l" added
aegis: project "example": change 1: file "main.c" added
pat%
```

The contents of the *config* file will not be described in this section, mostly because it is a rather complex subject; so complex it requires four chapters to describe: the chapter, the chapter, the *Difference Tools* chapter and the *Project Attributes* chapter. The contents of the *Howto.cook* file will not be described in this section, as it is covered in the *Dependency Maintenance Tool* chapter.

The file *main.c* will have been created by aegis as an empty file. Pat edits it to look like this

```
#include <stdio.h>

static void
usage()
{
        fprintf(stderr, "usage: example\n");
        exit(1);
}
```

[9] The default directory in which to place new development directories is configurable for each user.

```
void
main(argc, argv)
        int     argc;
        char    **argv;
{
        if (argc != 1)
                usage();
        yyparse();
        exit(0);
}
```

The file *gram.y* describes the grammar accepted by the calculator. This file was also created empty by aegis, and Pat edits it to look like this:

```
%token  DOUBLE
%token  NAME

%union
{
        int     lv_int;
        double  lv_double;
}

%type <lv_double> DOUBLE expr
%type <lv_int> NAME

%prec '+' '-'
%prec '*' '/'
%prec UNARY

%%

example
        : /* empty */
        | example command
command
        : expr
        | error
expr
        : DOUBLE
                { $$ = $1; }
        | '(' expr ')'
                { $$ = $2; }
        | '-' expr
                %prec UNARY
                { $$ = -$2; }
        | expr '*' expr
                { $$ = $1 * $3; }
        | expr '/' expr
                { $$ = $1 / $3; }
        | expr '+' expr
                { $$ = $1 + $3; }
        | expr '-' expr
                { $$ = $1 - $3; }
```

The file *lex.l* describes a simple lexical analyzer. It will be processed by *lex*(1) to produce C code implementing the lexical analyzer. This kind of simple lexer is usually hand crafted, but using lex allows the example to be far smaller. Pat edits the file to look like this:

```
%{
#include <math.h>
#include <gram.h>
%}
%%
[ \t\n]+      ;
[0-9]+(\.[0-9]*)?([eE][+-]?[0-9]+)?    {
                yylval.lv_double = atof(yytext);
                return DOUBLE;
        }
[a-z]   {
                yylval.lv_int = yytext[0] - 'a';
                return NAME;
        }
.       return yytext[0];
```

Note how the *gram.h* file is included using the `#include <filename>` form. This is very important for builds in later changes, and is discussed more fully in the *Using Cook* section of the *Dependency Maintenance Tool* chapter.

The files are processed, compiled and linked together using the *aeb* command; this is known as *building* a change. This is done through aegis so that aegis can know the success or failure of the build. (Build success is a precondition for a change to leave the *being developed* state.) The build command is in the *config* file so vaguely described earlier. In this example it will use the *cook*(1) command which in turn will use the *Howto.cook* file, also alluded to earlier. This file describes the commands and dependencies for the various processing, compiling and linking.

```
pat% aeb
aegis: project "example": change 1: development build started
aegis: cook -b Howto.cook project=example change=1
        version=1.0.C001 -nl
cook: yacc -d gram.y
cook: mv y.tab.c gram.c
cook: mv y.tab.h gram.h
cook: cc -I. -I/projects/example/baseline -O -c gram.c
cook: lex lex.l
cook: mv lex.yy.c lex.c
cook: cc -I. -I/projects/example/baseline -O -c lex.c
cook: cc -I. -I/projects/example/baseline -O -c main.c
cook: cc -o example gram.o lex.o main.o -ll -ly
aegis: project "example": change 1: development build complete
pat%
```

The example program is built, and Pat could even try it out:

```
pat% example
1 + 2
3
^D
pat%
```

At this point the change is apparently finished. The command to tell aegis this is the *develop end* command:

```
pat% aede
aegis: project "example": change 1: no current 'aegis -DIFFerence'
        registration
pat%
```

It didn't work, because aegis thinks you have missed the difference step.

The difference step is used to produce files useful for reviewing changes, mostly in the form of context difference files between the project baseline and the development directory. Context differences allow reviewers to see exactly what has changed, and not have to try to track them down and inevitably miss obscure but

important edits to large or complex files.

```
pat% aed
aegis: set +e; diff -c /dev/null /u/pat/example.001/Howto.cook >
        /u/pat/example.001/Howto.cook,D; test $? -eq 0 -o $? -eq 1
aegis: set +e; diff -c /dev/null /u/pat/example.001/config >
        /u/pat/example.001/config,D; test $? -eq 0 -o $? -eq 1
aegis: set +e; diff -c /dev/null /u/pat/example.001/gram.y >
        /u/pat/example.001/gram.y,D; test $? -eq 0 -o $? -eq 1
aegis: set +e; diff -c /dev/null /u/pat/example.001/lex.l >
        /u/pat/example.001/lex.l,D; test $? -eq 0 -o $? -eq 1
aegis: set +e; diff -c /dev/null /u/pat/example.001/main.c >
        /u/pat/example.001/main.c,D; test $? -eq 0 -o $? -eq 1
aegis: project "example": change 1: difference complete
pat%
```

Doing a difference for a new file may appear a little pedantic, but when a change consists of tens of files, so modifications of existing files and some new, there is a temptation for reviewers to use "more *,D" and thus completely miss the new files if it were not for this pedanticism[10].

So that reviewers, and conscientious developers, may locate and view all of these difference files, the command

```
pat% more `find . -name "*,D" -print | sort`
...examines each file...
pat%
```

could be used, however this is a little too long winded for most users, and so the *aedmore* alias does exactly this. There is a similar *aedless* alias for those who prefer the *less* (1) command.

So now Pat is done, let's try to sign off again:

```
pat% aede
aegis: project "example": change 1: no current 'aegis -Test'
        registration
pat%
```

It didn't work, again. This time aegis is reminding Pat that every change must be accompanied by at least one test. This is so that the project team can be confident at all times that a project works[11]. Making this a precondition to leave the *being developed* state means that a reviewer can be sure that a change builds and passes its tests before it can ever be reviewed. Pat adds the truant test:

```
pat% aent
aegis: project "example": change 1: file "test/00/t0001a.sh" new
        test
pat%
```

The test file is in a weird place, eh? This is because many flavours of UNIX are slow at searching directories, and so aegis limits itself to 100 tests per directory. Whatever the name, Pat edits the test file to look like this:

```
#!/bin/sh
#
# test simple arithmetic
#
tmp=/tmp/$$
here=`pwd`
if [ $? -ne 0 ]; then exit 1; fi
```

[10] This is especially true when you use a tool such as *fcomp*(1) which gives a complete file listing with the inserts and deletes marked in the margin. This tool is also available from the author of aegis.

[11] As discussed in the *How Aegis Works* chapter, aegis has the objective of ensuring that projects always work, where "works" is defined as passing all tests in the project's baseline. A change "works" if it passes all of its accompanying tests.

```
fail()
{
        echo FAILED 1>&2
        cd $here
        rm -rf $tmp
        exit 1
}

pass()
{
        cd $here
        rm -rf $tmp
        exit 0
}
trap "fail" 1 2 3 15

mkdir $tmp
if [ $? -ne 0 ]; then exit 1; fi
cd $tmp
if [ $? -ne 0 ]; then fail; fi

#
# with input like this
#
cat > test.in << 'foobar'
1
(24 - 22)
-(4 - 7)
2 * 2
10 / 2
4 + 2
10 - 3
foobar
if [ $? -ne 0 ]; then fail; fi

#
# the output should look like this
#
cat > test.ok << 'foobar'
1
2
3
4
5
6
7
foobar
if [ $? -ne 0 ]; then fail; fi

#
# run the calculator
# and see if the results match
#
$here/example < test.in > test.out
if [ $? -ne 0 ]; then fail; fi
diff test.ok test.out
if [ $? -ne 0 ]; then fail; fi

#
# this much worked
#
pass
```

There are several things to notice about this test file:

- It is a Bourne shell script. All test files are Bourne shell scripts because they are the most portable.[12] (Actually, aegis likes test files not to be executable, it passes them to the Bourne shell explicitly when running them.)
- It makes the assumption that the current directory is either the development directory or the baseline. This is valid, aegis always runs tests this way; if you run one manually, you must take care of this yourself.
- It checks the exit status of each and every command. It is essential that even unexpected and impossible failures are handled.
- A temporary directory is created for temporary files. It cannot be assumed that a test will be run from a directory which is writable; it is also easier to clean up after strange errors, since you need only throw the directory away, rather than track down individual temporary files. It mostly protects against rogue programs scrambling files in the current directory, too.
- Every test is self-contained. The test uses auxiliary files, but they are not separate source files (figuring where they are when some are in a change and some are in the baseline can be a nightmare). If a test want an auxiliary file, it must construct the file itself, in a temporary directory.
- Two functions have been defined, one for success and one for failure. Both forms remove the temporary directory. A test is defined as passing if it returns a 0 exit status, and failing if it returns anything else.
- Tests are treated just like any other source file, and are subject to the same process. They may be altered in another change, or even deleted later if they are no longer useful.

The most important feature to note about this test, after ignoring all of the trappings, is that it doesn't do much you wouldn't do manually! To test this program manually you would fire it up, just as the test does, you would give it some input, just as the test does, and you would compare the output against your expectations of what it will do, just as the test does.

The difference with using this test script and doing it manually is that most development contains many iterations of the "build, test, *think*, edit, build, test..." cycle. After a couple of iterations, the manual testing, the constant re-typing, becomes obviously unergonomic. Using a shell script is more efficient, doesn't forget to test things later, and is preserved for posterity (i.e. adds to the regression test suite).

This efficiency is especially evident when using commands[13] such as

```
pat% aeb && aet ; vi aegis.log
...
pat% !!
...
pat%
```

It is possible to talk to the shell extremely rarely, and then only to re-issue the same command, using a work pattern such as this.

As you have already guessed, Pat now runs the test like this:

```
pat% aet
aegis: sh /u/pat/example.001/test/00/t0001a.sh
aegis: project "example": change 1: test "test/00/t0001a.sh"
        passed
aegis: project "example": change 1: passed 1 test
pat%
```

Finally, Pat has built the change, prepared it for review and tested it. It is now ready for sign off.

---

[12] Portable for aegis' point of view: Bourne shell is the most widely available shell. Of course, if you are writing code to publish on USENET or for FTP, portability of the tests will be important from the developer's point of view also.

[13] This is a *csh* specific example, unlike most others.

```
pat% aede
aegis: project "example": change1: no current 'aegis -Build'
        registration
pat%
```

Say what? The problem is that the use of *aent* cancelled the previous build registration. This was because aegis is decoupled from the dependency maintenance tool (*cook* in this case), and thus has no way of knowing whether or not the new file in the change would affect the success or failure of a build[14]. All that is required is to re-build, re-test, re-difference (yes, the test gets differenced, too) and sign off.

```
pat% aeb
aegis: logging to "/u/pat/example.001/aegis.log"
aegis: project "example": change 1: development build started
aegis: cook -b Howto.cook project=example change=1
        version=1.0.C001 -nl
cook: "all" is up-to-date
aegis: project "example": change 1: development build complete
pat% aet
aegis: logging to "/u/pat/example.001/aegis.log"
aegis: sh /u/pat/example.001/test/00/t0001a.sh
aegis: project "example": change 1: test "test/00/t0001a.sh"
        passed
aegis: project "example": change 1: passed 1 test
pat% aed
aegis: logging to "/u/pat/example.001/aegis.log"
aegis: set +e; diff -c /dev/null /u/pat/example.001/test/00/
        t0001a.sh > /u/pat/example.001/test/00/t0001a.sh,D; test
        $? -eq 0 -o $? -eq 1
aegis: project "example": change 1: difference complete
pat% aede
aegis: sh /usr/local/lib/aegis/de.sh example 1 pat
aegis: project "example": change 1: development completed
pat%
```

The change is now ready to be reviewed. This section is about developers, so we will have to leave this change at this point in its history. Some time in the next day or so Pat receives electronic mail that this change has passed review, and another later to say that it passed integration. Pat is now free to develop another change, possibly for a different project.

3.1.2. The Second Change

The second change was created because someone wanted to name input and output files on the command line, and called the absence of this feature a bug. When Jan arrived for work, and lists the changes awaiting development, the following list appeared:

```
jan% aedb -l -p example
Project "example"
List of Changes
```

[14] Example: in addition to the executable file "example" shown here, the build may also produce an archive file of the project's source for export. The addition of one more file may push the size of this archive beyond a size limit; the build would thus fail because of the addition of a test.

```
Change  State           Description
------  ------          ------------
   2    awaiting_       Add input and output file names to the
        development     command line.
   3    awaiting_       add variables
        development
   4    awaiting_       add powers
        development
jan%
```

The first on the list is chosen.

```
jan% aedb -c 2 -p example
aegis: project "example": change 2: development directory "/u/
       jan/example.002"
aegis: project "example": change 2: user "jan" has begun
       development
jan% aecd
aegis: project "example": change 2: /u/jan/example.002
jan%
```

The best way to get details about a change is to used the "change details" listing.

```
jan% ael cd
Project "example", Change 2
Change Details

NAME
        Project "example", Change 2.

SUMMARY
        file names on command line

DESCRIPTION
        Optional input and output files may be specified on the
        command line.

CAUSE
        This change was caused by internal_bug.

STATE
        This change is in 'being_developed' state.

FILES
        Change has no files.

HISTORY
        What            When            Who     Comment
        ------          ------          -----   ---------
        new_change      Fri Dec 11      alex
                        14:55:06 1992
        develop_begin   Mon Dec 14      jan
                        09:07:08 1992
jan%
```

Through one process or another, Jan determines that the *main.c* file is the one to be modified. This file is copied into the change:

```
jan% aecp main.c
aegis: project "example": change 2: file "main.c" copied
jan%
```

This file is now extended to look like this:

```
#include <stdio.h>

static void
usage()
{
        fprintf(stderr, "usage: example [ <infile> [ <outfile> ]]\n");
        exit(1);
}

void
main(argc, argv)
        int     argc;
        char    **argv;
{
        char    *in = 0;
        char    *out = 0;
        int     j;

        for (j = 1; j < argc; ++j)
        {
                char *arg = argv[j];
                if (arg[0] == '-')
                        usage();
                if (!in)
                        in = arg;
                else if (!out)
                        out = arg;
                else
                        usage();
        }

        if (in && !freopen(in, "r", stdin))
        {
                perror(in);
                exit(1);
        }
        if (out && !freopen(out, "w", stdout))
        {
                perror(out);
                exit(1);
        }

        yyparse();
        exit(0);
}
```

A new test is also required,

```
jan% aent
aegis: project "example": change 2: file "test/00/t0002a.sh" new
        test
jan%
```

which is edited to look like this:

```
#!/bin/sh
#
# test command line arguments
#
tmp=/tmp/$$
here=`pwd`
if [ $? -ne 0 ]; then exit 1; fi
```

```
fail()
{
        echo FAILED 1>&2
        cd $here
        rm -rf $tmp
        exit 1
}

pass()
{
        cd $here
        rm -rf $tmp
        exit 0
}
trap "fail" 1 2 3 15

mkdir $tmp
if [ $? -ne 0 ]; then exit 1; fi
cd $tmp
if [ $? -ne 0 ]; then fail; fi

#
# with input like this
#
cat > test.in << 'foobar'
1
(24 - 22)
-(4 - 7)
2 * 2
10 / 2
4 + 2
10 - 3
foobar
if [ $? -ne 0 ]; then fail; fi

#
# the output should look like this
#
cat > test.ok << 'foobar'
1
2
3
4
5
6
7
foobar
if [ $? -ne 0 ]; then fail; fi
```

```
#
# run the calculator
# and see if the results match
#
# (Use /dev/null for input in case input redirect fails;
# don't want the test to hang!)
#
$here/example test.in test.out < /dev/null
if [ $? -ne 0 ]; then fail; fi
diff test.ok test.out
if [ $? -ne 0 ]; then fail; fi
$here/example test.in < /dev/null > test.out.2
if [ $? -ne 0 ]; then fail; fi
diff test.ok test.out.2
if [ $? -ne 0 ]; then fail; fi

#
# make sure complains about rubbish
# on the command line
#
$here/example -trash < test.in > test.out
if [ $? -ne 1 ]; then fail; fi

#
# this much worked
#
pass
```

Now it is time for Jan to build and test the change. Through the magic of static documentation, this works first time, and here is how it goes:

```
jan% aeb
aegis: logging to "/u/pat/example.002/aegis.log"
aegis: project "example": change 2: development build started
aegis: cook -b /projects/example/baseline/Howto.cook
        project=example change=2 version=1.0.C002 -nl
cook: cc -I. -I/projects/example/baseline -O -c main.c
cook: cc -o example main.o /projects/example/baseline/gram.o
        /projects/example/baseline/lex.o -ll -ly
aegis: project "example": change 2: development build complete
jan% aet
aegis: logging to "/u/pat/example.002/aegis.log"
aegis: sh /u/jan/example.002/test/00/t0002a.sh
aegis: project "example": change 2: test "test/00/t0002a.sh"
        passed
aegis: project "example": change 2: passed 1 test
jan%
```

All that remains if to difference the change and sign off.

