SE 3XA3: Test Plan
Rogue Reborn

Group #6, Team Rogue++

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Table 1: **Revision History**

Date	**Version**	**Notes**
12/06/16	0.1	Initial Draft
12/06/16	0.2	Added Automated Tests To PlayerChar
12/06/16	0.3	Added FR Evaluation
12/07/16	0.4	Added Introduction
12/07/16	0.5	Finished Automated Tests
12/07/16	0.6	Added Metrics and Comparison
12/07/16	0.7	Added NFR Evaluation
12/07/16	0.8	Added Unit Testing
12/08/16	0.9	Added Changes Due to Testing
12/08/16	1.0	Proofread and Editing

1 Introduction

1.1 Overview

The primary objective of this document is to provide a comprehensive report detailing the results of the verification process applied to the Rogue Reborn project. Interested parties are welcome to analyze this paper as a means of evaluating the success of the final application with respect to the requirements described in the SRS and tests prescribed in the Test Plan. After reviewing the document, the reader should understand the strengths and weaknesses of the Rogue Reborn project relative to the expectations of the client.

1.2 Sections

A brief description of the Test Reports sections is provided below:

§1 Brief overview of the Test Report

§2 Functional evaluation of Rogue Reborn

§3 Non-functional evaluation of Rogue Reborn

§4 Description of relationship to original *Rogue* with respect to testing

§5 Explanation of unit testing in Rogue Reborn

§6 List of changes that were performed as a consequence of testing

§7 Tabular depiction of automated tests

§8 Justification of test files with respect to functional requirements

§9 Decomposition of modules and trace to test files

§10 Summary of code coverage metrics

2 Functional Requirements Evaluation

With the implementation of the application drawing to close, it can be witnessed that Rogue Reborn is functionally complete. One of the primary driving forces behind reaching is goal is the elaborate unit testing suite. It was discovered that most of these tests were quite useful and discovered bugs as well as logic errors that might have otherwise gone unnoticed; these tests are discussed below. However, there were also many tests that were relatively mundane, generic, or crucial enough to have already been satisfied before testing was even considered. As a result, those tests will not be explicitly mentioned given that their complete satisfaction has already been verified countless times.

The list below refers to each functional requirement by its numerical identifier, as listed in the SRS.

FR.16: While performing tests over the Level module, a strange anomaly led to one test constantly failing. This test later revealed that the player character did not actually begin at the first level. Due to an off-by-one error and slight miscommunication between developers, the current level depth of the player character was i in some places and $i + 1$ in others. As soon as this bug was uncovered, the problem was remedied globally across the code.

FR.19: Whenever the player uncovers a new dungeon level (including the very first level), an algorithm decides on the player character's initial position. Although this algorithm appeared flawless in the past, there was actually a slight chance of placing the player character in an unreachable location, (i.e., surrounded by walls and therefore doomed forever). With the automatic tests running thousands upon thousands of simulations, this glitch was quickly exposed and resolved.

FR.35: Some monsters in Rogue Reborn follow a simple AI decision algorithm consisting of steps such as:

1. Check if the monster is sleeping or passive
2. If the monster is aggravated, attempt to chase the player character
3. If the monster is aggravated and adjacent to the player character, attempt to hit the player character

Although this is a very simple recipe and is easy to both invent and implement, several enemies in Rogue Reborn go beyond such simple schemes. For instance, some monsters do not seek to kill the player character, but rather steal their precious items or gold. One such pest is the Leprechaun (depicted by the "L" symbol). The Leprechaun necessitated the implementation of a variety of new methods, such as `getNearestGold()`. The tests related to this function revealed some very serious performance issues in the pathfinding algorithm used throughout the project, such as infinite path traces. It also revealed another bug in which the coordinates of several level features (items mostly) were accidentally set to `(0,0)`, rendering them impossible to reach. These issues were due in part by the assumption that all items are placed on tiles reachable from the player character. Fortunately, thanks to the various tests that were implemented, these bugs were fixed.

FR.39: Working with C++ was extremely beneficial in some respects, but also possessed some drawbacks. An anomaly in the way C++ handles integers revealed a very serious bug in the code, in which the player character's armor could reach ridiculous high values and essentially render them invincible. By simulating every possible Armor that can be instantiated, this bug was caught and patched. To elaborate, the bug existed because a particular integer had a possibility of never being assigned a value.

3 Non-Functional Requirements Evaluation

The following subsections evaluate the significant non-functional qualities of Rogue Reborn. To simplify notation, NFRT i is used to denote "Non-Functional Requirements Test # i" from the Test Plan document. Unfortunately, the usability and playtesting surveys referenced in NFRT 1, NFRT 2, NFRT 4, NFRT 7, NFRT 9, NFRT 10, NFRT 12, and NFRT 14 were not performed as a direct consequence of the time constraints imposed on the project (the Gantt Chart schedules this survey to be released in early January 2017). Another hindering factor is the sophisticated software environment required for compilation: publicly distributing a single executable file is not feasible since Rogue Reborn makes use of a library that exclusively compiles for Linux at the present moment. Despite these inconveniences, an effort has been made to mention several weaker versions of these tests under their corresponding sections.

3.1 Usability and Aesthetics

Overall, the visual appearance of the application was well-received and was universally praised as an improvement over the original *Rogue*. This conclusion was derived from the interactions between the Rogue++ team and the *SFWRENG 3XA3* instructor staff, as well as informal conversations with other colleagues. Unfortunately, the usability survey described in NFRT 1 will be carried out in the future, so the impressions of the general public are not yet known.

Since the usability of the original *Rogue* was relatively poor due to its arbitrary key bindings, the Rogue++ team took deliberate actions to improve this area. Specifically, the application featured arrow key bindings for the player character movements in order to accommodate a more standard and intuitive keyboard layout. Additionally, Rogue Reborn featured a convenient help menu inside the game that listed all actionable keys and their corresponding interpretations. However, due to the sheer quantity of key bindings, Rogue Reborn was *not* successful in alleviating this issue completely. With respect to the Test Plan, a report detailing NFRT 3 is given below.

Non-Functional Requirement Test # 3 Report	
Execution:	All strings in the Rogue Reborn source code were programmatically extracted and stored in a text file for later inspection with Microsoft Word. The Python script used to populate the text file is located at src/misc/strextract.py.
Results:	The aforementioned script discovered approximately 1400 strings. After manually verifying the grammatical correctness and spelling of each string, it was determined that the GUI output is free of linguistic errors.

3.2 Performance

In general, the technical performance of the Rogue Reborn client was exceptional as a consequence of the developers' decision to use C++ as opposed to a less efficient language such as Python or Java. According to *libtcod*, the application managed to average over 120 FPS (Frames Per Second) and delivered a smooth experience even while on a VM (Virtual Machine). During the final stages of development, the Rogue++ team decided to profile the application using the GDB (GNU Debugger) with respect to peak memory usage and pleasantly discovered that the maximum amount of RAM consumed by Rogue Reborn was 1 MB. With respect to the Test Plan, a report detailing NFRT 5 and NFRT 6 is portrayed below.

Non-Functional Requirement Test # 5 Report	
Execution:	The Rogue Reborn application was compiled with a special debug parameter that enabled particular sections of the MasterController module to measure the average maximum execution time between successive frames.
Results:	The average execution time between successive user actions appeared to stabilize around 20 ms. Clearly, this is appreciably lower than the maximum allowable delay of MINIMUM_RESPONSE_SPEED (currently $\sim$ 30 ms).

Non-Functional Requirement Test # 6 Report	
Execution:	The following regular expression was applied across the source code to extract all integer-typed declarations: `(unsigned|int|long)\s+[A-Za-z]+\s*(,|;|=.*)\s*` The Python script that performed the declaration extraction is located at src/misc/intdeclare.py.
Results:	The aforementioned script identified approximately 170 candidate declarations. Among these, there were no obvious candidates for integer overflow.

3.3 Robustness, Maintainability, and Compatibility

As discussed during the formal presentation, the Rogue Reborn project excelled in the domains of robustness and maintainability. One justification for this claim is that the developers implemented a CI (Continuous Integration) pipeline to immediately flag deficient commits. In addition, compiling the Rogue Reborn source code did not generate any warnings and the system documentation is thorough, expansive, and relevant. That being said, Rogue Reborn has yet to be released to the playtester community. As such, it is likely that several undiscovered bugs still reside within the code base.

Regarding compatibility, the project was significantly less successful: only Linux distributions are supported and SDL (Simple Directmedia Layer) must be installed on the developer's machine to compile the application (**?**). As well, the compilation and execution of Rogue Reborn was only tested on Intel x64 processors (the application is not tested on other brands or architectures). With respect to the Test Plan, a report detailing NFRT 8, NFRT 11, and NFRT 13 is conveyed below.

Non-Functional Requirement Test # 8 Report	
Execution:	The high score file was manually edited by a developer to include more than HIGH_SCORE_CAPACITY records.
Results:	Only the top HIGH_SCORE_CAPACITY records with the highest score were displayed on the RIP Screen; the rest of the records were internally acknowledged but otherwise ignored.

Non-Functional Requirement Test # 11 Report	
Execution:	All documented "Bug" issues on the Rogue Reborn GitLab page were examined to ensure they were closed within 30 days of their creation.
Results:	A total of 10 issues were discovered under the "Bug" label; all of these entries were closed within two weeks of their posting.

Non-Functional Requirement Test # 13 Report	
Execution:	The high score file was manually edited by a developer such that several records violated the expected record format.
Results:	All valid records were processed and displayed on the RUP Screen; the nonsensical records were internally acknowledged but otherwise ignored.

3.4 Legality and Safety

Every public software project should include a license to govern the software's terms of use, development, and distribution. Rogue Reborn was no exception and thus contained the licensing agreement from the original *Rogue*.

Regarding health and safety, the Rogue++ team was primarily concerned with the possibility of inducing a seizure by displaying two successive frames with excessively different contrasts. With respect to the Test Plan, a report detailing NFRT 15 is pictured below.

Non-Functional Requirement Test # 15 Report	
Execution:	Two consecutive frames with the largest estimated contrast difference were captured and later processed with a Python script to compute their respective monochrome luminosities. All resources pertaining to this test are located in the src/misc/luminosity directory.
Results:	The output of lumtester.py indicated that the frame illustrated in minlum.png was characterized by an average luminosity of 0.03105, while the maxlum.png frame possessed an average luminosity of 0.59774. Since the difference between these two values is 0.56669 and is therefore less than LUMINOSITY_DELTA, the application is relatively safe for epileptic users (although a cautionary notice should be included in the final distribution package).

4 Comparison to Existing Implementation

From an enveloping perspective, the project is very much reminiscent of the original implementation. This successful correlation can be attributed to the satisfaction of the functional and non-functional requirements that were set at the start of the project, most of which were directly influenced by features of the original game. By noting key features of the original game and expressing them as functional requirements, we were able to define a very precise target for functionality. With the same technique being applied to the non-functionals, the project was made very well defined.