```
jan% aed
aegis: logging to "/u/pat/example.002/aegis.log"
aegis: set +e; diff -c /projects/example/main.c /u/jan/
        example.002/main.c > /u/jan/example.002/main.c,D; test $?
        -eq 0 -o $? -eq 1
aegis: project "example": change 2: difference complete
jan% aedmore
...examines the file...
jan%
```

Note how the context difference shows exactly what has changed. And now the sign-off:

```
jan% aede
aegis: project "example": change 2: no current 'aegis -Test
        -BaseLine' registration
jan%
```

No, it wasn't enough. Tests must not only pass against a new change, but must fail against the project baseline. This is to establish, in the case of bug fixes, that the bug has been isolated *and* fixed. New functionality will usually fail against the baseline, because the baseline can't do it (if it could, you wouldn't be adding it!). So, Jan needs to use a variant of the *aet* command.

```
jan% aet -bl
aegis: sh /u/jan/example.002/test/00/t0002a.sh
usage: example
FAILED
aegis: project "example": change 2: test "test/00/t0002a.sh" on
        baseline failed (as it should)
aegis: project "example": change 2: passed 1 test
jan%
```

Running the regression tests is also a good idea

```
jan% aet -reg
aegis: logging to "/u/pat/example.002/aegis.log"
aegis: sh /projects/example/baseline/test/00/t0001a.sh
aegis: project "example": change 2: test "test/00/t0001a.sh"
        passed
aegis: project "example": change 2: passed 1 test
jan%
```

Now aegis will be satisfied

```
jan% aede
aegis: sh /usr/local/lib/aegis/de.sh example 2 jan
aegis: project "example": change 2: development completed
jan%
```

Like Pat in the change before, Jan will receive email that this change passed review, and later that it passed integration.

3.1.3. The Third and Fourth Changes

This section will show two people performing two changes, one each. The twist is that they have a file in common.

First Sam looks for a change to work on and starts, like this:

```
sam% aedb -l
Project "example"
List of Changes

Change  State           Description
------- -------         -------------
   3    awaiting_       add powers
        development
   4    awaiting_       add variables
        development
sam% aedb 3
aegis: project "example": change 3: development directory "/u/
        sam/example.003"
aegis: project "example": change 3: user "sam" has begun
        development
sam% aecd
aegis: project "example": change 3: /u/sam/example.003
sam%
```

A little sniffing around reveals that only the *gram.y* grammar file needs to be altered, so it is copied into the change.

```
sam% aecp gram.y
aegis: project "example": change 3: file "gram.y" copied
sam%
```

The grammar file is changed to look like this:

```
%token DOUBLE
%token NAME
%union
{
        double  lv_double;
        int     lv_int;
};

%type <lv_double> DOUBLE expr
%type <lv_int> NAME
%left '+' '-'
%left '*' '/'
%right '^'
%right UNARY

%%
example
        : /* empty */
        | example command '0
                { yyerrflag = 0; fflush(stderr); fflush(stdout); }
        ;

command
        : expr
                { printf("%g0, $1); }
        | error
        ;

expr
        : DOUBLE
        | '(' expr ')'
                { $$ = $2; }
        | '-' expr
                %prec UNARY
                { $$ = -$2; }
        | expr '^' expr
                { $$ = pow($1, $3); }
        | expr '*' expr
                { $$ = $1 * $3; }
        | expr '/' expr
                { $$ = $1 / $3; }
        | expr '+' expr
                { $$ = $1 + $3; }
        | expr '-' expr
                { $$ = $1 - $3; }
        ;
```

The changes are very small. Sam checks to make sure using the difference command:

```
sam% aed
aegis: logging to "/u/sam/example.003/aegis.log"
aegis: set +e; diff -c /projects/example/baseline/gram.y /u/sam/
        example.003/gram.y > /u/sam/example.003/gram.y,D; test $?
        -eq 0 -o $? -eq 1
aegis: project "example": change 3: difference complete
sam% aedmore
...examines the file...
sam%
```

The difference file looks like this

```
*** /projects/example/baseline/gram.y
--- /u/sam/example.003/gram.y
***************
*** 1,5 ****
--- 1,6 ----
  %{
  #include <stdio.h>
+ #include <math.h>
  %}
  %token DOUBLE
  %token NAME

***************
*** 13,18 ****
--- 14,20 ----
  %type <lv_int> NAME
  %left '+' '-'
  %left '*' '/'
+ %right '^'
  %right UNARY
  %%
  example

***************
*** 32,37 ****
--- 34,41 ----
        | '-' expr
                %prec UNARY
                { $$ = -$2; }
+       | expr '^' expr
+               { $$ = pow($1, $3); }
        | expr '*' expr
                { $$ = $1 * $3; }
        | expr '/' expr
```

These are the differences Sam expected to see.

At this point Sam creates a test. All good software developers create the tests first, don't they?

```
sam% aent
aegis: project "example": change 3: file "test/00/t0003a.sh" new
       test
sam%
```

The test is created empty, and Sam edit it to look like this:

```
:
here=`pwd`
if test $? -ne 0 ; then exit 1; fi
tmp=/tmp/$$
mkdir $tmp
if test $? -ne 0 ; then exit 1; fi
cd $tmp
if test $? -ne 0 ; then exit 1; fi

fail()
{
        echo FAILED 1>&2
        cd $here
        chmod u+w `find $tmp -type d -print`
        rm -rf $tmp
        exit 1
}

pass()
{
        cd $here
        chmod u+w `find $tmp -type d -print`
        rm -rf $tmp
        exit 0
}
trap "fail" 1 2 3 15

cat > test.in << 'end'
5.3 ^ 0
4 ^ 0.5
27 ^ (1/3)
end
if test $? -ne 0 ; then fail; fi

cat > test.ok << 'end'
1
2
3
end
if test $? -ne 0 ; then fail; fi

$here/example test.in < /dev/null > test.out 2>&1
if test $? -ne 0 ; then fail; fi

diff test.ok test.out
if test $? -ne 0 ; then fail; fi

$here/example test.in test.out.2 < /dev/null
if test $? -ne 0 ; then fail; fi

diff test.ok test.out.2
if test $? -ne 0 ; then fail; fi

# it probably worked
pass
```

Everything is ready. Now the change can be built and tested, just like the earlier changes.

```
sam% aeb
aegis: logging to "/u/sam/example.003/aegis.log"
aegis: project "example": change 3: development build started
aegis: cook -b /projects/example/baseline/Howto.cook
        project=example change=3 version=1.0.C003 -nl
cook: yacc -d gram.y
cook: mv y.tab.c gram.c
cook: mv y.tab.h gram.h
cook: cc -I. -I/projects/example/baseline -O -c gram.c
cook: cc -I. -I/projects/example/baseline -O -c /projects/
        example/baseline/lex.c
cook: cc -o example gram.o lex.o /projects/example/baseline/
        main.o -ll -ly -lm
aegis: project "example": change 3: development build complete
sam%
```

Notice how the yacc run produces a *gram.h* which logically invalidates the *lex.o* in the baseline, and so the *lex.c* file in the baseline is recompiled, using the *gram.h* include file from the development directory, leaving a new *lex.o* in the development directory. This is the reason for the use of

```
#include <filename>
```

directives, rather then the double quote form.

Now the change is tested.

```
sam% aet
aegis: logging to "/u/sam/example.003/aegis.log"
aegis: sh /u/sam/example.003/test/00/t0003a.sh
aegis: project "example": change 3: test "test/00/t0003a.sh"
        passed
aegis: project "example": change 3: passed 1 test
sam%
```

The change must also be tested against the baseline, and fail. Sam knows this, and does it here.

```
sam% aet -bl
aegis: logging to "/u/sam/example.003/aegis.log"
aegis: sh /u/sam/example.003/test/00/t0003a.sh
1,3c1,6
< 1
< 2
< 3
---
> syntax error
> 5.3
> syntax error
> 4
> syntax error
> 27
FAILED
aegis: project "example": change 3: test "test/00/t0003a.sh" on
        baseline failed (as it should)
aegis: project "example": change 3: passed 1 test
sam%
```

Running the regression tests is also a good idea.

```
sam% aet -reg
aegis: logging to "/u/sam/example.003/aegis.log"
aegis: sh /projects/example/baseline/test/00/t0001a.sh
aegis: project "example": change 3: test "test/00/t0001a.sh"
        passed
aegis: sh /projects/example/baseline/test/00/t0002a.sh
aegis: project "example": change 3: test "test/00/t0002a.sh"
        passed
aegis: project "example": change 3: passed 2 tests
sam%
```

A this point Sam has just enough time to get to the lunchtime aerobics class in the staff common room.

Earlier the same day, Pat arrived for work a little after Sam, and also looked for a change to work on.

```
pat% aedb -l
Project "example"
List of Changes

Change  State           Description
------- -------         -------------
   4    awaiting_       add variables
        development
pat%
```

With such a wide choice, Pat selected change 4.

```
pat% aedb 4
aegis: project "example": change 4: development directory "/u/
        pat/example.004"
aegis: project "example": change 4: user "pat" has begun
        development
pat% aecd
aegis: project "example": change 4: /u/pat/example.004
pat%
```

To get more information about the change, Pat then uses the "change details" listing:

```
pat% ael cd
Project "example", Change 4
Change Details

NAME
        Project "example", Change 4.

SUMMARY
        add variables

DESCRIPTION
        Enhance the grammar to allow variables. Only single
        letter variable names are required.

CAUSE
        This change was caused by internal_enhancement.

STATE
        This change is in 'being_developed' state.

FILES
        This change has no files.
```

```
HISTORY
        What            When            Who     Comment
        ------          ------          -----   ---------
        new_change      Mon Dec 14      alex
                        13:08:52 1992
        develop_begin   Tue Dec 15      pat
                        13:38:26 1992
pat%
```

To add the variables the grammar needs to be extended to understand them, and a new file for remembering and recalling the values of the variables needs to be added.

```
pat% aecp gram.y
aegis: project "example": change 4: file "gram.y" copied
pat% aenf var.c
aegis: project "example": change 4: file "var.c" added
pat%
```

Notice how aegis raises no objection to both Jan and Pat having a copy of the *gram.y* file. Resolving this contention is the subject of this section.

Pat now edits the grammar file.

```
pat% vi gram.y
...edit the file...
pat% aed
aegis: logging to "/u/pat/example.004/aegis.log"
aegis: set +e; diff -c /projects/example/baseline/gram.y /u/pat/
        example.004/gram.y > /u/pat/example.004/gram.y,D; test $?
        -eq 0 -o $? -eq 1
aegis: project "example": change 4: difference complete
pat%
```

The difference file looks like this

```
...
```

The new *var.c* file was created empty by aegis, and Pat edits it to look like this:

```
static double memory[26];

void
assign(name, value)
        int     name;
        double  value;
{
        memory[name] = value;
}

double
recall(name)
        int     name;
{
        return memory[name];
}
```

Little remains except to build the change.

```
pat% aeb
aegis: logging to "/u/pat/example.004/aegis.log"
aegis: cook -b /tmp/8508/example.proj/baseline/Howto.cook
        project=example change=4 version=1.0.C004 -nl
cook: yacc -d gram.y
cook: mv y.tab.c gram.c
cook: mv y.tab.h gram.h
cook: cc -I. -I/projects/example/baseline -O -c gram.c
cook: cc -I. -I/projects/example/baseline -O -c /projects/
        example/baseline/lex.c
cook: cc -I. -I/projects/example/baseline -O -c var.c
cook: cc -o example gram.o lex.o /projects/example/baseline/
        main.o var.o -ll -ly -lm
aegis: project "example": change 4: development build complete
pat%
```

A new test for the new functionality is required.

```
:
here=`pwd`
if test $? -ne 0 ; then exit 1; fi
tmp=/tmp/$$
mkdir $tmp
if test $? -ne 0 ; then exit 1; fi
cd $tmp
if test $? -ne 0 ; then exit 1; fi

fail()
{
        echo FAILED 1>&2
        cd $here
        chmod u+w `find $tmp -type d -print`
        rm -rf $tmp
        exit 1
}
pass()
{
        cd $here
        chmod u+w `find $tmp -type d -print`
        rm -rf $tmp
        exit 0
}
trap "fail" 1 2 3 15

cat > test.in << 'end'
a = 1
a + 1
c = a * 40 + 5
c / (a + 4)
end
if test $? -ne 0 ; then fail; fi

cat > test.ok << 'end'
2
9
end
if test $? -ne 0 ; then fail; fi

$here/example test.in < /dev/null > test.out 2>&1
if test $? -ne 0 ; then fail; fi

diff test.ok test.out
if test $? -ne 0 ; then fail; fi
```

```
$here/example test.in test.out.2 < /dev/null
if test $? -ne 0 ; then fail; fi

diff test.ok test.out.2
if test $? -ne 0 ; then fail; fi

# it probably worked
pass
```

The new files are then differenced:

```
pat% aed
aegis: logging to "/u/pat/example.004/aegis.log"
aegis: set +e; diff -c /projects/example/baseline/gram.y /u/pat/
        example.004/gram.y > /u/pat/example.004/gram.y,D; test $?
        -eq 0 -o $? -eq 1
aegis: set +e; diff -c /dev/null /u/pat/example.004/test/00/
        t0004a.sh > /u/pat/example.004/test/00/t0004a.sh,D; test
        $? -eq 0 -o $? -eq 1
aegis: set +e; diff -c /dev/null /u/pat/example.004/var.c > /u/
        pat/example.004/var.c,D; test $? -eq 0 -o $? -eq 1
aegis: project "example": change 4: difference complete
pat%
```

Notice how the difference for the *gram.y* file is still current, and so is not run again.

The change is tested.

```
pat% aet
aegis: logging to "/u/pat/example.004/aegis.log"
aegis: sh /u/pat/example.004/test/00/t0001a.sh
aegis: project "example": change 4: test "test/00/t0004a.sh"
        passed
aegis: project "example": change 4: passed 2 tests
pat%
```

The change is tested against the baseline.

```
pat% aet -bl
aegis: logging to "/u/pat/example.004/aegis.log"
aegis: sh /u/pat/example.004/test/00/t0001a.sh
1,2c1,4
< 2
< 9
---
> syntax error
> syntax error
> syntax error
> syntax error
FAILED
aegis: project "example": change 4: test "test/00/t0004a.sh" on
        baseline failed (as it should)
pat%
```

And the regression tests

```
pat% aet -reg
aegis: logging to "/u/pat/example.004/aegis.log"
aegis: sh /projects/example/baseline/test/00/t0001a.sh
aegis: project "example": change 4: test "test/00/t0001a.sh"
        passed
aegis: sh /projects/example/baseline/test/00/t0002a.sh
aegis: project "example": change 4: test "test/00/t0002a.sh"
        passed
aegis: project "example": change 4: passed 2 tests
pat%
```

Note how test 3 has not been run, in any form of testing. This is because test 3 is part of another change, and is not yet integrated with the baseline.

All is finished for this change,

```
pat% aede
aegis: sh /usr/local/lib/aegis/de.sh example 4 pat
aegis: project "example": change 4: development completed
pat%
```

Anxious to get this change into the baseline, Pat now wanders down the hall in search of a reviewer, but more of that in the next section.

Some time later, Jan returns from aerobics feeling much improved. All that is required for change 3 is to do develop end, or is it?

```
jan% aede
aegis: project "example": change 3: file "gram.y" in baseline
        has changed since last 'aegis -DIFFerence' command
jan%
```

A little sleuthing on Jan's part with the aegis list command will reveal how this came about. The way to resolve this problem is with the difference command.