Despite the similarities between the projects, there were some differences. Our implementation added several features to the game, which we feel added to the overall quality. One example of such improvements was color: the original game was colorless, and in today's standards could be considered tame, mundane, or even boring. This is of course untrue, as anyone who has played the original can tell, but we strongly feel that the colors of our implementation add life and flavor to the original. We detailed our expected improvements primarily as non-functional requirements, as those tended to have a more applicable scope to the changes we had in mind.

The combination of requirements based off of the original implementation and the faithful improvements we had made to the project led to a final result that is very similar to the original, but better. As a team we can truthfully say that we have taken the original product and improved it. It is Rogue - Reborn.

5 Unit Testing

As a means of verifying the implementation of various functions and components, the Rogue++ developers devised a suite of unit tests. Unit testing was employed as a consequence of its superior ability to localize errors and encourage contributors to write code that is highly modular and relatively free of side effects. Broadly speaking, the Rogue Reborn unit tests were designed to gain confidence in the code with respect to the satisfaction of the functional requirements.

To mitigate the dependencies and significant overhead of integrating a professional unit testing framework, the Rogue Reborn team decided to code their own custom test runner. The implemented solution required all tests to extend an abstract class `Testable` with the interface described in Figure 1. This restriction enabled the test driver `test.main.cpp` to invoke all of the concrete unit test classes in a uniform manner. Finally, to ensure that the unit tests remained relevant and visible throughout development, the CI pipeline included a stage to build, run, and evaluate the output of the testing executable.

Figure 1: **Testable Class Interface**

```
class Testable {
   public:
      // Test entry point
      virtual void test() = 0;

      void assert(bool condition, std::string comment);
      void comment(std::string comment);
};
```

Regarding coverage, the tests encompassed all item types and abilities, various player actions and monster mechanics, virtually all level generation and processing algorithms, and even several UI functions. As depicted in Figure 1, each test assertion was also complemented with a comment to explain the purpose of the test. For the convenience of the reader, a descriptive summary of every implemented test is included in the Automated Testing section of this report.

On the whole, these tests served to guarantee a minimal level of functionality for each documented feature across the builds. Naturally, the suite did not consider the non-functional requirements of the project since these qualities lend themselves better to manual testing.

6 Changes Due to Testing

Since the Rogue++ developers did not embrace a TDD (Test-Driven Development) methodology, all of the unit tests were designed to catch flaws in existing code rather than guide the development of new code. As such, the unit testing phase of the Rogue Reborn application did not spawn any new features but instead served to minimize the quantity of programming errors.

One area that the greatly benefited from the unit tests were the Item modules, as numerous bugs were caught with respect to the initialization of particular variables (or lack thereof). For example, there was an error where a disenchanted Armor object would claim a completely nonsensical effective armor value since the enchantment variable was never initialized. Another portion of the tests detected several logic flaws (e.g., the negation of a condition was accidentally checked) present in the effects of certain items. For instance, the *Wand of Cold* was reveled to deal critical damage to ice monsters and almost no damage to fire monsters as a consequence of a negated condition.

With respect to the non-functional testing, the most significant changes arose in the modules that interacted with the file system. In particular, the RipScreen module was drastically improved by implementing input validation checks to detect anomalies in the high score record file. Additionally, although the actual testing itself did not compel any changes, various GUI elements in Rogue Reborn were enhanced (such as the help screen and splash screen) in preparation for future usability tests.

Aside from catching implementation mistakes, the testing process also influenced the architecture and design of the software system. To facilitate unit testing, various modules such as PlayState were revamped to improve modularization. Other modules introduced blocks of code that were activated by a special `#define DEBUG` directive; these sections either displayed debug information to standard output or modified conditionals to guarantee a particular trace through a function. Finally, as mentioned in the Unit Testing section of this document, the CI pipeline of the project was also modified to accommodate the execution of unit tests after each commit to the repository.

7 Automated Testing

7.1 Automated Testing Strategy

With respect to the Unit Testing section of this document, a custom testing framework was developed for the Rogue Reborn project. A series of files following the naming convention `test.<Class Name>.cpp` were created and contained the unit tests specific to the `<Class Name>` class. Whenever a change was pushed to the Rogue Reborn repository, all of these tests were run and their corresponding output was analyzed by a Python script to determine if any failures occurred.

7.2 Specific System Tests

The following is a list of all system tests in the project.

Name: **Initial State:** **Input:** **Expected Output:**	Amulet Construction None Coordinate, context value Amulet object in valid initial state
Name: **Initial State:** **Input:** **Expected Output:**	Armor Construction 1 None Coordinate Armor object in valid initial state
Name: **Initial State:** **Input:** **Expected Output:**	Armor Construction 2 None Coordinate, Context value, type value Armor object in valid initial state
Name: **Initial State:** **Input:** **Expected Output:**	Armor Identification Cursed Armor None Verification that Armor is identified
Name:	Armor Curse

Initial State:	Cursed Armor
Input:	None
Expected Output:	Verification that Armor is cursed
Name:	Armor Enchantment
Initial State:	Cursed Armor
Input:	Curse level
Expected Output:	Verification that Armor enchantment is correct
Name:	Armor Rating
Initial State:	Cursed Armor
Input:	None
Expected Output:	Verification that Armor rating is correct
Name:	Coordinate Ordering
Initial State:	None
Input:	(0,0) Coordinate and (1,1) Coordinate
Expected Output:	Verification that (0,0) <(1,1)
Name:	Coordinate Equality
Initial State:	None
Input:	Two (0,0) Coordinates
Expected Output:	Verification that the two inputs are equal
Name:	Coordinate Inequality
Initial State:	None
Input:	(0,0) Coordinate and (1,1) Coordinate
Expected Output:	Verification that the two inputs are not equal
Name:	Coordinate Addition
Initial State:	None
Input:	(2,3) Coordinate and (1,2) Coordinate
Expected Output:	(3,5) Coordinate
Name:	Coordinate Subtraction
Initial State:	None
Input:	(2,3) Coordinate and (1,2) Coordinate

Expected Output:	(1,1) coordinate
Name: **Initial State:** **Input:** **Expected Output:**	Feature Construction None Symbol, Coordinate, visibility, TCODColor Feature object in valid initial state
Name: **Initial State:** **Input:** **Expected Output:**	Feature Symbol Check Feature with given symbol Symbol Verification that Feature's symbol matches given symbol
Name: **Initial State:** **Input:** **Expected Output:**	Feature Invisibility Check Invisible Feature None Verification that Feature is invisible
Name: **Initial State:** **Input:** **Expected Output:**	Feature Visibility Check Visible Feature None Verification that Feature is visible
Name: **Initial State:** **Input:** **Expected Output:**	Feature Location Check Feature with given location Coordinate Verification that Feature's location matches given Coordinate
Name: **Initial State:** **Input:** **Expected Output:**	Food Construction None Coordinate and Context value Food object in valid initial state
Name: **Initial State:** **Input:**	Food Eating Food and PlayerChar objects None

Expected Output:	Verification that Food has increased the player character's food life by an appropriate amount
Name:	GoldPile Construction
Initial State:	None
Input:	Coordinate, gold amount
Expected Output:	GoldPile object in valid initial state
Name:	GoldPile Quantity Check
Initial State:	GoldPile with given amount of gold
Input:	Amount of gold value
Expected Output:	Verification that GoldPile's amount matches given amount
Name:	Item Construction 1
Initial State:	None
Input:	Symbol, Coordinate, Context value, class specifier, name value, psuedoname value, type specifier, stackability value, throwability value, weight value
Expected Output:	Item object in valid initial state
Name:	Item Construction 2
Initial State:	None
Input:	Symbol, Coordinate, context value, class specifier, name value, psuedoname value, type specifier, stackability value, throwability value, weight value
Expected Output:	Item object in valid initial state
Name:	Name Vector Check
Initial State:	None
Input:	Vector of Item names
Expected Output:	Shuffled vector of Item names
Name:	Item Curse Check
Initial State:	Uncursed Item
Input:	None
Expected Output:	Verification that Item is uncursed

Name:	Item Curse/Effect Check 1
Initial State:	Uncursed Item to which the cursed effect has been applied
Input:	None
Expected Output:	Verification that Item is cursed
Name:	Item Curse/Effect Check 2
Initial State:	Cursed Item whose curse effect has been removed
Input:	None
Expected Output:	Verification that Item is uncursed
Name:	Item Unindentified Check
Initial State:	Identified Item
Input:	None
Expected Output:	Verification that Item is unidentified
Name:	Item Identified Check
Initial State:	Unidentified Item
Input:	None
Expected Output:	Verification that Item is identified
Name:	Item Display Name Check 1
Initial State:	Unidentified Item
Input:	Psuedoname
Expected Output:	Verification that Item's display name matches psuedoname
Name:	Item Display Name Check 2
Initial State:	Identified Item
Input:	True name
Expected Output:	Verification that Item's display name matches true name
Name:	ItemZone Containment Check 1
Initial State:	ItemZone with 2 Items
Input:	None

Expected Output:	Verification that ItemZone contains the first Item
Name:	ItemZone Containment Check 2
Initial State:	ItemZone with 2 Items
Input:	None
Expected Output:	Verification that ItemZone contains the second Item
Name:	ItemZone Empty Check
Initial State:	ItemZone with 2 Items
Input:	None
Expected Output:	Verification that ItemZone is not empty
Name:	ItemZone Size Check
Initial State:	ItemZone with 2 Items
Input:	None
Expected Output:	Verification that ItemZone's size is 2
Name:	ItemZone Keybind Check 1
Initial State:	ItemZone with 2 Items
Input:	None
Expected Output:	Verification that first Item is bound to 'a' key
Name:	ItemZone Keybind Check 2
Initial State:	ItemZone with 2 Items
Input:	None
Expected Output:	Verification that second Item is bound to 'b' key
Name:	ItemZone Contents Retrieval 1
Initial State:	ItemZone with 2 Items
Input:	None
Expected Output:	Item map with exactly 1 copy of first Item
Name:	ItemZone Contents Retrieval 2
Initial State:	ItemZone with 2 Items
Input:	None
Expected Output:	Item map with exactly 1 copy of second Item

Name:	ItemZone Removal
Initial State:	ItemZone with 2 Items
Input:	Removal command
Expected Output:	ItemZone with only second Item
Name:	ItemZone Keybind Persistence
Initial State:	ItemZone with first Item removed
Input:	None
Expected Output:	Verification that second Item is still bound to 'b'
Name:	ItemZone Weight Enforcement
Initial State:	Empty ItemZone
Input:	Attempt to add 500 Armor instances to ItemZone
Expected Output:	ItemZone with max-weight worth of Armor
Name:	Level Construction
Initial State:	None
Input:	Depth, PlayerChar object
Expected Output:	Level object in valid initial state
Name:	Level Depth Check
Initial State:	Level with given depth
Input:	Depth value
Expected Output:	Verification that Level's depth matches given value
Name:	Level BFSPerp Diagonal Small
Initial State:	Empty level object
Input:	Pair of Coordinates diagonally adjacent
Expected Output:	Path between Coordinates with expected length, utilizing taxicab movement
Name:	Level BFSPerp Horizontal
Initial State:	Empty level object
Input:	Pair of Coordinates with equal y-values