```
jan% aed
aegis: logging to "/u/pat/example.003/aegis.log"
aegis: co -u'1.1' -p /projects/example/history/gram.y,v > /tmp/
        aegis.14594
/projects/example/history/gram.y,v  -->  stdout revision 1.1 (unlocked)
aegis: (diff3 -e /projects/example/baseline/gram.y /tmp/
        aegis.14594 /u/jan/example.003/gram.y | sed -e '/^w$/d'
        -e '/^q$/d';      echo '1,$p' ) | ed - /projects/example/
        baseline/gram.y > /u/jan/example.003/gram.y,D
aegis: project "example": change 3: difference complete
aegis: project "example": change 3: file "gram.y" was out of
        date, see "gram.y,D" for details
aegis: new 'aegis -Build' required
jan%
```

This was caused by the conflict between change 4, which is now integrated, and change 3; both of which are editing the *gram.y* file. Jan examines the *gram.y,D* file, and discovers that it contains an accurate merge of the edit done by change 4 and the edits for this change. The difference file looks like this:

```
%{
#include <stdio.h>
#include <math.h>
%}
%token DOUBLE
%token NAME
%union
{
        double  lv_double;
        int     lv_int;
};

%type <lv_double> DOUBLE expr
%type <lv_int> NAME
%left '+' '-'
%left '*' '/'
%right '^'
%right UNARY

%%
example
        : /* empty */
        | example command '\n'
                { yyerrflag = 0; fflush(stderr); fflush(stdout); }
        ;

command
        : expr
                { printf("%g0, $1); }
        | NAME '=' expr
                { assign($1, $3); }
        | error
        ;

expr
        : DOUBLE
        | NAME
                { extern double recall(); $$ = recall($1); }
        | '(' expr ')'
                { $$ = $2; }
        | '-' expr
                %prec UNARY
                { $$ = -$2; }
        | expr '^' expr
                { $$ = pow($1, $3); }
        | expr '*' expr
                { $$ = $1 * $3; }
        | expr '/' expr
                { $$ = $1 / $3; }
        | expr '+' expr
                { $$ = $1 + $3; }
        | expr '-' expr
                { $$ = $1 - $3; }
        ;
```

This is because most such conflicts are actually working on logically separate portions of the file. Two different areas of the grammar in this case. In practice, there is rarely a real conflict, and it is usually small enough to detect fairly quickly. Notice that aegis did not automatically put the merge in place of your edited file, for just this reason.

Jan simply copies the difference file on top of the original, and rebuilds:

```
jan% mv gram.y,D gram.y
jan% aeb
aegis: logging to "/u/jan/example.003/aegis.log"
aegis: project "example": change 3: development build started
aegis: cook -b /tmp/13906/example.proj/baseline/Howto.cook
        project=example change=3 version=1.0.C003 -nl
cook: rm gram.c
cook: rm gram.h
cook: yacc -d gram.y
cook: mv y.tab.c gram.c
cook: mv y.tab.h gram.h
cook: rm gram.o
cook: cc -I. -I/projects/example/baseline -O -c gram.c
cook: rm lex.o
cook: cc -I. -I/projects/example/baseline -O -c /projects/
        example/baseline/lex.c
cook: rm example
cook: cc -o example gram.o lex.o /projects/example/baseline/
        main.o /projects/example/baseline/var.o -ll -ly -lm
aegis: project "example": change 3: development build complete
jan%
```

Notice how the list of object files linked has also adapted to the addition of another file in the baseline, without any extra work by Jan.

All that remains is to test the change again.

```
jan% aet
aegis: /bin/sh /tmp/13906/example.chan.3/test/00/t0003a.sh
aegis: project "example": change 3: test "test/00/t0003a.sh"
        passed
aegis: project "example": change 3: passed 1 test
jan%
```

And test against the baseline,

```
jan% aet -bl
aegis: /bin/sh /tmp/13906/example.chan.3/test/00/t0003a.sh
1,3c1,6
< 1
< 2
< 3
---
> syntax error
> 5.3
> syntax error
> 4
> syntax error
> 27
FAILED
aegis: project "example": change 3: test "test/00/t0003a.sh" on
        baseline failed (as it should)
aegis: project "example": change 3: passed 1 test
jan%
```

Perform the regression tests, too. This is important for a merged change, to make sure you didn't break the functionality of the code you merged with.

```
jan% aet -reg
aegis: logging to "/u/jan/example.003/aegis.log"
aegis: /bin/sh /projects/example/baseline/test/00/
        t0001a.sh
aegis: project "example": change 3: test "test/00/t0001a.sh"
        passed
aegis: /bin/sh /projects/example/baseline/test/00/
        t0002a.sh
aegis: project "example": change 3: test "test/00/t0002a.sh"
        passed
aegis: /bin/sh /projects/example/baseline/test/00/
        t0004a.sh
aegis: project "example": change 3: test "test/00/t0004a.sh"
        passed
aegis: project "example": change 3: passed 3 tests
jan%
```

All done, or are we?

```
jan% aede
aegis: project "example": change 3: no current 'aegis -Diff'
        registration
jan%
```

The difference we did earlier, which revealed that we were out of date, does not show the differences since the two changes were merged, and possibly further edited.

```
jan% aed
aegis: logging to "/u/jan/example.003/aegis.log"
aegis: set +e; diff /projects/example/baseline/gram.y /u/pat/
        example.003/gram.y > /u/pat/example.003/gram.y,D; test $? -le 1
aegis: project "example": change 3: difference complete
jan%
```

This time everything will run smoothly,

```
jan% aede
aegis: project "example": change 3: development completed
jan%
```

Some time soon Jan will receive email that this change passed review, and later that it passed integration.

Within the scope of a limited example, you have seen most of what aegis can do. To get a true feeling for the program you need to try it in a similarly simple case. You could even try doing this example manually.

3.1.4. Developer Command Summary

Only a few of the aegis commands available to developers have been used in the example. The following table (very tersely) describes the aegis commands most useful to developers.

Command	Description
aeb	Build
aeca	edit Change Attributes
aecd	Change Directory
aecp	Copy File
aecpu	Copy File Undo
aed	Difference
aedb	Develop Begin
aedbu	Develop Begin Undo
aede	Develop End
aedeu	Develop End Undo
ael	List Stuff
aenf	New File
aenfu	New File Undo
aent	New Test
aentu	New Test Undo
aerm	Remove File
aermu	Remove File Undo
aet	Test

You will want to read the manual entries for all of these commands. Note that all aegis commands have a *−Help* option, which will give a result very similar to the corresponding *man* (1) output. Most aegis commands also have a *−List* option, which usually lists interesting context sensitive information.

3.2. The Reviewer

The role of a reviewer is to check another user's work. You are helped in this by aegis, because changes can never reach the *being reviewed* state without several preconditions:

• The change is known to build. You know that it compiled successfully, so there is no need to search for syntax errors.

• The change has tests, and those tests have been run, and have passed.

This information allows you to concentrate on implementation issues, completeness issues, and local standards issues.

To help the reviewer, a set of "command D" files is available in the change development directory. Every file which is to be added to the baseline, removed from the baseline, or changed in some way, has a corresponding "comma D" file.

3.2.1. The First Change

Robyn finds out what changes are available for review by asking aegis:

```
robyn% aerpass -l -p example

Project "example"
List of Changes

Change  State           Description
------- -------         -------------
   1    being_reviewed  Place under aegis
robyn%
```

Any of the above changes could be reviewed, Robyn chooses the first.

```
robyn% aecd -p example -c 1
aegis: project "example": change 1: /u/pat/example.001
robyn% aedmore
...examines each file...
robyn%
```

The *aedmore* command walks the development directory tree to find all of the "comma D" files, and displays them using There is a corresponding *aedless* for those who prefer the command.

Once the change has been reviewed and found acceptable, it is passed:

```
robyn% aerpass example 1
aegis: sh /usr/local/lib/aegis/rp.sh example 1 pat robyn
aegis: project "example": change 1: passed review
robyn%
```

Some time soon Isa will notice the email notification and commence integration of the change.

3.2.2. The Second Change

Most reviews have the same pattern as the first.

```
robyn% aerpass -l -p example

Project "example"
List of Changes

Change  State           Description
------- -------         -------------
   2    being_reviewed  file names on command line
robyn%
```

Always change directory to the change's development directory, otherwise you will not be able to review the files.

```
robyn% aecd -p example -c 2
aegis: project "example": change 2: /u/jan/example.002
robyn%
```

Another useful way of finding out about a change is the "list change details" command, viz:

```
robyn% ael cd -p example -c 2

Project "example", Change 2
Change Details

NAME
        Project "example", Change 2.

SUMMARY
        file names on command line

DESCRIPTION
        Optional input and output files may be specified on
        the command line.

CAUSE
        This change was caused by internal_bug.

STATE
        This change is in 'being_integrated' state.

FILES
        Type    Action  Edit    File Name
        ------- ------- ------- -----------
        source  modify  1.1     main.c
        test    create          test/00/t0002a.sh

HISTORY
        What            When            Who     Comment
        ------          ------          -----   ---------
        new_change      Fri Dec 11      alex
                        14:55:06 1992
        develop_begin   Mon Dec 14      jan
                        09:07:08 1992
        develop_end     Mon Dec 14      jan
                        11:43:23 1992
robyn%
```

Once Robyn knows what the change is meant to be doing, the files are then examined:

```
robyn% aedmore
...examines each file...
robyn%
```

Once the change is found to be acceptable, it is passed:

```
robyn% aerpass example 2
aegis: sh /usr/local/lib/aegis/rp.sh example 2 jan robyn
aegis: project "example": change 2: passed review
robyn%
```

Some time soon Isa will notice the email notification and commence integration of the change.

The reviews of the third and fourth changes will not be given here, because they are almost identical to the other changes. If you want to know how to fail a review, see the manual entry.

3.2.3. Reviewer Command Summary

Only a few of the aegis commands available to reviewers have been used in this example. The following table (very tersely) describes the aegis commands most useful to reviewers.

Command	Description
aecd	Change Directory
aerpass	Review Pass
aerpu	Review Pass Undo
aerfail	Review Fail
ael	List Stuff

You will want to read the manual entries for all of these commands. Note that all aegis commands have a *−Help* option, which will give a result very similar to the corresponding *man*(1) output. Most aegis commands also have a *−List* option, which usually lists interesting context sensitive information.

3.3. The Integrator

This section shows what the integrator must do for each of the changes shown to date. The integrator does not have the ability to alter anything in the change; if a change being integrated is defective, it is simply failed back to the developer. This documented example has no such failures, in order to keep it manageably small.

3.3.1. The First Change

The first change of a project is often the trickiest, and the integrator is the last to know. This example goes smoothly, and you may want to consider using the example project as a template.

The integrator for this example project is Isa. Isa knows there is a change ready for integration from the notification which arrived by email.

```
isa% aeib -l -p example

Project "example"
List of Changes

Change  State           Description
------- -------         -------------
   1    awaiting_       Place under aegis
        integration
isa% aeib example 1
aegis: project "example": change 1: link baseline to integration
        directory
aegis: project "example": change 1: apply change to integration
        directory
aegis: project "example": change 1: integration has begun
isa%
```

The integrator must rebuild and retest each change. This ensures that it was no quirk of the developer's environment which resulted in the success at the development stage.

```
isa% aeb
aegis: logging to "/projects/example/delta.001/aegis.log"
aegis: project "example": change 1: integration build started
aegis: cook -b Howto.cook project=example change=1
        version=1.0.D001 -nl
cook: yacc -d gram.y
cook: mv y.tab.c gram.c
cook: mv y.tab.h gram.h
cook: cc -I. -O -c gram.c
cook: lex lex.l
cook: mv lex.yy.c lex.c
cook: cc -I. -O -c lex.c
cook: cc -I. -O -c main.c
cook: cc -o example gram.o lex.o main.o -ll -ly
aegis: project "example": change 1: integration build complete
isa%
```

Notice how the above build differed from the builds that were done while in the *being developed* state; the extra baseline include is gone. This is because the integration directory will shortly be the new baseline, and must be entirely internally consistent and self-sufficient.

You are probably wondering why this isn't all rolled into the one aegis command. It is not because there may be some manual process to be performed after the build and before the test. This may be making a command set-uid-root (as in the case of aegis) or it may require some tinkering with the local oracle or ingress database. Instructions for the integrator may be placed in the description field of the change attributes.

The change is now re-tested:

```
isa% aet
aegis: logging to "/projects/example/delta.001/aegis.log"
aegis: sh /project/example/delta.001/test/00/t0001a.sh
aegis: project "example": change 1: test "test/00/t0001a.sh"
        passed
aegis: project "example": change 1: passed 1 test
isa%
```

The change builds and tests. Once Isa is happy with the change, perhaps after browsing the files, Isa then passes the integration, causing the history files to be updated and the integration directory becomes the baseline.

```
isa% aeipass
aegis: logging to "/projects/example/delta.001/aegis.log"
aegis: ci -u -m/dev/null -t/dev/null /projects/example/delta.001/
        Howto.cook /projects/example/history/Howto.cook,v;
        rcs -U /projects/example/history/Howto.cook,v
/projects/example/history/Howto.cook,v  <--
        /projects/example/delta.001/Howto.cook
initial revision: 1.1
done
RCS file: /projects/example/history/Howto.cook,v
done
aegis: rlog -r /projects/example/history/Howto.cook,v | awk
        '/^head:/ {print $2}' > /tmp/aegis.15309
...lots of similar RCS output...
aegis: project "example": change 1: remove development directory
aegis: sh /usr/local/lib/aegis/ip.sh example 1 pat robyn isa
aegis: project "example": change 1: integrate pass
isa%
```

All of the staff involved, will receive email to say that the change has been integrated. This notification is a shell script, so USENET could be usefully used instead.

You should note that the development directory has been deleted. It is expected that each development directory will only contain files necessary to develop the change. You should keep "precious" files somewhere else.

3.3.2. The Other Changes

There is no difference to integrating any of the later changes. The integration process is very simple, as it is a cut-down version of what the developer does, without all the complexity.

Your project may elect to have the integrator also monitor the quality of the reviews. An answer to "who will watch the watchers" if you like.

It is also a good idea to rotate people out of the integrator position after a few weeks in a busy project, this is a very stressful position. The position of integrator gives a unique perspective to software quality, but the person also needs to be able to say "NO!" when a cruddy change comes along.

3.3.3. Integrator Command Summary

Only a few of the aegis commands available to integrators have been used in this example. The following table (very tersely) describes the aegis commands most useful to integrators.

Command	Description
aeb	Build
aecd	Change Directory
aeib	Integrate Begin
aeibu	Integrate Begin Undo
aeifail	Integrate Fail
ael	List Stuff
aet	Test
aeupass	Integrate Pass

You will want to read the manual entries for all of these commands. Note that all aegis commands have a *−Help* option, which will give a result very similar to the corresponding *man*(1) output. Most aegis commands also have a *−List* option, which usually lists interesting context sensitive information.

3.4. The Administrator

The previous discussion of developers, reviewers and integrators has covered many aspects of the production of software using the aegis program. The administrator has responsibility for everything they don't, but there is very little left.

These responsibilities include:

• access control: The administrator adds and removes all categories of user, including administrators. This is on a per-project basis, and has nothing to do with UNIX user administration. This simply nominates which users may do what.

• change creation: The administrator adds (and sometimes removes) changes to the system. At later stages, developers may alter some attributes of the change, such as the description, to say what they fixed.

• project creation: The aegis program does not limit who may create projects, but when a project is created the user who created the project is set to be the administrator of that project.

All of these things will be examined

3.4.1. The First Change

Many things need to happen before development can begin on the first change; the project must be created, the staff but be given access permissions, the change must be created.

```
alex% aenpr example -dir /projects/example
aegis: project "example": project directory "/projects/example"
aegis: project "example": created
alex%
```

Once the project has been created, the project attributes are set. Alex will set the desired project attributes using the **-Edit** option of the **aepa** command. This will invoke an editor (*vi*(1) by default) to edit the project attributes. Alex edits them to look like this:

```
description = "Aegis Documentation Example Project";
developer_may_review = false;
developer_may_integrate = false;
reviewer_may_integrate = false;
```

The project attributes are set as follows:

```
alex% aepa -edit -p example
...edit as above...
aegis: project "example": attributes changed
alex% ael p
List of Projects

Project Directory              Description
------- -----------            -------------
example /projects/example      Aegis Documentation Example
                               Project
alex%
```

The various staff must be added to the project. Developers are the only staff who may actually edit files.