Expected Output:	Path between Coordinates with expected length, utilizing taxicab movement
Name: **Initial State:** **Input:** **Expected Output:**	Level BFSPerp Vertical Empty level object Pair of Coordinates with equal x-values Path between coordinates with expected length, utilizing taxicab movement
Name: **Initial State:** **Input:** **Expected Output:**	Level BFSDiag Horizontal Empty level object Pair of Coordinates with equal y-values Path between Coordinates with expected length, utilizing orthogonal movement
Name: **Initial State:** **Input:** **Expected Output:**	Level BFSDiag Vertical Empty Level object Pair of Coordinates with equal x-values Path between Coordinates with expected length, utilizing orthogonal movement
Name: **Initial State:** **Input:** **Expected Output:**	Level BFSPerp Diagonal Empty Level object Pair of Coordinates on diagonal line Path between Coordinates with expected length, utilizing taxicab movement
Name: **Initial State:** **Input:** **Expected Output:**	Level Starting Position Empty Level object None Valid starting position Coordinate
Name: **Initial State:** **Input:** **Expected Output:**	Level Adjacent Passable Empty Level object Coordinate List of Coordinates orthogonally adjacent to given coordinate

Name:	Level Path Generation
Initial State:	PlayerChar object and generated Level
Input:	Series of path requests between random Coordinates
Expected Output:	Valid paths between locations
Name:	Level Connectedness
Initial State:	PlayerChar object and generated Level
Input:	Series of path requests between all Rooms in the Level
Expected Output:	Valid paths between each Room
Name:	Level Staircase Check
Initial State:	PlayerChar object and generated Level
Input:	None
Expected Output:	Verification that Level contains a reachable Stairs object
Name:	Level GoldPile Check
Initial State:	PlayerChar object and generated Level
Input:	None
Expected Output:	Verification that Level contains at least one GoldPile
Name:	Monster Construction
Initial State:	None
Input:	Symbol, Coordinate, armor value, HP value, exp value, level value, maxHP value, name value
Expected Output:	Monster object in valid initial state
Name:	Dice-Math 1
Initial State:	None
Input:	1 1-sided die
Expected Output:	Sum of values of 1
Name:	Dice-Math 2
Initial State:	None
Input:	2 1-sided die
Expected Output:	Sum of values of 2

Name:	Dice-Math 3
Initial State:	None
Input:	1 2-sided die
Expected Output:	$1 \leq$ Sum of values ≤ 2
Name:	Dice-Math 4
Initial State:	None
Input:	3 4-sided die
Expected Output:	$3 \leq$ Sum of values ≤ 12
Name:	Mob Armor Check
Initial State:	Mob object
Input:	None
Expected Output:	Verification that Mob armor is in valid range
Name:	Mob HP Check 1
Initial State:	Mob with given HP value
Input:	HP value
Expected Output:	Verification tat Mob has correct HP value
Name:	Mob MaxHP Check
Initial State:	Mob with given MaxHP value
Input:	MaxHP value
Expected Output:	Verification that Mob has correct MaxHP value
Name:	Mob Level Check
Initial State:	Mob with given level value
Input:	Level value
Expected Output:	Verification that Mob has correct level value
Name:	Mob Location Check
Initial State:	Mob with given location
Input:	Coordinate
Expected Output:	Verification that Mob has correct location
Name:	Mob Name Check

Initial State:	Mob with given name
Input:	Name value
Expected Output:	Verification that Mob has correct name
Name:	Mob Set Max HP
Initial State:	Mob with default MaxHP
Input:	`setMaxHP` command with MaxHP value
Expected Output:	Verification that Mob has given MaxHP value
Name:	Mob Set Current HP
Initial State:	Mob with default currentHP
Input:	`setCurrentHP` command with currentHP value
Expected Output:	Verification that Mob has given currentHP value
Name:	Mob Dead Check 1
Initial State:	Living Mob object
Input:	None
Expected Output:	Verification that Mob is alive
Name:	Mob HP Check 2
Initial State:	Living Mob object
Input:	Hit command for $\gg$ Mob's current HP
Expected Output:	Verification that Mob has HP ≤ 0
Name:	Mob Dead Check 2
Initial State:	Dead Mob object
Input:	None
Expected Output:	Verification that Mob is dead
Name:	Monster Construction
Initial State:	None
Input:	Symbol, Coordinate
Expected Output:	Monster object in valid initial state
Name:	Monster Flag/Invisibility
Initial State:	Visible Monster object
Input:	Set Flag command to make Monster invisible

Expected Output:	Invisible Monster object
Name:	Monster Aggravate
Initial State:	Idling, sleeping Monster object
Input:	Aggravate command
Expected Output:	Awake, chasing Monster object
Name:	Monster Damage Calculation
Initial State:	Monster object
Input:	Calculate Damage command
Expected Output:	Correct amount of damage
Name:	Monster Hit Chance
Initial State:	Monster and PlayerChar objects
Input:	Calculate Hit Chance command
Expected Output:	Hit chance in valid range
Name:	Monster Armor Check
Initial State:	Monster object
Input:	None
Expected Output:	Verification that Monster armor is in valid range
Name:	Invisible Monster Name Check
Initial State:	Invisible Monster object
Input:	None
Expected Output:	Verification that Monster has hidden name
Name:	Visible Monster Name Check
Initial State:	Invisible Monster object
Input:	Remove Flag command to make Monster invisible
Expected Output:	Verification that Monster has real name
Name:	Monster Symbol/Level Association
Initial State:	None
Input:	Depth value