```
alex% aend pat jan sam -p example
aegis: project "example": user "pat" is now a developer
aegis: project "example": user "jan" is now a developer
aegis: project "example": user "sam" is now a developer
alex%
```

Reviewers may veto a change. There may be overlap between the various categories, as show here for Jan:

```
alex% aenr robyn jan -p example
aegis: project "example": user "robyn" is now a reviewer
aegis: project "example": user "jan" is now a reviewer
alex%
```

The next role we need to fill is an integrator.

```
alex% aeni isa -p example
aegis: project "example": user "isa" is now an integrator
alex%
```

Once the staff have been given access, Alex creates the first change. The **-Edit** option of the **annc** command is used, to create the attributes of the change. They are edited to look like this:

```
brief_description = "Create initial skeleton.";
description = "A simple calculator using native \
floating point precision.  \
The four basic arithmetic operators to be provided, \
using conventional infix notation.  \
Parentheses and negation also required.";
cause = internal_enhancement;
```

The change is created as follows:

```
alex% aenc -edit -p example
...edit as above...
aegis: project "example": change 1: created
alex%
```

At this point, Alex walks down the hall to Pat's office, to ask Pat to develop the first change. Pat has had some practice using aegis, and can be relied on to do the rest of the project configuration speedily.

3.4.2. The Second Change

Some time later, Alex patiently sits through the whining and grumbling of an especially pedantic user. The following change description is duly entered:

```
brief_description = "file names on command line";
description = "Optional input and output files may be \
specified on the command line.";
cause = internal_bug;
```

The pedantic user wanted to be able to name files on the command line, rather than use I/O redirection. Also, having a bug in this example is useful. The change is created as follows:

```
alex% aenc -edit -p example
...edit as above...
aegis: project "example": change 2: created
alex%
```

At some point a developer will notice this change and start work on it.

3.4.3. The Third Change

Other features are required for the calculator, and also for this example. The second change adds exponentiation to the calculator, and is described as follows:

```
brief_description = "add powers";
description = "Enhance the grammar to allow exponentiation.  \
No error checking required.";
cause = internal_enhancement;
```

The change is created as follows:

```
alex% aenc -edit -p example
...edit as above...
aegis: project "example": change 3: created
alex%
```

At some point a developer will notice, and this change will be worked on.

3.4.4. The Fourth Change

A fourth change, this time adding variables to the calculator is added.

```
brief_description = "add variables";
description = "Enhance the grammar to allow variables.  \
Only single letter variable names are required.";
cause = internal_enhancement;
```

The change is created as follows:

```
alex% aenc -edit -p example
...edit as above...
aegis: project "example": change 4: created
alex%
```

At some point a developer will notice, and this change will be worked on.

3.4.5. Administrator Command Summary

Only a few of the aegis commands available to administrators have been used in this example. The following table lists the aegis commands most useful to administrators.

Command	Description
aeca	edit Change Attributes
ael	List Stuff
aena	New Administrator
aenc	New Change
aencu	New Change Undo
aend	New Developer
aeni	New Integrator
aenpr	New Project
aenrv	New Reviewer
aepa	edit Project Attributes
aera	Remove Administrator
aerd	Remove Developer
aeri	Remove Integrator
aermpr	Remove Project
aerrv	Remove Reviewer

You will want to read the manual entries for all of these commands. Note that all aegis commands have a *−Help* option, which will give a result very similar to the corresponding *man*(1) output. Most aegis commands also have a *−List* option, which usually lists interesting context sensitive information.

3.5. What to do Next

This chapter has given an overview of what using aegis feels like. As a next step in getting to know aegis, it would be a good idea if you created a project and went through this same exercise; you could use this exact example, or you could use a similar small project. This idea simply to run through many of the same steps as in the example. Typos and other natural events will ensure that you come across a number of situations not directly covered by this chapter.

If you have not already done do, a printed copy of the section 1 and 5 manual entries will be invaluable. If you don't want to use that many trees, they will be available on-line, by using the "-Help" option of the appropriate command variant. Try:

```
% aedb -help
...manual entry...
%
```

Note that this example has not demonstrated all of the available functionality. One item of particular interest is that tests, like any other source file, may be copied into a change and modified, or even deleted, just like any other source file.

4. The History Tool

The aegis program is decoupled from the history mechanism. This allows you to use the history mechanism of your choice, SCCS or RCS, for example. You may even wish to write your own.

The intention of this is that you may use a history mechanism which suits your special needs, or the one that comes free with your flavour of UNIX operating system.

The aegis program uses the history mechanism for file *history* and so does not require many of the features of SCCS or RCS. This simplistic approach can sometimes make the interface to these utilities look a little strange.

4.1. Interfacing

The history mechanism interface is found in the project configuration file called *config* , relative to the root of the baseline. It is a source file and subject to the same controls as any other source file. The history fields of the file are described as follows

4.1.1. history_create_command

This field is used to create a new history. The command is always executed as the project owner. Substitutions available for the command string are:

${Input}
: absolute path of source file

${History}
: absolute path of history file

In addition, all substitutions described in *aesub*(5) are available.

4.1.2. history_get_command

This field is used to get a file from history. The command may be executed by developers. Substitutions available for the command string are:

${History}
: absolute path of history file

${Edit}
: edit number, as given by the history_get_-command.

${Output}
: absolute path of destination file

In addition, all substitutions described in *aesub*(5) are available.

4.1.3. history_put_command

This field is used to add a new change to the history. The command is always executed as the project owner. Substitutions available for the command string are:

${Input}
: absolute path of source file

${History}
: absolute path of history file

In addition, all substitutions described in *aesub*(5) are available.

4.1.4. history_query_command

This field is used to query the topmost edit of a history file. Result to be printed on the standard output. This command may be executed by developers. Substitutions available for the command string are:

${History}
: absolute path of history file

In addition, all substitutions described in *aesub*(5) are available.

4.2. Using SCCS

The entries for the commands are listed below. SCCS uses a slightly different model than aegis wants, so some maneuvering is required. The command strings in this section assume that the SCCS commands *admin* and *get* and *delta* are in the command search PATH, but you may like to hard-wire the paths, or set PATH at the start of each. You should also note that the strings are always handed to the Bourne shell to be executed, and are set to exit with an error immediately a sub-command fails.

4.2.1. history_create_command

This command is used to create a new project history. The command is always executed as the project owner.

The following substitutions are available:

${Input}
: absolute path of the source file

${History}
: absolute path of the history file

The entry in the *config* file looks like this:

```
history_create_command =
  "admin -n -i$i -y \
    ${d $h}/s.${b $h}; \
  admin -di ${d $h}/s.${b $h}; \
  get -e -t -p -s \
    ${d $h}/s.${b $h} \
    > /dev/null";
```

Note that the "get -e" is necessary to put the s.file into the edit state, but the result of the get can be discarded, because the "admin -i" did not remove the file.

4.2.2. history_get_command

This command is used to get a specific edit back from history. The command may be executed by developers.

The following substitutions are available:

${History}
: absolute path of the history file

${Edit}
: edit number, as given by history_query_command

${Output}
: absolute path of the destination file

The entry in the *config* file looks like this:

```
history_get_command =
  "get -r'$e' -s -p -k \
    ${d $h}/s.${b $h} > $o";
```

4.2.3. history_put_command

This command is used to add a new "top-most" entry to the history file. This command is always executed as the project owner.

The following substitutions are available:

${Input}
: absolute path of source file

${History}
: absolute path of history file

The entry in the *config* file looks like this:

```
history_put_command =
  "cd ${d $i}; \
  delta -s -y ${d $h}/s.${b $h}; \
  get -e -t -p -s \
    ${d $h}/s.${b $h} > $i";
```

Note that the SCCS file is left in the edit state, and that the source file is left in the baseline.

4.2.4. history_query_command

This command is used to query what the history mechanism calls the top-most edit of a history file. The result may be any arbitrary string, it need not be anything like a number, just so long as it uniquely identifies the edit for use by the *history_get_command* at a later date. The edit number is to be printed on the standard output. This command may be executed by developers.

The following substitutions are available:

${History}
: absolute path of the history file

The entry in the *config* file looks like this:

```
history_query_command =
  "get -t -g ${d $h}/s.${b $h} 2>&1";
```

Note that "get" reports the edit number on stderr.

4.2.5. Templates

The *lib/config.example/sccs* file in the Aegis distribution contains all of the above commands, so that you may readily insert them into your project *config* file.

4.3. Using RCS

The entries for the commands are listed below. RCS uses a slightly different model than aegis wants, so some maneuvering is required. The command strings in this section assume that the RCS commands *ci* and *co* and *rcs* and *rlog* are in the command search PATH, but you may like to hard-wire the paths, or set PATH at the start of each. You should also note that the strings are always handed to the Bourne shell to be executed, and are set to exit with an error immediately a sub-command fails.

In these commands, the RCS file is kept unlocked, since only the owner will be checking changes in. The RCS functionality for coordinating shared access is not required.

One advantage of using RCS version 5.6 or later is that binary files are supported, should you want to have binary files in the baseline.

4.3.1. history_create_command

This command is used to create a new file history. This command is always executed as the project owner.

The following substitutions are available:

${Input}
: absolute path of the source file

${History}
: absolute path of the history file

The entry in the *config* file looks like this:

```
history_create_command =
  "ci -f -u -d -M -m$c -t/dev/null \
  $i $h,v; rcs -U $h,v";
```

The "`ci -f`" option is used to specify that a copy is to be checked-in even if there are no changes. The "`ci -u`" option is used to specify that an unlocked copy will remain in the baseline. The "`ci -d`" option is used to specify that the file time rather than the current time is to be used for the new revision. The "`ci -M`" option is used to specify that the mode date on the original file is not to be altered. The "`ci -t`" option is used to specify that there is to be no description text for the new RCS file. The "`ci -m`" option is used to specify that the change number is to be stored in the file log if this is actually an update (typically from *aenf* after *aerm* on the same file name). The "`rcs -U`" option is used to specify that the new RCS file is to have unstrict locking.

4.3.2. history_get_command

This command is used to get a specific edit back from history. This command is always executed as the project owner.

The following substitutions are available:

${History}
: absolute path of the history file

${Edit}
: edit number, as given by history_query_command

${Output}
: absolute path of the destination file

The entry in the *config* file looks like this:

```
history_get_command =
  "co -r'$e' -p $h,v > $o";
```

The "`co -r` option is used to specify the edit to be retrieved. The "`co -p` option is used to specify that the results be printed on the standard output; this is because the destination filename will *never* look anything like the history source filename.

4.3.3. history_put_command

This command is used to add a new "top-most" entry to the history file. This command is always executed as the project owner.

The following substitutions are available:

${Input}
: absolute path of source file

${History}
: absolute path of history file

The entry in the *config* file looks like this:

```
history_put_command =
  "ci -f -u -d -M -m$c $i $h,v"
```

/* Uses ci to deposit a new revision, using -d and -M as described */ /* for history_create_command. The -m flag stores the change number */ /* in the file log, which allows rlog to be used to find the Aegis */ /* change numbers to which each revision of the file corresponds. */ history_put_command =
"ci -u -d -M -m$c $i $h,v";

The "`ci -f`" option is used to specify that a copy is to be checked-in even if there are no changes. The "`ci -u`" option is used to specify that an unlocked copy will remain in the baseline. The "`ci -d`" option is used to specify that the file time rather than the current time is to be used

for the new revision. The "`ci -M`" option is used to specify that the mode date on the original file is not to be altered. The "`ci -m`" option is used to specify that the change number is to be stored in the file log, which allows *rlog* to be used to find the change numbers to which each revision of the file corresponds.

It is possible for a a very cautious approach has been taken, in which case the *history_put_command* may be set to the same string specified above for the

4.3.4. history_query_command

This command is used to query what the history mechanism calls the top-most edit of a history file. The result may be any arbitrary string, it need not be anything like a number, just so long as it uniquely identifies the edit for use by the *history_get_command* at a later date. The edit number is to be printed on the standard output. This command is always executed as the project owner.

The following substitutions are available:

${History}
: absolute path of the history file

The entry in the *config* file looks like this:

```
history_query_command =
  "rlog -r $h,v | \
   awk '/^head:/ {print $$2}'";
```

4.3.5. diff3_command

RCS also provides a *merge* program, which can be used to provide a three-way merge.

All of the command substitutions described in *aesub* (5) are available. In addition, the following substitutions are also available:

${ORiginal}
: The absolute path name of a file containing the version originally copied. Usually in a temporary file.

${Most_Recent}
: The absolute path name of a file containing the most recent version. Usually in the baseline.

${Input}
: The absolute path name of the edited version of the file. Usually in the development directory.

${Output}
: The absolute path name of the file in which to write the difference listing. Usually in the development directory.

The entry in the *config* file looks like this:

```
diff3_command =
  "set +e; \
  merge -p -L baseline -L C$c \
  $mr $orig $in > $out; \
  test $? -le 1";
```

The "`merge -L`" options are used to specify labels for the baseline and the development directory, respectively, when conflict lines are inserted into the result. The "`merge -p`" options is used to specify that the results are to be printed on the standard output.

A variation found useful by some sites[15] is to replace the source file in the development directory with the output of the merge.

```
diff3_command =
  "set +e; \
  merge -p -L baseline -L C$c \
  $mr $orig $in > $out; \
  test $? -le 1 && \
  mv $input $input,B && \
  mv $output $input";
```

Note that this variation replaces the `$input` file with the the result of the merge, in the hope that conflicts will cause syntax errors if they are not resolved. The `$input` file is kept in a `,B` (backup) file for reference by the developer, if required.

4.3.6. Templates The *lib/config.example/rcs* file in the Aegis distribution contains all of the above commands, so that you may readily insert them into your project *config* file.

[15] My thanks to Simon Pickup <simon@adacel.com.au> for this suggestion.

4.4. Using fhist

The *fhist* program was written by David I. Bell and is admirably suited to providing a history mechanism with out the "cruft" that SCCS and RCS impose.

4.4.1. history_create_command

This command is used to create a new project history. The command is always executed as the project owner.

The following substitutions are available:

${Input}
: absolute path of the source file

${History}
: absolute path of the history file

The entry in the *config* file looks like this:

```
history_create_command =
  "fhist ${b $i} -create -cu -i $i \
   -p ${d $h} -r";
```

4.4.2. history_get_command

This command is used to get a specific edit back from history. The command may be executed by developers.

The following substitutions are available:

${History}
: absolute path of the history file

${Edit}
: edit number, as given by history_query_-command

${Output}
: absolute path of the destination file

The entry in the *config* file looks like this:

```
history_get_command =
  "fhist ${b $h} -e '$e' -o $o \
   -p ${d $h}";
```

Note that the destination filename will *never* look anything like the history source filename, so the -p is essential.

4.4.3. history_put_command

This command is used to add a new "top-most" entry to the history file. This command is always executed as the project owner.

The following substitutions are available:

${Input}
: absolute path of source file

${History}
: absolute path of history file

The entry in the *config* file looks like this:

```
history_put_command =
  "fhist ${b $i} -cu -i $i \
   -p ${d $h} -r";
```

Note that the source file is left in the baseline.

4.4.4. history_query_command

This command is used to query what the history mechanism calls the "top-most" edit of a history file. The result may be any arbitrary string, it need not be anything like a number, just so long as it uniquely identifies the edit for use by the *history_get_command* at a later date. The edit number is to be printed on the standard output. This command may be executed by developers.

The following substitutions are available:

${History}
: absolute path of the history file

The entry in the *config* file looks like this:

```
history_query_command =
  "fhist ${b $h} -l 0 \
   -p ${d $h} -q";
```

4.4.5. Templates

The *lib/config.example/fhist* file in the Aegis distribution contains all of the above commands, so that you may readily insert them into your project *config* file.

5. The Dependency Maintenance Tool

The aegis program places heavy demands on the dependency maintenance tool, so it is important that you select an appropriate one. This chapter talks about what a dependency tool requires, and gives examples of how to use the various alternatives.

At this writing, the author has seen few sufficiently capable dependency maintenance tools.

5.1. Required Features

When selecting a Dependency Maintenance Tool it is important to keep in mind that, ideally, it must be able to cope with a hierarchy of parallel source directory trees.

The heart of any DMT is an *inference engine*. This inference engine accepts a *goal* of what you want it to construct and a set of *rules* for how to construct things, and attempts to construct what you asked for given the rules you specified. This is exactly a description of an expert system, and the DMT needs to be an expert system for constructing files.

This perspective on what the aegis program needs from a DMT reveals that the old-faithful *make*(1) distributed with so many flavours of UNIX really isn't good enough, and that something like PROLOG is probably ideal.

5.1.1. Search Lists

For the union of all files in a project and all files in a change (remembering that a change only copies those files it is modifying, plus it may add or remove files) for all files you must be able to say to the dependency maintenance tool,

> "If and only if the file is up-to-date in the baseline, use the baseline copy of the file, otherwise construct the file in the development directory".

The presence of a source file in the change makes the copy in the baseline out-of-date.

Most DMTs with this capability implement it by using some sort of search path, allowing a hierarchy of directories to be scanned with little or no modification to the rules.

If your DMT of choice does not provide this functionality, the *create_symlinks_before_build* field of the project *config* file may be set to which tells aegis to maintain symbolic links in the development directory for all files in the baseline which are not present in the development directory. (See and for more information.) This incurs a certain amount of overhead when aegis maintains these links, but a similar amount of work is done within DMTs which have search path functionality.

5.1.2. Dynamic Include File Dependencies

Include file dependencies are very important, because a change may alter an include file, and all of the sources in the baseline which use that include file must be recompiled.

Consider the example given earlier: the include file describing the interface definition of a function is copied into a change and edited, and so is the source file defining the function. It is essential that all source files in the baseline which include that file re recompiled, which will usually result in suitable diagnostic errors if any of the clients of the altered function have yet to be included in the change.

There are two ways of handling include file dependencies:

• They can be kept in a file, and the file can be maintained by suitable programs (maintaining it manually never works, that's just human nature).

• They can be determined by the DMT when it is scanning the rules to determine what needs updating.

5.1.2.1. Static File

Keeping include dependencies in a file has a number of advantages:

• Most existing DMTs have the ability to include other rules files, so that when performing a development build from a baseline rules file, it could include a dependencies file in the development directory.

• Reading a file is much faster than scanning all of the source files.

Keeping include dependencies in a file has a number of disadvantages:

• The file is independent of the DMT, it is either generated before the DMT is invoked, in which case it may do more work than is necessary, or it may be invoked after the DMT (or after the DMT has scanned its rules), in which case it may well be out-of-date when the DMT needs it.

For example, the use of *gcc -M* produces "dot d" files, which may be merged to construct such an includable dependency file. This happens after the DMT has read and applied the rules, but possibly before the DMT has finished executing.[16]

[16] See the *Using Make* section for how GNU Make may be used. It effectively combines both methods:

• Many tools which can generate this information, such as the *gcc -M* option, are triggered by source files, and are unable to manage a case where it is an include file which is changing, to include a different set of other include files. In this case, the inaccurate dependencies file may contain references to the old set of nested include files, some of which may no longer exist, This causes the DMT to incorrectly generate an error stating that the old include file is missing, when it is actually no longer required.

If a DMT can only support this kind of include file dependencies, it is not suitable for use with aegis.

5.1.2.2. Dynamic

In order for a DMT to be suitable for use with aegis, it is essential that rules for the DMT may be specified in such a way that include file dependencies are determined "on the fly" when the DMT is determining if a given rule is applicable, and before the rule is applied.

This method suffers from the problem being rather slow; but this is amenable to some caching and the losses of performance are not as bad as could be imagined.

This method has the advantage of correctness in all cases, where a static file may at times be out-of-date.

---

keeping *.d* files and dynamically updating them. Because it combines both methods, it has some of the advantages and disadvantages of both.

5.2. Using Cook

The *cook* program is the only dependency maintenance tool, known to the author, which is sufficiently capable to supply aegis' needs.[17] Tools such as *cake* and *GNU Make* are described later. They need a special tweak to make them work.

This section describes appropriate contents for the *Howto.cook* file, input to the *cook*(1) program. It also discusses the *build_command* and *integrate_build_command* and *link_baseline* and *change_file_command* and *project_file_command* and *link_integration_directory* fields of the *config* file. See *aepconf*(5) for more information about this file.

5.2.1. Invoking Cook

The *build_command* field of the *config* file is used to invoke the relevant build command. In this case, it is set as follows

```
build_command =
  "cook -b ${s Howto.cook} -nl\
   project=$p change=$c version=$v";
```

This command tells cook where to find the recipes. The `${s Howto.cook}` expands to a path into the baseline during development if the file is not in the change. Look in *aesub*(5) for more information about command substitutions.

The recipes which follow will all remove their targets before constructing them, which qualifies them for the next entry in the *config* file:

```
link_integration_directory = true;
```

The files must be removed first, otherwise the baseline would cease to be self-consistent.

5.2.2. The Recipe File

The file containing the recipes is called *Howto.cook* and is given to cook on the command line.

The following items are preamble to the rest of the file; they ask aegis for the source files of the project and change so that cook can determine what needs to be compiled and linked.

```
project_files =
  [collect aegis -l pf -terse
    -p [project] -c [change]];
change_files =
  [collect aegis -l cf -terse
    -p [project] -c [change]];
source_files =
  [sort [project_files]
    [change_files]];
```

This example continues the one from chapter 3, and thus has a single executable to be linked from all the object files

```
object_files =
  [fromto %.y %.o [match_mask %.y
    [source_files]]]
  [fromto %.l %.o [match_mask %.l
    [source_files]]]
  [fromto %.c %.o [match_mask %.c
    [source_files]]]
  ;
```

It is necessary to determine if this is a development build, and thus has the baseline for additional ingredients searches, or an integration build, which does not. The version supplied by aegis will tell us this information, because it will be *major.minor.*C*change* for development builds and *major.minor.*D*delta* for integration builds.

```
if [match_mask %1C%2 [version]] then
{
  baseline = [collect aegis -cd -bl
    -p [project]];
  search_list = . [baseline];
}
```

The *search_list* variable in cook is the list of directories to search for dependencies; it defaults to only the current directory. The *resolve* builtin function of cook may be used to ask cook for the name of the file actually used to resolve dependencies, so that recipe bodies may reference the appropriate file:

```
example: [object_files]
{
  [cc] -o example
    [resolve [object_files]]
    -ly -ll;
}
```

This recipe says that to cook the example program, you need the object files determined earlier, and them link them together. Object files which were up to date in the baseline are used wherever possible, but files which were out of date are constructed in the current directory and those will be linked.

[17] The version in use when writing this section was 1.5. All versions from 1.3 onwards are known to work with the recipes described here.

5.2.3. The Recipe for C

Next we need to tell cook how to manage C sources. On the surface, this is a simple recipe:

```
%.o: %.c
{
  rm %.o;
  [cc] [cc_flags] -c %.c;
}
```

Unfortunately it has forgotten about finding the include file dependencies. The cook package includes a program called *c_incl* which is used to find them. The recipe now becomes

```
%.o: %.c: [collect c_incl -eia %.c]
{
  rm %.o;
  [cc] [cc_flags] -c %.c;
}
```

The file may not always be present to be removed (causing a fatal error), and it is irritating to execute a redundant command, so the remove is mangled to look like this:

```
%.o: %.c: [collect c_incl -eia %.c]
{
  if [exists %.o] then
    rm %.o
      set clearstat;
  [cc] [cc_flags] -c %.c;
}
```

The "set clearstat" clause tells cook that the command will invalidate parts of its *stat* cache, and to look at the command for what to invalidate.

Another thing this recipe needs is to use the baseline for include files not in a change, and so the recipe is altered again:

```
%.o: %.c: [collect c_incl -eia
  [prepost "-I" "" [search_list]]
    %.c]
{
 if [exists %.o] then
    rm %.o
      set clearstat;
  [cc] [cc_flags] [prepost "-I" ""
    [search_list]] -c %.c;
}
```

See the *Cook Reference Manual* for a description of the *prepost* builtin function, and other cook details.

There is one last change that must be made to this recipe, it must use the resolve function to reference the appropriate file once cook has found it on the search list:

```
%.o: %.c: [collect c_incl -eia
  [prepost "-I" "" [search_list]]
    [resolve %.c]]
{
  if [exists %.o] then
    rm %.o
      set clearstat;
  [cc] [cc_flags] [prepost "-I" ""
    [search_list]] -c [resolve %.c];
}
```

Only use this last recipe for C sources, the others are only shown so that the derivation of the recipe is clear; while it is very similar to the original, it looks daunting at first.

5.2.3.1. C Include Semantics

The semantics of C include directives make the

```
#include "filename"
```

directive dangerous in a project developed with the aegis program and cook.

Depending on the age of your compiler, whether it is AT&T traditional C or newer ANSI C, this form of directive will search first in the current directory and then along the search path, or in the directory of the including file and then along the search path.

The first case is fairly benign, except that compilers are rapidly becoming ANSI C compliant, and an operating system upgrade could result in a nasty surprise.

The second case is bad news. If the source file is in the baseline and the include file is in the change, you don't want the source file to use the include file in the baseline.

Always use the

```
#include <filename>
```

form of the include directive, and set the include search path explicitly on the command line used by cook.

Cook is able to dynamically adapt to include file dependencies, because they are not static. The presence of an include file in a change means that any file which includes this include file, whether that source file is in the baseline or in the change, must have a dependency on the change's include file. Potentially, files in the baseline will need to be recompiled, and the object file stored in the change, not the baseline. Subsequent linking needs to pick up the object file in the change, not from the baseline.

5.2.4. The Recipe for Yacc

Having explained the complexities of the recipes in the above section about C, the recipe for yacc will be given without delay:

```
%.c %.h: %.y
{
  if [exists %.c] then
    rm %.c
      set clearstat;
  if [exists %.h] then
    rm %.h
      set clearstat;
  [yacc] [yacc_flags] -d
    [resolve %.y];
  mv y.tab.c %.c;
  mv y.tab.h %.h;
}
```

This recipe could be jazzed up to cope with the listing file, too, if that was desired, but this is sufficient to work with the example.

Cook's ability to cope with transitive dependencies will pick up the generated .c file and construct the necessary .o file.

5.2.5. The Recipe for Lex

The recipe for lex is vary similar to the recipe for yacc.

```
%.c: %.l
{
  if [exists %.c] then
    rm %.c
      set clearstat;
  [lex] [lex_flags] -d [resolve %.l];
  mv lex.yy.c %.c;
}
```

Cook's ability to cope with transitive dependencies will pick up the generated .c file and construct the necessary .o file.

5.2.6. Recipes for Documents

You can format documents, such as user guides and manual entries with aegis and cook, and the recipes are similar to the ones above.

```
%.ps: %.ms: [collect c_incl -r -eia
  [prepost "-I" "" [search_list]]
  [resolve %.ms]]
{
  if [exists %.ps] then
    rm %.ps
      set clearstat;
  roffpp [prepost "-I" ""
    [search_list]] [resolve %.ms]
    | groff -p -t -ms
    > [target];
}
```

This recipe says to run the document through groff, with the *pic* (1) and *tbl* (1) filters, use the *ms* (7) macro package, to produce PostScript output. The *roffpp* program comes with cook, and is like *soelim* (1) but it accepts include search path options on the command line.

Manual entries may be handled in a similar way

```
%.cat: %.man: [collect c_incl -r -eia
  [prepost "-I" "" [search_list]]
  [resolve %.man]]
{
  if [exists %.cat] then
    rm %.cat
      set clearstat;
  roffpp [prepost "-I" ""
    [search_list]] [resolve %.man]
    | groff -Tascii -t -man
    > [target];
}
```

5.2.7. Templates

The *lib/config.example/cook* file in the Aegis distribution contains all of the above commands, so that you may readily insert them into your project *config* file.

5.3. Using Cake

This section describes how to use *cake* as the dependency maintenance tool. The *cake* package was published in the *comp.sources.unix* USENET newsgroup volume 12, around February 1988, and is thus easily accessible from the many archives around the internet.

It does not have a search path of any form, not even something like *VPATH*. It does, however, have facilities for dynamic include file dependencies.

5.3.1. Invoking Cake

The *build_command* field of the *config* file is used to invoke the relevant build command. In this case, it is set as follows

```
build_command =
  "cake -f ${s Cakefile} \
   -DPROJECT=$p -DCHANGE=$c \
   -DVERSION=$v";
```

This command tells *cake* where to find the rules. The `${s Cakefile}` expands to a path into the baseline during development if the file is not in the change. Look in *aesub*(5) for more information about command substitutions.

The rules which follow will all remove their targets before constructing them, which qualifies them for the next entry in the *config* file:

```
link_integration_directory = true;
```

The files must be removed first, otherwise the baseline would cease to be self-consistent.

Another field to be set in this file is

```
create_symlinks_before_build =
  true;
```

which tells aegis to maintain symbolic links between the development directory and the basline. This also requires that rules remove their targest before constructing them, to ensure that rules do not attempt to write their results onto the read-only versions in the baseline.

5.3.2. The Rules File

The file containing the rules is called *Cakefile* and is given to cake on the command line.

The following items are preamble to the rest of the file; they ask aegis for the source files of the project and change so that cake can determine what needs to be compiled and linked.

```
#define project_files \
  [[aegis -l pf -terse -p PROJECT \
   -c CHANGE]];
#define change_files \
  [[aegis -l cf -terse -p PROJECT \
   -c CHANGE]];
#define source_files \
  project_files change_files

#define CC     gcc
#define CFLAGS -O
```

This example parallels the one from chapter 3, and thus has a single executable to be linked from all the object files

```
#define object_files \
  [[sub -i X.c %.o source_files]] \
  [[sub -i X.y %.o source_files]] \
  [[sub -i X.l %.o source_files]]
```

Constructing the program is straightforward

```
example: object_files
  rm -f example
  CC -o example object_files
```

This rule says that to construct the example program, you need the object files determined earlier, and them link them together. Object files which were up to date in the baseline are used wherever possible, but files which were out of date are constructed in the current directory and those will be linked.

5.3.3. The Rule for C

Next we need to tell cake how to manage C sources. On the surface, this is a simple rule:

```
%.o: %.c
  CC CFLAGS -c %.c
```

paralleling that found in most makes, however it needs to delete the target first, and to avoid deleting the *.o* file whenever cake thinks it is transitive.

```
%.o!: %.c
  rm -f %.o
  CC CFLAGS -c %.c
```

The *-f* option to the *rm* command is because the file does not always exist.

Unfortunately this rule omits finding the include file dependencies. The cake package includes a program called *ccincl* which is used to find them. The rule now becomes

```
%.o!: %.c* [[ccincl %.c]]
  rm -f %.o
  CC CFLAGS -c %.c
```

This rule is a little quirky about include files

which do not yet exists, but must be constructed by some other rule. You may want to use *gcc -MM* instead, which is almost as quirky when used with cake. Another alternative, used by the author with far more success, is to use the *c_incl* program from the *cook* package, mentioned in an earlier section. The *gcc -MM* understands C include semantics perfectly, the *c_incl* command caches its results and thus goes faster, so you will need to figure which you most want.

5.3.3.1. Include Directives

Unlike *cook* described in an earlier section, using *cake* as described here allows you to continue using the

```
#include "filename"
```

form of the include directive. This is because the development directory appears, to the compiler, to be a complete copy of the baseline.

5.3.4. The Rule for Yacc

Having explained the complexities of the rules in the above section about C, the rule for yacc will be given without delay:

```
#define YACC yacc
#define YFLAGS

%.c! %.h!: %.y  if exist %.y
  rm -f %.c %.h y.tab.c y.tab.h
  YACC YFLAGS -d %.y
  mv y.tab.c %.c
  mv y.tab.h %.h
```

This rule could be jazzed up to cope with the listing file, too, if that was desired, but this is sufficient to work with the example.

Cake's ability to cope with transitive dependencies will pick up the generated *.c* file and construct the necessary *.o* file.

5.3.5. The Rule for Lex

The rule for lex is vary similar to the rule for yacc.

```
#define LEX lex
#define LFLAGS

%.c!: %.l  if exist %.l
  rm -f %.c
  LEX LFLAGS %.l
  mv lex.yy.c %.c
```

Cake's ability to cope with transitive dependencies will pick up the generated *.c* file and construct the necessary *.o* file.

5.3.6. Rules for Documents

You can format documents, such as user guides and manual entries with aegis and cake, and the rules are similar to the ones above.