Expected Output:	Set of symbols for Monsters that are valid candidates for given depth
Name:	Monster Symbol/Treasure/Level Association
Initial State:	None
Input:	Depth value
Expected Output:	Set of symbols for Monsters that are valid candidates for given depth for a treasure room
Name:	PlayerChar Initial Amulet Check
Initial State:	Just initialized PlayerChar object
Input:	None
Expected Output:	Verification the game does not believe the PlayerChar has the amulet
Name:	PlayerChar Initial HP Check
Initial State:	Just initialized PlayerChar object
Input:	None
Expected Output:	Verification PlayerChar has full hp
Name:	PlayerChar Level-Up Exp
Initial State:	PlayerChar object at initial level
Input:	Exp input into PlayerChar object
Expected Output:	PlayerChar object with increased level
Name:	PlayerChar Level-Up Manual
Initial State:	PlayerChar object
Input:	Level-up command
Expected Output:	PlayerChar object with increased level
Name:	PlayerChar Damage
Initial State:	PlayerChar object at full HP
Input:	Series of damage commands applied to PlayerChar object
Expected Output:	PlayerChar object with less than full HP
Name:	PlayerChar Unarmed 1

Initial State:	Unarmed PlayerChar object
Input:	Calculate Damage command
Expected Output:	0 damage value
Name:	PlayerChar Armed
Initial State:	PlayerChar object armed with Weapon
Input:	Calculate Damage command
Expected Output:	Damage value ¿ 0
Name:	PlayerChar Stow Weapon
Initial State:	PlayerChar object armed with uncursed weapon
Input:	Remove Weapon command
Expected Output:	PlayerChar object unarmed
Name:	PlayerChar Unarmed 2
Initial State:	Armed PlayerChar object
Input:	Remove Weapon command, then Calculate Damage
Expected Output:	0 damage value
Name:	PlayerChar Remove Non-Armor
Initial State:	PlayerChar object with no Armor
Input:	Remove Armor command
Expected Output:	Boolean indicating failure to remove Armor
Name:	PlayerChar Remove Armor
Initial State:	PlayerChar object with uncursed Armor
Input:	Remove Armor command
Expected Output:	PlayerChar object without Armor
Name:	Potion Construction 1
Initial State:	None
Input:	Coordinate
Expected Output:	Potion object in valid initial state
Name:	Potion Construction 2
Initial State:	None
Input:	Coordinate, Item context value, Item type specifier

Expected Output:	Potion object in valid initial state
Name: **Initial State:** **Input:** **Expected Output:**	Potion of Strength PlayerChar object Potion of strength PlayerChar with strength increased by 1
Name: **Initial State:** **Input:** **Expected Output:**	Potion of Restore Strength PlayerChar object with reduced strength Potion of restore strength PlayerChar object with pre-reduction strength
Name: **Initial State:** **Input:** **Expected Output:**	Potion of Healing PlayerChar object with full hp Potion of healing PlayerChar object with maxHP increased by 1
Name: **Initial State:** **Input:** **Expected Output:**	Potion of Extra Healing PlayerChar object with full hp Potion of extra healing PlayerChar object with maxHP increased by 2
Name: **Initial State:** **Input:** **Expected Output:**	Potion of Poison PlayerChar object with strength ¿ 0 Potion of poison PlayerChar object with reduced strength
Name: **Initial State:** **Input:** **Expected Output:**	Potion of Raise Level PlayerChar object with less than max level Potion or raise level PlayerChar object with level + 1
Name: **Initial State:** **Input:** **Expected Output:**	Potion of Blindness PlayerChar object without the blindness condition Potion of blindness PlayerChar object with the blindness condition

Name:	Potion of Hallucination
Initial State:	PlayerChar object without the hallucination condition
Input:	Potion of hallucination
Expected Output:	PlayerChar object with the hallucination condition
Name:	Potion of Detect Monster
Initial State:	PlayerChar object without the detect-monsters condition
Input:	Potion of detect monsters
Expected Output:	PlayerChar object with the detect-monsters condition
Name:	Potion of Detect Object
Initial State:	PlayerChar object without the detect-objects condition
Input:	Potion of detect objects
Expected Output:	PlayerChar object with the detect-objects condition
Name:	Potion of Confusion
Initial State:	PlayerChar object without the confusion condition
Input:	Potion of confusion
Expected Output:	PlayerChar object with the confusion condition
Name:	Potion of Confusion
Initial State:	PlayerChar object without the confusion condition
Input:	Potion of confusion
Expected Output:	PlayerChar object with the confusion condition
Name:	Potion of Levitation
Initial State:	PlayerChar object without the levitation condition
Input:	Potion of levitation
Expected Output:	PlayerChar object with the levitation condition
Name:	Potion of Haste
Initial State:	PlayerChar object without the haste condition
Input:	Potion of haste
Expected Output:	PlayerChar object with the haste condition

Name:	Potion of See-Invisible
Initial State:	PlayerChar object without the invisible-sight condition
Input:	Potion of invisible
Expected Output:	PlayerChar object with the invisible-sight condition
Name:	Random Range 1
Initial State:	None
Input:	Upper and lower bounds 0,0
Expected Output:	0
Name:	Random Range 2
Initial State:	None
Input:	Upper and lower bounds 5,5
Expected Output:	5
Name:	Random Range 3
Initial State:	None
Input:	Upper and lower bounds 0,60, repeated 40 times
Expected Output:	$0 \leq$ result ≤ 60
Name:	Random Float
Initial State:	None
Input:	40 repeats
Expected Output:	$0 \leq$ result ≤ 1
Name:	Random Boolean
Initial State:	None
Input:	10 repeats
Expected Output:	Both `true` and `false` are generated
Name:	Random Percent
Initial State:	None
Input:	40 repeats
Expected Output:	$0 \leq$ result ≤ 100
Name:	Random Position

Initial State:	None
Input:	Two Coordinates (top-left and bottom-right of rectangle)
Expected Output:	Random Coordinate within bounds
Name:	Ring Construction 1
Initial State:	None
Input:	Coordinate
Expected Output:	Ring object with valid initial state
Name:	Ring Construction 2
Initial State:	None
Input:	Coordinate, Item context value, type identifier
Expected Output:	Ring object with valid initial state
Name:	Ring of Stealth
Initial State:	PlayerChar object without stealth condition
Input:	Ring of stealth
Expected Output:	PlayerChar object with the stealth condition
Name:	Ring of Stealth Deactivate
Initial State:	PlayerChar object with ring of stealth
Input:	Remove ring
Expected Output:	PlayerChar object without the stealth condition
Name:	Ring of Teleportation
Initial State:	PlayerChar object without random teleportation condition
Input:	Ring of teleportation
Expected Output:	PlayerChar object with the random teleportation condition
Name:	Ring of Teleportation Deactivate
Initial State:	PlayerChar object with ring of teleportation
Input:	Remove ring
Expected Output:	PlayerChar object without the random teleportation condition

Name:	Ring of Regeneration
Initial State:	PlayerChar object without regeneration condition
Input:	Ring of regeneration
Expected Output:	PlayerChar object with the regeneration condition
Name:	Ring of Regeneration Deactivate
Initial State:	PlayerChar object with ring of regeneration
Input:	Remove Ring
Expected Output:	PlayerChar object without the regeneration condition
Name:	Ring of Digestion
Initial State:	PlayerChar object without digestion condition
Input:	Ring of digestion
Expected Output:	PlayerChar object with the digestion condition
Name:	Ring of Digestion Deactivate
Initial State:	PlayerChar object with ring of digestion
Input:	Remove Ring
Expected Output:	PlayerChar object without the digestion condition
Name:	Ring of Dexterity
Initial State:	PlayerChar object
Input:	Ring of dexterity
Expected Output:	PlayerChar object with dexterity increased by the appropriate amount
Name:	Ring of Dexterity Deactivate
Initial State:	PlayerChar object with ring of dexterity
Input:	Remove ring
Expected Output:	PlayerChar object with normal dexterity
Name:	Ring of Adornment
Initial State:	PlayerChar object
Input:	Ring of adornment
Expected Output:	Identical PlayerChar object

Name:	Ring of Adornment
Initial State:	PlayerChar object with ring of adornment
Input:	Remove Ring
Expected Output:	Identical PlayerChar object
Name:	Ring of See-Invisible
Initial State:	PlayerChar object without the see-invisible condition
Input:	Ring of See-Invisible
Expected Output:	PlayerChar object with the see-invisible condition
Name:	Ring of See-Invisible Deactivate
Initial State:	PlayerChar object with ring of see-invisible
Input:	Remove Ring
Expected Output:	PlayerChar object without the see-invisible condition
Name:	Ring of Maintain-Armor
Initial State:	PlayerChar object without the maintain-armor condition
Input:	Ring of Maintain-Armor
Expected Output:	PlayerChar object with the maintain-armor condition
Name:	Ring of Maintain-Armor Deactivate
Initial State:	PlayerChar object with ring of maintain-armor
Input:	Remove Ring
Expected Output:	PlayerChar object without the maintain-armor condition
Name:	Ring of Searching
Initial State:	PlayerChar object without the auto-search condition
Input:	Ring of Searching
Expected Output:	PlayerChar object with the auto-search condition
Name:	Ring of Searching Deactivate
Initial State:	PlayerChar object with ring of searching
Input:	Remove Ring

Expected Output:	PlayerChar object without the auto-search condition
Name:	Room Construction Check 1
Initial State:	Randomly generated Room
Input:	None
Expected Output:	Verification that Room's size is in valid range
Name:	Room Construction Check 2
Initial State:	Randomly generated Room
Input:	None
Expected Output:	Verification that Room edges are within valid bounds
Name:	Scroll Construction 1
Initial State:	None
Input:	Coordinate
Expected Output:	Scroll object in valid initial state
Name:	Scroll Construction 2
Initial State:	None
Input:	Coordinate, Item context value, type identifier
Expected Output:	Scroll object in valid initial state
Name:	Scroll PseudoNames
Initial State:	Scrolls are uninitialized
Input:	Initialize Scroll Names command
Expected Output:	Vector of valid scroll psuedonames
Name:	Scroll of Protect Armor
Initial State:	PlayerChar with cursed armor
Input:	Scroll of Protect Armor
Expected Output:	PlayerChar with uncursed Armor with protect-armor effect
Name:	Scroll of Hold Monster
Initial State:	Monster without the held flag
Input:	Scroll of Hold Monster