```
%.ps!: %.ms* [[soincl %.ms]]
  rm -f %.ps
  groff -s -p -t -ms %.ms > %.ps
```

This rule says to run the document through groff, with the *soelim*(1) and *pic*(1) and *tbl*(1) filters, use the *ms*(7) macro package, to produce PostScript output.

This suffers from many of the problems with include files which need to be generated, as does the C rule, above. You may want to use *c_incl -r* from the *cook* package, rather than the *soincl* supplied by the *cake* package.

Manual entries may be handled in a similar way

```
%.cat!: %.man* [[soincl %.man]]
  rm -f %.cat
  groff -Tascii -s -t -man %.man \
    > %.cat
```

5.4. Using Make

The program exists in many forms, usually one is available with each UNIX version. The one used in the writing of this section is *GNU Make 3.70*, available by anonymous FTP from your nearest GNU archive site. GNU Make was chosen because it was the most powerful, it is widely available (usually for little or no cost) and discussion of the alternatives (SunOS make, BSD 4.3 make, etc), would not be universally applicable. "Plain vanilla" make (with no transitive closure, no pattern rules, no functions) is not sufficiently capable to satisfy the demands placed on it by aegis.

As mentioned earlier in this chapter, *make* is not really sufficient, because it lacks dynamic include dependencies. However, GNU Make has a form of dynamic include dependencies, and it has a few quirks, but mostly works well.

The other feature lacking in *make* is a search path. While GNU Make has functionality called *VPATH*, the implementation leaves something to be desired, and can't be used for the search path functionality required by aegis. Because of this, the *create_symlinks_before_build* field of the project *config* file is set to *true* so that aegis will arrange for the development directory to be full of symbolic links, making it appear that the entire project is in each change's development directory.

5.4.1. Invoking Make

The *build_command* field of the project *config* file is used to invoke the relevant build command. In this case, it is set as follows

```
build_command =
  "gmake -f ${s Makefile} project=$p \
   change=$c version=$v";
```

This command tells make where to find the rules. The `${s Makefile}` expands to a path into the baseline during development if the file is not in the change. Look in *aesub*(5) for more information about command substitutions.

The rules which follow will all remove their targets before constructing them, which qualifies them for the next entry in the *config* file:

```
link_integration_directory = true;
```

The files must be removed first, otherwise the baseline would cease to be self-consistent.

Another field to be set in this file is

```
create_symlinks_before_build =
  true;
```

which tells aegis to maintain symbolic links between the development directory and the baseline. This also requires that rules remove their targets before constructing them, to ensure that rules do not attempt to write their results onto the read-only versions in the baseline.

5.4.2. The Rule File

The file containing the rules is called *Makefile* and is given to make on the command line.

The following items are preamble to the rest of the file; they ask aegis for the source files of the project and change so that make can determine what needs to be compiled and linked.

```
project_files := \
  $(shell aegis -l pf -terse -p \
    $(project) -c $(change))
change_files := \
  $(shell aegis -l cf -terse -p \
    $(project) -c $(change))
source_files := \
  $(sort $(project_files) \
    $(change_files))
CC := gcc
CFLAGS := -O
```

This example parallels the one from chapter 3, and thus has a single executable to be linked from all the object files

```
object_files := \
  $(patsubst %.y,%.o,$(filter \
    %.y,$(source_files)))     \
  $(patsubst %.l,%.o,$(filter \
    %.l,$(source_files)))     \
  $(patsubst %.c,%.o,$(filter \
    %.c,$(source_files)))
```

Constructing the program is straightforward, remembering to remove the target first.

```
example: $(object_files)
  rm -f example
  $(CC) -o example $(object_files) \
    -ly -ll
```

This rule says that to make the example program, you need the object files determined earlier, and them link them together. Object files which were up to date in the baseline are used wherever possible, but files which were out of date are constructed in the current directory and those will be linked.

5.4.3. The Rule for C

Next we need to tell make how to manage C sources. On the surface, this is a simple rule:

```
%.o: %.c
  $(CC) $(CFLAGS) -c $*.c
```

This example matches the built-in rule for most *make*s. But it forgets to remove the target before constructing it.

```
%.o: %.c
  rm -f $*.o
  $(CC) $(CFLAGS) -c $*.c
```

The target may not yet exist, hence the *-f* option.

Something missing from this rule is finding the include file dependencies. The GNU Make User Guide describes a method for obtaining include file dependencies. A set of dependency files are constructed, one per *.c* file.

```
%.d: %.c
  rm -f %.d
  $(CC) $(CFLAGS) -MM $*.c \
  | sed 's/^\(.*\).o :/\1.o \1.d :/' \
  > $*.d
```

These dependency files are then included into the *Makefile* to inform GNU Make of the dependencies.

```
include $(patsubst \
  %.o,%.d,$(object_files))
```

GNU Make has the property of making sure all its include files are up-to-date. If any are not, they are made, and then GNU Make starts over, and re-reads the Makefile and the include files from scratch, before proceeding with the operation requested. In this case, it means that our dependency construction rule will be applied before any of the sources are constructed.

This method is occasionally quirky about absent include files which you have yet to write, or which are generated and don't yet exist, but this is usually easily corrected, though you do need to watch out for things which will stall an integration (because the integrator will not have write permission on the integration directory).

The *-MM* option to the $(CC) command means that this rule requires the *gcc* program in order to work correctly. It may be possible to use *c_incl*(1) from cook, or *ccincl*(1) from cake to build the dependency lists instead; but they don't understand the conditional preprocessing as well as *gcc* does.

This method also suffers when heterogeneous development is performed. If you include different files, depending on the environment being compiled within, the *.d* files may be incorrect, and GNU Make has no way of knowing this.

5.4.3.1. Include Directives

Unlike *cook* described in an earlier section, using GNU Make as described here allows you to continue using the

```
#include "filename"
```

form of the include directive. This is because the development directory appears, to the compiler, to be a complete copy of the baseline.

5.4.4. The Rule for Yacc

Having explained the complexities of the rules in the above section about C, the rule for yacc will be given without delay:

```
%.c %.h: %.y
  rm -f $*.c $*.h y.tab.c y.tab.h
  $(YACC) $(YFLAGS) -d $*.y
  mv y.tab.c $*.c
  mv y.tab.h $*.h
```

This rule could be jazzed up to cope with the listing file, too, if that was desired, but this is sufficient to work with the example.

GNU Make's ability to cope with transitive closure will pick up the generated *.c* file and construct the necessary *.o* file.

To prevent GNU Make throwing away the transitive files, and thus slowing things down in some cases, make them precious:

```
.PRECIOUS: \
  $(patsubst %.y,%.c,$(filter \
    %.y,$(source_files)))     \
  $(patsubst %.y,%.h,$(filter \
    %.y,$(source_files)))
```

5.4.5. The Rule for Lex

The rule for lex is vary similar to the rule for yacc.

```
%.c: %.l
  rm -f $*.c lex.yy.c
  $(LEX) $(LFLAGS) $*.l
  mv lex.yy.c $*.c
```

GNU Make's ability to cope with transitive closure will pick up the generated *.c* file and construct the necessary *.o* file.

To prevent GNU Make throwing away the transitive files, and thus slowing things down in some cases, make them precious:

```
.PRECIOUS: \
  $(patsubst %.l,%.c,$(filter \
    %.l,$(source_files)))
```

5.4.6. Rules for Documents

You can format documents, such as user guides and manual entries with aegis and GNU Make, and the rules are similar to the ones above.

```
%.ps: %.ms
  rm -f $*.ps
  groff -p -t -ms $*.ms > $*.ps
```

This rule says to run the document through groff, with the *pic*(1) and *tbl*(1) filters, use the *ms*(7) macro package, to produce PostScript output.

This omits include file dependencies. If this is important to you, the *c_incl* program from *cook* can be used to find them. Filtering its output can then produce the necessary dependency files to be included, rather like the C rules, above.

Manual entries may be handled in a similar way

```
%.cat: %.man
  rm $*.cat
  groff -Tascii -s -t -man $*.man \
    > $*.cat
```

5.4.7. Other Makes

All of the above discussion assumes that GNU Make and GCC are used. If you do not want to do this, or may not do this because of internal company politics, it is possible to perform all of the automated features manually.

This may, however, rapidly become spectacularly tedious. For example: if a user needs to copy the *Makefile* into their change for any reason, they will need to constantly use *aed*(1) to "catch up" with integrations into the baseline.

Reviewers are also affected: they must check that each change to the *Makefile* accurately reflects the object list and the dependencies of each source file.

5.4.8. Templates The *lib/config.example/make* file in the Aegis distribution contains all of the above commands, so that you may readily insert them into your project *config* file.

6. The Difference Tools

This chapter describes the difference commands in the project configuration file. Usually these commands are used by the *aegis -DIFFerence* command when differencing files, but they may be used to accomplish some other things.

6.1. Interfacing

The build commands are accessed from two fields of the project configuration file (*config*).

6.1.1. diff_command

This command is used by *aed* (1) to produce a difference listing when file in the development directory was originally copied from the current version in the baseline[18].

All of the command substitutions described in *aesub* (5) are available. In addition, the following substitutions are also available:

${ORiginal}
: The absolute path name of a file containing the version originally copied. Usually in the baseline.

${Input}
: The absolute path name of the edited version of the file. Usually in the development directory.

${Output}
: The absolute path name of the file in which to write the difference listing. Usually in the development directory.

An exit status of 0 means successful, even of the files differ (and they usually do). An exit status which is non-zero means something is wrong.

The non-zero exit status may be used to overload this command with extra tests, such as line length limits. The difference files must be produced in addition to these extra tests.

6.1.2. diff3_command

This command is used by *aed* (1) to produce a difference listing when file in the development directory is out of date compared to the current version in the baseline.

All of the command substitutions described in *aesub* (5) are available. In addition, the following substitutions are also available:

${ORiginal}
: The absolute path name of a file containing the version originally copied. Usually in a temporary file.

${Most_Recent}
: The absolute path name of a file containing the most recent version. Usually in the baseline.

${Input}
: The absolute path name of the edited version of the file. Usually in the development directory.

${Output}
: The absolute path name of the file in which to write the difference listing. Usually in the development directory.

An exit status of 0 means successful, even of the files differ (and they usually do). An exit status which is non-zero means something is wrong.

[18] Or this is logically the case.

6.2. Using diff and diff3

These two tools are available with most flavours of UNIX, but often in a very limited form. One severe limitation is the *diff3*(1) command, which often can only cope with 200 lines of differences. The best alternative is to use GNU diff, with context differences available, and a far more robust diff3.

See the earlier *Interfacing* section for substitution details.

6.2.1. diff_command

The entry in the *config* file looks like this:

```
diff_command =
  "set +e; diff -c $original \
   $input > $output; test $? -le 1";
```

This needs a little explanation:
• This command is always executed with the shell's **-e** option enabled, causing the shell to exit on the first error. The "set +e" turns this off.
• The *diff*(1) command exits with a status of 0 if the files are identical, and a status of 1 if they differ. Any other status means something horrible happened. The "test" command is used to change this to the exit status aegis expects.

6.2.2. diff3_command

The entry in the *config* file looks like this:

```
diff3_command =
  "(diff3 -e $MostRecent $original  \
   $input | sed -e '/^w$$/d' -e     \
   '/^q$$/d'; echo '1,$$p' ) | ed - \
   $MostRecent > $output";
```

This needs a lot of explanation.
• The *diff3*(1) command is used to produce an edit script that will incorporate into $MostRecent, all the changes between $original and $input.
• The *sed*(1) command is used to remove the "write" and "quit" commands from the generated edit script.
• The *ed*(1) command is used to apply the generated edit script to the $MostRecent file, and print the results on the standard output, which are redirected into the $output file.

6.3. Using fhist

The **fhist** program by David I. Bell also comes with two other utilities, *fcomp* and *fmerge*, which use the same minimal difference algorithm.

See the earlier *Interfacing* section for substitution details.

6.3.1. diff_command

The entry in the *config* file looks like this:

```
diff_command =
  "fcomp -w $original $input \
   -o $output";
```

The **-w** option produces an output of the entire file, with insertions an deletions marked by "change bars" in the left margin. This is superior to context difference, as it shows the entire file as context.

For more information, see the *fcomp*(1) manual entry.

6.3.2. diff3_command

The entry in the *config* file looks like this:

```
diff3_command =
  "fmerge $original $MostRecent \
   $input -o $output -c /dev/null";
```

The output of this command is similar to the output of the diff3_command in the last section. Conflicts are marked in the output. For more information, see the *fmerge*(1) manual entry.

7. The Project Attributes

The project attributes are manipulated using the *aepa* (1) command. This command reads a project attributes file to set the project attributes. This file can be thought of as having several sections, each of which will be covered by this chapter. You should see the *aepattr* (5) manual entry for more details.

7.1. Description and Access

The *description* field is a string which contains a description of the project. Large amounts of prose are not required; a single line is sufficient.

The *default_development_directory* field is a string which contains the pathname of where to place new development directories. The pathname must be absolute. This field is only consulted if the *uconf* (5) field of the same name is not set. Defaults to *$HOME*.

The *umask* field is an integer which is set to the file permission mode mask. See *umask* (2) for more information. This value will always be OR'ed with 022, because aegis is paranoid.

7.2. Notification Commands

The *develop_end_notify_command* field is a string which contains a command to be used to notify that a change requires reviewing. All of the substitutions described in *aesub* (5) are available. This field is optional, if it is not specified no notification will be issued. This command could also be used to notify other management systems, such as progress and defect tracking, in addition to notifying users.

The *develop_end_undo_notify_command* field is a string containing a command used to notify that a change has been withdrawn from review for further development. All of the substitutions described in *aesub* (5) are available. This field is optional, if it is not specified no notification will be issued. This command could also be used to notify other management systems, such as progress and defect tracking, in addition to notifying users.

The *review_pass_notify_command* field is a string containing the command to notify that the review has passed. All of the substitutions described in *aesub* (5) are available. This field is optional, if it is not specified no notification will be issued. This command could also be used to notify other management systems, such as progress and defect tracking, in addition to notifying users.

The *review_pass_undo_notify_command* field is a string containing the command to notify that a review pass has has been rescinded. All of the substitutions described in *aesub* (5) are available. This field is optional, and defaults to the *develop_end_notify_command* field if not specified. If neither is specified, no notification will be issued. This command could also be used to notify other management systems, such as progress and defect tracking, in addition to notifying users.

The *review_fail_notify_command* field is a string containing the command to notify that the review has failed. All of the substitutions described in *aesub* (5) are available. This field is optional, if it is not specified no notification will be issued. This command could also be used to notify other management systems, such as progress and defect tracking, in addition to notifying users.

The *integrate_pass_notify_command* field is a string containing the command to notify that the integration has passed. All of the substitutions described in *aesub* (5) are available. This field is optional, if it is not specified no notification will be issued. This command could also be used to notify other management systems, such as progress and defect tracking, in addition to notifying users.

The *integrate_fail_notify_command* field is a string containing the command to notify that the integration has failed. All of the substitutions described in *aesub* (5) are available. This field is optional, if it is not specified no notification will be issued. This command could also be used to notify other management systems, such as progress and defect tracking, in addition to notifying users.

7.2.1. Notification by email

The aegis command is distributed with a set of shell scripts to perform these notifications by email. They are installed into the */usr/local/lib/aegis* directory, by default; the actual installed directory at your site is available as the *${LIBrary}* substitution. The entries in the project attribute file look like this:

```
develop_end_notify_command =
  "sh $lib/de.sh $project $change \
  $developer";
develop_end_undo_notify_command =
  "sh $lib/deu.sh $project $change \
  $developer";
review_pass_notify_command =
  "sh $lib/rp.sh $project $change \
  $developer $reviewer";
review_pass_undo_notify_command =
  "sh $lib/rpu.sh $project $change \
  $developer $reviewer";
review_fail_notify_command =
  "sh $lib/rf.sh $project $change \
  $developer $reviewer";
integrate_pass_notify_command =
  "sh $lib/ip.sh $project $change \
  $developer $reviewer $integrator";
integrate_fail_notify_command =
  "sh $lib/if.sh $project $change \
  $developer $reviewer $integrator";
```

7.2.2. Notification by USENET

The aegis command is distributed with a set of shell scripts to perform these notifications by USENET. They are installed into the */usr/local/lib/aegis* directory, by default; the actual installed directory at your site is available as the *${LIBrary}* substitution. The entries in the project attribute file look like this:

```
develop_end_notify_command =
  "sh $lib/de.inews.sh $p $c alt.$p";
develop_end_undo_notify_command =
  "sh $lib/deu.inews.sh $p $c alt.$p";
review_pass_notify_command =
  "sh $lib/rp.inews.sh $p $c alt.$p";
review_pass_undo_notify_command =
  "sh $lib/rpu.inews.sh $p $c alt.$p";
review_fail_notify_command =
  "sh $lib/rf.inews.sh $p $c alt.$p";
integrate_pass_notify_command =
  "sh $lib/ip.inews.sh $p $c alt.$p";
integrate_fail_notify_command =
  "sh $lib/if.inews.sh $p $c alt.$p";
```

The last argument to each command is the newsgroup to post the article in, you may want to use some other group. Note that "$p" is an abbreviation for "$project" and "$c" is an abbreviation for "$change".

7.3. Exemption Controls

The *developer_may_review* field is a boolean. If this field is true, then a developer may review her own change. This is probably only a good idea for projects of less than 3 people. The idea is for as many people as possible to critically examine a change.

The *developer_may_integrate* field is a boolean. If this field is true, then a developer may integrate her own change. This is probably only a good idea for projects of less than 3 people. The idea is for as many people as possible to critically examine a change.

The *reviewer_may_integrate* field is a boolean. If this field is true, then a reviewer may integrate a change she reviewed. This is probably only a good idea for projects of less than 3 people. The idea is for as many people as possible to critically examine a change.

The *developers_may_create_changes* field is a boolean. This field is true if developers may created changes, in addition to administrators. This tends to be a very useful thing, since developers find most of the bugs.

The *default_test_exemption* field is a boolean. This field contains what to do when a change is created with no test exemption specified. The default is "false", i.e. no testing exemption, tests must be provided.

This kind of blanket exemption should only be set when a project has absolutely no functionality available from the command line; examples include X11 programs. The program could possibly be improved by providing access to the functionality from the command line, thus allowing tests to be written.

7.3.1. One Person Projects

The entries in the project attributes file for a one person project look like this:

```
developer_may_review = true;
developer_may_integrate = true;
reviewer_may_integrate = true;
developers_may_create_changes = true;
```

All of the staff roles (administrator, developer, reviewer and integrator) are all set to be the same user.

7.3.2. Two Person Projects

A two person project has the opportunity for each to review the other's work.

The entries in the project attributes file for a one person project look like this:

```
developer_may_review = false.
developer_may_integrate = true;
reviewer_may_integrate = true;
developers_may_create_changes = true;
```

All of the staff roles (developer, reviewer and integrator) are all set to allow both users.

7.3.3. Larger Projects

Once you have 3 or more staff on a project, you can assign all of the roles to separate people. The idea is for the greatest number of eyes to see each change and detect flaws before they reach the baseline.

The entries in the project attributes file for a one person project look like this:

```
developer_may_review = false.
developer_may_integrate = false;
reviewer_may_integrate = false;
developers_may_create_changes = true;
```

For smaller teams, everyone may be a developer. As the teams get larger, the more experienced staff are often the reviewers, rather than everyone.

8. Tips and Traps

This chapter contains hints for how to use the aegis program more efficiently and documents a number of pitfalls you may encounter.

This chapter is at present very "ad hoc" with no particular ordering. Fortunately, it is, as yet, rather small. The final size of this chapter is expected to be quite large.

8.1. Renaming Include Files

Renaming include files can be a disaster, either finding all of the clients, or making sure the new copy is used rather than the old copy still in the baseline.

Aegis provies some assistance. When the *aemv*(1) command is used, a file in the development directory is created in the *old* location, filled with garbage. Compiles will fail very diagnostically, and you can change the reference in the source file, probably after *aecp*(1)ing it first.

If you are moving an include file from one directory to another, but leaving the basename unchanged, create a link[19] between the new and old names, but only in the development directory (i.e. replacing the "garbage" file aegis created for you). Create the link after *aemv*(1) has succeeded. This insulates you from a number of nasty Catch-22 situations in writing the dependency maintenance tool's rules file.

8.2. Symbolic Links

If you are on a flavour of UNIX which has symbolic links, it is often useful to create a symbolic link from the development directory to the baseline. This can make browsing the baseline very simple.

Assuming that the project and change defaults are appropriate, the following command

```
ln -s `aegis -cd -bl` bl
```

is all that is required to create a symbolic link called *bl* pointing to the baseline. Note that the *aecd* alias is inappropriate in this case.

This can be done automatically for every change, by placing the line

```
develop_begin_command =
        "ln -s $baseline bl";
```

into the project *config* file.

[19] A hard link uses fewer disk blocks. Symbolic links survive the subject file being deleted and recreated.

8.3. User Setup

There are a number of things which users of aegis can do to make it more useful, or more user friendly. This section describes just a few of them.

8.3.1. The .cshrc file

The aliases for the various user commands used throughout this manual are obtained by appending a line of the form

```
source /usr/local/lib/aegis/cshrc
```

to the *.cshrc* file in the user's home directory.

8.3.2. The AEGIS_PATH environment variable

If users wish to use aegis for their own projects, in addition to the "system" projects, the *AEGIS_PATH* environment variable forms a colon separated search path of aegis "library" directories. The */usr/local/lib/aegis* directory is always implicitly added to this list.

The user should not create this library directory, but let aegis do this for itself (otherwise you will get an error message).

The *AEGIS_PATH* environment variable should be set in the *.cshrc* file in the user's home directory. Typical setting is

```
setenv AEGIS_PATH ~/lib/aegis
```

and this is the default used in the */usr/local/lib/aegis/cshrc* file.

8.3.3. The .aegisrc file

The *.aegisrc* file in the user's home directory contains a number of useful fields. See *aeuconf*(5) for more information.

8.3.4. The defaulting mechanism

In order for you to specify the minimum possible information on the command line, aegis has been designed to work most of it out itself.

The default project is the project which you are working on changes for, if there is only one, otherwise it is gleaned from the *.aegisrc* file. The command line overrides any default.

The default change is the one you are working on within the (default or specified) project, if there is only one. The command line overrides any default.

8.4. The Project Owner

For the greatest protection from accidental change, it is best if the project is owned by a UNIX account which is none of the staff. This account is often named the same as the project, or sometimes there is a single umbrella account for all projects.

When an aegis project is created, the owner is the user creating the project, and the group is the user's default group. The creating user is installed as the project's first administrator.

A new project administrator should be created - an actual user account. The UNIX password should then be disabled on the project account - it will never be necessary to use it again.[20]

The user nominated as project administrator many then assign all of the other staff roles. Aegis takes care of ensuring that the baseline is owned by the project account, not any of the other staff, while development directories always belong to the developer (but the group will always be the project group, irrespective of the developer's default group).

All of the staff working on a project should be members of the project's group, to be able to browse the baseline, for reviewers to be able to review changes. This use of UNIX groups means that projects may be as secure or open as desired.

8.5. USENET Publication Standards

If you are writing software to publish on USENET, a number of the source newsgroups have publication standards. This section describes ways of generating the following files, required by many of the newsgroups' moderators:

MANIFEST	List of files in the distribution.
Makefile	How to build the distribution.
CHANGES	What happened for this distribution.
patchlevel.h	An identification of this distribution.

Each of these files may be generated from information known to aegis, with the aid of some fairly simple shell scripts.

[20] Unless bugs in aegis corrupt the database, in which case repairs can be accomplished as the project account using a text editor.

8.5.1. CHANGES

Write this section.

Look in the *aux/CHANGES.sh* file included in the aegis distribution for an example of one way to do this.

8.5.2. MANIFEST

Write this section.

Look in the *aux/MANIFEST.sh* and *aux/MANIFEST.awk* files included in the aegis distribution for an example of one way to do this.

8.5.3. Makefile

Write this section.

Look in the *aux/Makefile.sh* and *aux/Makefile.awk* files included in the aegis distribution for an example of one way to do this.

8.5.4. patchlevel.h

Write this section.

Look in the *aux/Howto.cook* file included in the aegis distribution for an example of one way to do this.

8.5.5. Building Patch Files

The *patch* program by Larry Wall is one of the enduring marvels of USENET. This section describes how to build input files for this miracle program.

Write this section.

Look in the *aux/patches.sh* file included in the aegis distribution for an example of one way to do this.

8.6. Heterogeneous Development

The aegis program has support for heterogeneous development. It will enforce that each change be built and tested on each of a list of architectures. It determines which architecture it is currently executing on by using the *uname*(2) system call.

The *uname*(2) system call can yield uneven results, depending on the operating systems vendor's interpretation of what it should return[21]. To cope with this, each required architecture for a project is specified as a name and a pattern.

The name is used by aegis internally, and is also available in the *${ARCHitecture}* substitution (see *aesub*(5) for more information).

The patterns are simple shell file name patterns (see *sh*(1) for more information) matched against the output of the *uname*(2) system call.

The result of *uname*(2) has four fields of interest: *sysname*, *release*, *version* and *machine*. These are stitched together with hyphens to form an architecture *variant* to be matched by the pattern.

For example, a system the author commonly uses is "SunOS-4.1.3-8-sun4m" which matches the "SunOS-4.1*-*-sun4*" pattern. A solaris system, a very different beast, matches the "SunOS-5.*-*-sun4*" pattern. Sun's 386 version of Solaris matches the "SunOS-5.*-*-i86pc" pattern. A convex system matches the "ConvexOS-*-10.*-convex" pattern.

8.6.1. Project *config* File

To require a project to build and test on each of these architectures, the *architecture* field of the project *config* file is set. See *aepconf*(5) for more details on this file. The above examples of architectures could be represented as

```
architecture =
[
  {
    name = "sun4";
    pattern = "SunOS-4.1*-*-sun4*";
  },
  {
    name = "sun5";
    pattern = "SunOS-5.*-*-sun4*";
  },
  {
    name = "sun5pc";
    pattern = "SunOS-5.*-*-i86pc";
  },
  {
    name = "convex";
    pattern = "ConvexOS-*-10.*-*";
  }
];
```

This would require that all changes build and test on each of the "sun4", "sun5", "sun5pc" and "convex" architectures.

If the *architecture* field does not appear in the project *config* file, it defaults to

```
architecture =
[
  {
    name = "unspecified";
    pattern = "*";
  }
];
```

Setting the architectures is usually done as part of the first change of a project, but it also may be done to existing projects. This information is kept in the project *config* file, rather than as a project attribute, because it requires that the DMT configuration file and the tests have corresponding details (see below).

The *lib/config.example/architecture* file in the Aegis distribution contains many architecture variations, so that you may readily insert them into your project *config* file.

8.6.2. Change Attribute

The *architecture* attribute is inherited by each new change. A project administrator may subsequently edit the change attributes to grant exemptions for specific architectures. See *aeca*(1) for how to do this.

A build must be successfully performed on each of the target architectures. Similarly, the tests must be performed successfully on each. These requirements are because there is often conditional code present to cope with the vagaries of each architecture, and this needs to be compiled and tested in each case.

This multiple build and test requirement includes both development and integration states of each change.

[21] For example, SCO 3.2 returns the nodename in the sysname field, when it should place "SCO" there; Convex and Pyramid scramble it even worse.

8.6.3. Network Files

This method of heterogeneous development assumes that the baseline and development directories are available as the same pathname in all target architectures. With software such as NFS, this does not present a great problem, however NFS locking must also work.

There is also an assumption that all the hosts remotely mounting NFS file systems will agree on the time, because aegis uses time stamps to record that various tasks have been performed. Software such as *timed*(8) is required[22].

8.6.4. DMT Implications

This method of heterogeneous development assumes that the baseline will have a copy of all object files for all target architectures *simultaneously*.

This means that the configuration file for the DMT will need to distinguish all the variations of the object files in some way. The easiest method is to have a separate object tree for each architecture[23]. To facilitate this, there is an *${ARCHitecture}* substitution available, which may then be passed to the DMT using the *build_command* field of the project *config* file.

The architecture name used by aegis needs to be used by the DMT, so that both aegis and the DMT can agree on which architecture is currently targeted.

8.6.4.1. Cook Example

As and example of how to do this, the cook recipes from the DMT chapter are modified as appropriate. First, the *build_command* field of the project *config* file is changed to include the *${ARCHitecture}* substitution:

```
build_command =
  "cook -b ${s Howto.cook} \
  project=$p change=$c \
  version=$v arch='$arch' -nl";
```

Second, the C recipe must be changed to include the architecture in the path of the result:

```
[arch]/%.o: %.c: [collect c_incl
  -eia [prepost "-I" ""
  [search_list]] [resolve %.c]]
{
  if [not [exists [arch]]] then
    mkdir [arch]
      set clearstat;
  if [exists [target]] then
    rm [target]
      set clearstat;
  [cc] [cc_flags] [prepost "-I"
    "" [search_list]] -c
    [resolve %.c];
  mv %.o [target];
}
```

Third, the link recipe must be changed to include the architecture in the name of the result:

```
[arch]/example: [object_files]
{
  if [not [exists [arch]]] then
    mkdir [arch]
      set clearstat;
  if [exists [target]] then
    rm [target]
      set clearstat;
  [cc] -o [target] [resolve
    [object_files]] -ly -ll;
}
```

The method used to determine the `object_files` variable is the same as before, but the object file names now include the architecture:

```
object_files =
  [fromto %.y [arch]/%.o
    [match_mask %.y [source_files]]]
  [fromto %.l [arch]/%.o
    [match_mask %.l [source_files]]]
  [fromto %.c [arch]/%.o
    [match_mask %.c [source_files]]]
  ;
```

Note that the form of these recipes precludes performing a build in each target architecture simultaneously, because intermediate files in the recipes may clash. However, aegis prevents simultaneous build, for this and other reasons.

8.6.5. Test Implications

Tests will need to know in which directory the relevant binary files reside. The *test_command* field of the project *config* file may be changed from the default

```
test_command =
  "$shell $file_name";
```

to pass the architecture name to the test

---

[22] Some sites manage by running *rdate*(8) from *cron*(8) every 15 minutes.

[23] A tree the same shape as the source tree makes navigation easier, and users need not think of file names unique across all directories.

```
test_command =
  "$shell $file_name $arch";
```

This will make the architecture name available as `$1` within the shell script. Tests should fail elegantly when the architecture name is not given, or should assume a sensible default.

8.6.6. Cross Compiling

If you are cross compiling to a number of different target architectures, you would not use aegis' heterogeneous development support, since it depends on the *uname*(2) system call, which would tell it nothing useful when cross compiling. In this case, simply write the DMT configuration file to cross compile to all architectures in every build.

8.6.7. File Version by Architecture

There is no intention of ever providing the facility where a project source file may have different versions depending on the architecture, but all of these versions overload the same file name[24].

The same effect may be achieved by naming files by architecture, and using the DMT to compile and link those files in the appropriate architecture.

This has the advantage of making it clear that several variations of a file exist, one for each architecture, rather than hiding several related but independent source files behind the one file name.

[24] Some other SCM tools provide a repository with this facility.

8.7. Writing Tests

This section describes a number of things you can do to write better tests, and some pitfalls to be avoided.

There are a number of suggestions for portability of tests; this will definitely be important if you are writing software to publish on USENET or for FTP. Portability is often required *within* an organization, also. Examples include a change in company policy from one 386 UNIX to another (e.g. company doesn't like Linux, now you must use AT&T's SVR4 offering), or the development team use *gcc* until the company finds out and forces you to use the prototype-less compiler supplied with the operating system.

8.7.1. Bourne Shell

The aegis program mandates that all tests be Bourne shell scripts. This is because this shell is available on all flavours of the UNIX operating system. The script files need not have execute permissions set, because the aegis program always invokes them as

```
sh filename
```

so tests should not expect command line arguments. The test is not passed the name of the project nor the number of the change.

This means that if you can write in in a shell script, you can test it. This includes such things as client-server model interfaces, and multi-user synchronization testing.

Some indication that the test script is a Bourne shell script is a good idea. While many systems accept that a first line starting with a colon is a Bourne shell "magic number", a more widely understood "magic number" is

```
#! /bin/sh
```

as the first line of the script file.

8.7.2. Current Directory

Tests are always run with the current directory set to either the development directory change under test when testing a change, or the integration directory when integrating a change, or the baseline when performing independent tests.

A test must not make assumptions about where it is being executed from, except to the extent that it is somewhere a build has been performed. A test must not assume that the current directory is writable, and must not try to write to it, as this could damage the source code of a change under development, potentially destroying weeks of work.

8.7.3. Check Exit Status

A test script should check the exit status of every single command, even those which cannot fail. Do not rely on, or use, the *set -e* shell option (it provides no ability to clean up on error).

Checking the exit status involves testing the contents of the **$?** shell variable. Do not use an *if* statement wrapped around an execution of the program under test as this will miss core dumps and other terminations caused by signals.

Checking the exit status of every command in the script ensures that strange permission settings, or disk space problems, will cause the test to fail, rather than plow on and produce spurious results.

8.7.4. Trap Interrupts

Use the *trap* statement to catch interrupts 1 2 3 and 15 an cause the test to fail. This should perform any cleanup the test requires (such as removing the temporary directory; see next item).

8.7.5. Temporary Directory

Tests should create a temporary directory in */tmp* and then *cd* into this directory.

This tends to isolate any vandalism that the program under test may indulge in, and serves as a place to write temporary files. At the end of the test, it is sufficient to *cd* out of the temporary directory and then *rm -rf* it, rather than track and remove all test files which may or may not be created.

8.7.6. PAGER

If the program under test invokes pagers on its output, a la *more*(1) et al, it should be coded to use the PAGER environment variable. Tests of such programs should always set PAGER to *cat* so that tests always behave the same, irrespective of invocation method (either by aegis or from the command line).

8.7.7. [test]

You should always use the *test* command, rather than the square bracket form, as many systems do not have the square bracket form, if you publish to USENET or for FTP.

8.7.8. Auxiliary Files

If a test requires extra files as input or output to a command, it must construct them itself, using *here* documents (see *sh*(1) for more information).

It is almost impossible to determine the location of an auxiliary file, if that auxiliary file is part of the project source. It could be in either the change under test or the baseline.

8.7.9. New Test Templates

It is possible to specify most of the repetitious items above in a *file template* used every time a user creates a new test. See the *aent*(1) command for more information.

Having the machine do it for you means that you are more likely to do it.

9. Appendix A: New Project Quick Reference

For those of you too impatient to read a whole great big document about how to use the aegis program, this appendix gives a quick look at how to place a project under aegis.

The style here is an itemized list. It does not try to be exhaustive. For exact details on how to use the various aegis commands, you should see the manual pages, ditto for the formats and contents of some files.

Probably the quickest start of all is to copy an already existing project. The project used in chapter 2 is complete, assuming you use the author's "cook" dependency maintenance tool. The entirety of this example may be found, if slightly obfuscated, in the aegis source file *test/00/t0011a.sh* distributed with aegis.

9.1. Create the Project

The *aenpr* command is used to create a project. You must supply the name on the command line. The name should be ten characters or less, six characters or less if you want version numbers included.

The user who creates the project is the owner of the project, and is set as the administrator. The default group of the user who created the project is used as the project's group.

You may want to have a user account which owns the project. You must create the project as this user, and then use the *aena* and *aera* commands to add an appropriate administrator, and remove the owning user as an administrator. After this, the password for the owning user may be disabled, because the aegis program will, at appropriate times, set file ownership to reflect project ownership or execute commands on behalf of the project owner *as* the project owner.

9.1.1. Add the Staff

The *aend* command is used to add developers. The *aenrv* command is used to add reviewers. The *aeni* command is used to add integrators. These commands may only be performed by a project administrator.

You will still have to do this, even if the person who created the project will be among these people, or even be all of these people.

9.1.2. Project Attributes

The *aepa* command is used to change project attributes. These attributes include the description of the project, and booleans controlling whether, for example, developers may review their own work.

The project attributes file is described in the *aepattr*(5) manual entry.

9.2. Create Change One

The *aenc* command is used to create a new change. You will need to construct a change attributes file with your favorite text editor before running this command.

The change attributes file is described in the *aecattr*(5) manual entry.

9.3. Develop Change One

This is the most grueling step. Indeed, the integration step will probably reveal things you missed, and you may return to the *being developed* state several times.

One of the people you nominated as a developer will have to use the *aedb* command to commence development of change 1. The *aecd* command can be used to change directory into the just-created development directory.

Add files to the change. The *aenf* command is used to create new files. If you don't use *aenf* then the aegis program has no way of knowing whether that file lying there in the development directory is significant to the project, or just a shopping list of the groceries you forgot to buy yesterday.

One particular new file which *must* be created by this change is the *config* file. This tells the aegis program what history mechanism you wish to use, what dependency maintenance command to use, what file difference tools to use, and much more. The *aepconf*(5) manual entry describes this file.

If you are going to use the "cook" dependency maintenance tool, another new file you will need to create in this change is the "Howto.cook" file. Some other tool will want some other rules file.

You probably have a prototype or some other "seed" you have sort-of working. Create new files for each source file and *then* copy the files from wherever they are now into the development directory.

Use the *aeb* command to build the change. It will need to build cleanly before it can advance to the next step.

Use the *aed* command to difference the change. It will need to difference cleanly before it can advance to the next step.

Use the *aent* command to add new tests to the command. It will need to have tests before it can advance to the next step.

Most existing projects don't have formal tests. These tests will form a regression test-bed, used to make sure that future changes never compromise existing functionality.

Use the *aet* command to test the change. It will need to test cleanly before it can advance to the next step.

Once the change builds, differences and tests cleanly, use the *aede* command to end development. At this point, the mode of the files will be changed to read only, preventing accidental modification of the files.

9.4. Review The Change

One of the people nominated as reviewers will have to run the *aerpass* command to say that the change passed review.

The aegis program does not mandate any particular review mechanism: you could use a single peer to do the review, you could use a panel, you could set the project so that developers may review their own work and effectively eliminating the review step. In projects with as few as two people, it is always beneficial for someone other than the developer to review changes.

Should a reviewer actually want to *see* the change, the *aecd* command may be used to change directory to the development directory of the change. The difference files all end with a "comma D" suffix, so the

```
more `find . -name "*,D" -print | sort`
```

command may be used to search them out and see them. This is probably fairly useless for the first change, but is vital for all subsequent changes. There is a supplied alias for this command, it is *aedmore* and there is a similar *aedless* alias if you prefer the *less* (1) command.

There are some facts that a reviewer *knows* because otherwise the change would not be in the "being reviewed" state: • the change compiles cleanly, • the change passes all of its tests. Other information about the change may be obtained using the "change_details" variation of the *ael* command.

The *aerfail* command may also be used by reviewers to fail reviews and return a change to the developer for further work; the reviewer must supply a reason for the change history to record for all time. Similarly, the *aedeu* command may be used by the developer to resume development of a change at any time before it is integrated; no stated reason is required.

9.5. Integrate the Change

A person nominated as an project integrator then integrates the change. This involves making a copy of the integration directory, applying the modifications described by the change to this integration directory, then building and testing all over again.

This re-build and re-test is to ensure that no special aspect of the developers environment influenced the success up to this point, such as a unique environment variable setting. The re-build also ensures that all of the files in the baseline, remembering that this includes source files and all other intermediate files required by the build process, ensures that all of these files are consistent with each other, that the baseline is self-consistent. The definition of the baseline is that it passes its own tests, so the tests are run on the baseline.

Use the *aeib* command to begin integration.

The *aeb* command is used to build the integration copy of the change.

The *aet* command is used to test the integration copy of the change.

On later changes, the integration may also require the *aet -bl* command to test the change against the baseline. This tests ensures that the test *fails* against the baseline. This failure is to ensure that bug fixes are accompanied by tests which reproduce the bug initially, and that the change has fixed it. New functionality, naturally, will not be present in the old baseline, and so tests of new functionality will also fail against the old baseline.

Later changes may also have the regression tests run, using the *aet -reg* command. This can be a very time-consuming step for projects with a long history, and thus a large collection of tests. The *aet* command can also be used to run "representative" sets of existing tests, but a full regression

test run is recommended before a major release, or, say, weekly if it will complete over the weekend. This command is also available to developers, so that they have fewer surprises from irate integrators.

The integrator may use the *aeifail* command to return a change to its developer for further work; a reason must be supplied, and should include relevant excerpts from the build log in the case of a build failure (not the *whole* log!), or a list of the tests which failed for test failures.

The *aeipass* command may be used to pass an integration. When the change passes, the file histories are updated. In the case of the first change, the history is created, and problems with the *config* file's history commands will be revealed at this point. The integration won't pass, and should be failed, so that the developer may effect repairs. There are rarely problems at this point for subsequent changes, except for disk space problems.

Once the history is successfully updated, aegis renames the integration directory as the baseline, and throws the old baseline away. The development directory is deleted at this time, too.

9.6. What to do Next

There, the first change is completed. The whole cycle may now be repeated, starting at "Create Change," for all subsequent changes, with very few differences.

It is recommended that you read the *Change Development Cycle* chapter for a full worked example of the first four changes of an example project, including some of the twists which occur in real-world use of aegis.

Remember, too, the definition:

> **aegis** (ee.j.iz) *n.* a protection, a defence.

It is not always the case that aegis exists to make life "easier" for the software engineers. The goal is to have a baseline which always "works", where "works" is defined as passing all of its own tests. Wherever possible, the aegis program attempts to be as helpful and as unintrusive as possible, but when the "working" definition is threatened, the aegis program intrudes as necessary. (Example: you can't do an integrate pass without the integration copy building successfully.)

All of the "extra work" of writing tests is a long-term win, where old problems never again reappear. All of the "extra work" of reviewing changes means that another pair of eyes sights the code and finds potential problems before they manifest themselves in shipped product. All of the "extra work" of integration ensures that the baseline always works, and is always self-consistent. All of the "extra work" of having a baseline and separate development directories allows multiple parallel development, with no inter-developer interference; and the baseline always works, it is never in an "in-between" state. In each case, not doing this "extra work" is a false economy.

10. Appendix B: Glossary

The following is an alphabetical list of terms used in this document.

administrator
: Person responsible for administering a *project* .

awaiting_development
: The state a change is in immediately after creation.

awaiting_integration
: The state a change is in after it has passed review and before it is integrated.

baseline
: The repository; where the project master source is kept.

being developed
: The state a change is in when it is being worked on.

being integrated
: The state a change is in when it is being integrated with the baseline.

being reviewed
: The state a change is in after it is developed.

change
: A collection of files to be applied as a single atomic alteration of the baseline.

change number
: Each *change* has a unique number identifying it.

completed
: The state a change is in after it has been integrated with the baseline.

delta number
: Each time the *aeib* (1) command is used to start integrating a *change* into the *baseline* a unique number is assigned. This number is the delta number. This allows ascending version numbers to be generated for the baseline, independent of change numbers, which are inevitably integrated in a different order to their creation.

dependency maintenance tool
: A program or programs external to aegis which may be given a set of rules for how to efficiently take a set of source files and process them to produce the final product.

DMT
: Abbreviation of Dependency Maintenance Tool.

develop_begin
: The command issued to take a change from the *awaiting development* state to the *being developed* state. The change will be assigned to the user who executed the command.

develop_begin_undo
: The command issued to take a change from the *being developed* state to the *awaiting development* state. The change must have no files associated with it.

develop_end
: The command issued to take a change from the *being developed* state to the *being reviewed* state. The change must be known to build and test successfully.

develop_end_undo
: The command issued to take a change from the *being reviewed* state back to the *being developed* state. The command must be executed by the original developer.

developer
: A member of staff allowed to develop changes.

development directory
: Each change is given a unique development directory in which to edit files and build and test.

history tool
: A program to save and restore previous versions of a file, usually by storing edits between the versions for efficiency.

integrate_pass
: The command used to take a change from the *being integrated* state to the *completed* state. The change must be known to build and test successfully.

integrate_begin
: The command used to take a change from the *awaiting integration* state to the *being integrated* state.

integrate_begin_undo
: The command used to take a change from the *being integrated* state to the *awaiting integration* state.

integrate_fail
: The command used to take a change from the *being integrated* state back to the *being developed* state.

integration
: The process of merging the *baseline* with

the *development directory* to form a new baseline. This includes building and testing the merged directory, before replacing the original *baseline* with the new merged version.

integration directory
: The directory used during *integration* to merge the existing *baseline* with a change's *development directory*.

integrator
: A staff member who performs *integration*s.

new_change
: The command used to create new changes.

new_change_undo
: The command used to destroy changes.

review_fail
: The command used to take a change from the *being reviewed* state back to the *being developed* state.

review_pass
: The command used to take a change from the *being reviewed* state to the *awaiting integration* state.

reviewer
: A person who may review *changes* and either pass or fail them (*review_pass* or *review_fail* respectively).

state
: Each *change* is in one of six states: *awaiting development*, *being developed*, *being reviewed*, *awaiting integration*, *being integrated* or *completed*.

state transition
: The event resulting in a *change* changing from one state to another.

11. Appendix D: Why is Aegis Set-Uid-Root?

The goal for aegis is to have a project that "works". There is a fairly long discussion about this earlier in this User Guide. One of the first things that must be done to ensure that a project is not subject to mystery break downs, is to make sure that the master source of the project cannot be in any way altered in an unauthorized fashion. Note this says "cannot", a stronger statement than "should not".

Aegis is more complicated than, say, set-group-id RCS, because of the flaw with set-group-id: the baseline is writable by the entire development team, so if a developer says "this development process stinks" he can always bypass it, and write the baseline directly. This is a *very* common source of project disasters. To prevent this, you must have the baseline read-only, and so the set-group-id trick does not work. (The idea here is that there is *no* way to bypass the QA portions of the process. Sure, set-group-id will prevent accidental edits on the baseline, if the developers are not members of the group, but it does not prevent *deliberate* checkin of unauthorized code. Again, the emphasis is on "cannot" rather than "should not".)

Also, using the set-group-id trick, you need multiple copies of RCS, one for each project. Aegis can handle many projects, each with a different owner and group, with a single set-uid-root executable.

Aegis has no internal model of security, it uses UNIX security, and so becomes each user in turn, so UNIX can determine the permissions.

11.1. Examples

Here are a few examples of the uid changes in common aegis functions. Unix "permission denied" errors are not shown, but it should be clear where they would occur.

new change (aenc):
: become invoking user and read (edit) the change attribute file, validate the attribute file, then become the project owner to write the change state file and the project state file.

develop begin (aedb):
: become the project owner and read the project state file and the change state file, to see if the change exists and is available for development, and if the invoking user is on the developer access control list. Become the invoking user, but set the default group to the project group, and make a development directory. Become the project again, and update the change state file to say who is developing it and where.

build (aeb):
: become the project owner to read the project and change state files, check that the invoking user is the developer of the change, and that the change is in the *being developed* state. Become the invoking user, but set the default group to the project group, to invoke the build command. Become the project owner to update the change state to remember the build result (the exit status).

copy file into change (aecp):
: become the project owner to read the project and change state files. Check that the invoking user is the developer and that the change is in the *being developed* state, and that the file is not already in the change, and that the file exists in the baseline. Become the invoking user, but set the default group to the project group, and copy the file from the baseline into the development directory. Become the project owner, and update the change state file to remember that the file is included in the change.

integrate pass (aeip):
: become the project owner to read the project and change state files. Check that in invoking user is the integrator of the change, and that the change is in the *being integrated* state. Become the integrator to collect the integrate fail comments, then become the project owner to delete the integration directory, then become the developer to make the development directory writable again. Then become the project owner to write the change state file, to remember that the change is back in the *being developed* state.

All the mucking about with default groups is to ensure that the reviewers, other members of the same group, have access to the files when it comes time to review the change. The umask is also set (not shown) so that the desired level of "other" access is enforced.

As can be seen, each of the uid change either (a) allows UNIX to enforce appropriate security, or (b) uses UNIX security to ensure that unauthorized tampering of project files cannot occur.

Each project has an owner and a group: members of the devlopment team obtain read-only access to the project files by membership to the appropriate group, to actually alter project files requires that the development procedure embodied by aegis is carried out. You could have a single account (not a user's account, usually, for obvious conflicts of interest) which owns all project sources, or you could have one account per project. You can have one group per project, if you don't want your various projects to be able to see each other's work, or you could have a single group for all projects.

11.2. Source Details

For implementation details, see the `os_become*` functions in the *aegis/os.c* file. The `os_become_init` function is called very early in `main`, in the *aegis/main.c* file. After that, all accesses are bracketed by `os_become` and `os_become_undo` function calls, sometimes indirectly as `project_become*` or `user_become*`, etc, functions. You need to actually become each user, because root is not root over NFS, and thus `chown` tricks do not work, and also because duplicating kernel permission checking in aegis is a little non-portable.

Note, also, that most system calls go via the interface sescribed in the *aegis/glue.h* file. This isolates the system calls for UNIX variants which do not have the `seteuid` function, or do not have a correctly working one. The code in the *aegis/glue.c* file spawns "proxy" process which uses the `setuid` function to become the user and stay that way. If the `seteuid` function is available, it is used instead, making aegis more efficient. This isolation, however, makes it possible for a system administrator to audit the aegis code (for trojans) with some degree of confidence. System calls should be confined to the *aegis/log.c*, *aegis/pager.c*, *aegis/os.c* and *aegis/glue.c* files. System calls anywhere else are probably a Bad Thing.

Table of Contents