Expected Output:	Monster with the held flag
Name: **Initial State:** **Input:** **Expected Output:**	Scroll of Enchant Weapon PlayerChar with weapon Scroll of Enchant Weapon PlayerChar with uncursed Weapon with higher enchant level
Name: **Initial State:** **Input:** **Expected Output:**	Scroll of Enchant Armor PlayerChar with armor Scroll of Enchant Armor PlayerChar with uncursed Armor with higher enchant level
Name: **Initial State:** **Input:** **Expected Output:**	Scroll of Identity None Scroll identity No exceptions
Name: **Initial State:** **Input:** **Expected Output:**	Scroll of Teleportation PlayerChar at coordinate (0,0) Scroll of Teleportation PlayerChar at coordinate $\neq$ (0,0)
Name: **Initial State:** **Input:** **Expected Output:**	Scroll of Sleep PlayerChar without the sleep condition Scroll of Sleep PlayerChar with the sleep condition
Name: **Initial State:** **Input:** **Expected Output:**	Scroll of Scare Monster None Scroll of Scare Monster No exceptions
Name: **Initial State:** **Input:**	Scroll of Remove Curse PlayerChar with cursed Weapon Scroll of Remove Curse

Expected Output:	PlayerChar with uncursed Weapon
Name:	Scroll of Create Monster
Initial State:	Level object
Input:	Scroll of create Monster
Expected Output:	Level with 1 additional Monster
Name:	Scroll of Aggravate Monster
Initial State:	Level with sleeping Monsters
Input:	Scroll of Aggravate Monster
Expected Output:	Level with no sleeping Monsters
Name:	Scroll of Magic Mapping
Initial State:	Unrevealed Level
Input:	Scroll of Magic Mapping
Expected Output:	Level where all Tiles have been revealed
Name:	Scroll of Confuse Monster
Initial State:	PlayerChar without the confuse-monster condition
Input:	Scroll of Confuse Monster
Expected Output:	PlayerChar with the confuse-monster condition
Name:	Stairs Construction
Initial State:	None
Input:	Coordinate, direction value
Expected Output:	Stairs object in valid initial state
Name:	Stairs Direction Check
Initial State:	Stairs constructed with direction
Input:	Direction value
Expected Output:	Verification that Stairs has given direction value
Name:	Floor Passability Check
Initial State:	Floor object
Input:	None
Expected Output:	Verification that Floor is passable

Name:	Floor Symbol Check
Initial State:	Floor object
Input:	None
Expected Output:	Verification that Floor has correct symbol
Name:	Floor Transparency Check
Initial State:	Floor object
Input:	None
Expected Output:	Verification that Floor is transparent
Name:	Wall Passability Check
Initial State:	Wall object
Input:	None
Expected Output:	Verification that Wall is not passable
Name:	Wall Symbol Check
Initial State:	Wall object
Input:	None
Expected Output:	Verification that Wall has correct symbol
Name:	Wall Opacity Check
Initial State:	Wall object
Input:	None
Expected Output:	Verification that Wall is transparent
Name:	Corridor Passability Check
Initial State:	Corridor object
Input:	None
Expected Output:	Verification that Corridor is passable
Name:	Corridor Symbol Check
Initial State:	Corridor object
Input:	None
Expected Output:	Verification that Corridor has correct symbol
Name:	Corridor Transparency Check

Initial State:	Corridor object
Input:	None
Expected Output:	Verification that Corridor has special corridor transparency
Name:	Door Passability Check
Initial State:	Door object
Input:	None
Expected Output:	Verification that Door is not passable
Name:	Door Symbol Check
Initial State:	Door object
Input:	None
Expected Output:	Verification that Door has correct symbol
Name:	Door Transparency Check
Initial State:	Door object
Input:	None
Expected Output:	Verification that Door has special Corridor transparency
Name:	Door Trap
Initial State:	PlayerChar and Level
Input:	Door trap
Expected Output:	PlayerChar at a Level with depth + 1
Name:	Rust Trap
Initial State:	PlayerChar with enchanted Weapon
Input:	Rust trap
Expected Output:	PlayerChar with unenchanted Weapon
Name:	Sleep Trap
Initial State:	PlayerChar without the sleep condition
Input:	Sleep trap
Expected Output:	PlayerChar with the sleep condition
Name:	Bear Trap
Initial State:	PlayerChar without the immobilized condition

Input:	Bear trap
Expected Output:	PlayerChar with the immobilized condition
Name:	Teleport Trap
Initial State:	PlayerChar
Input:	Teleport trap
Expected Output:	PlayerChar at a different location
Name:	Dart Trap
Initial State:	PlayerChar
Input:	Dart trap
Expected Output:	PlayerChar with less HP
Name:	Tunnel Digging
Initial State:	Level and pair of unconnected Rooms
Input:	Dig command
Expected Output:	Valid path between the two Rooms
Name:	Open Inventory Screen
Initial State:	Playstate, PlayerChar, empty Level
Input:	Inventory key
Expected Output:	Inventory screen
Name:	Close Inventory Screen
Initial State:	Inventory screen, PlayerChar, empty Level
Input:	Exit key
Expected Output:	PlayState
Name:	Movement
Initial State:	PlayState, player, empty Level
Input:	Movement key
Expected Output:	PlayerChar should be in expected location in the Level
Name:	Open Status Screen
Initial State:	PlayState, PlayerChar, empty Level
Input:	Status key

Expected Output:	Status screen
Name:	Exit Status Screen
Initial State:	Status Screen, PlayerChar, empty Level
Input:	Exit key
Expected Output:	PlayState
Name:	No Wand Zap
Initial State:	PlayState, PlayerChar with no Wand
Input:	Zap key
Expected Output:	Unchanged playState
Name:	Zap Wand Select
Initial State:	PlayState, PlayerChar with wand, empty Level
Input:	Zap key, then direction key
Expected Output:	Inventory screen
Name:	Zap Wand Fire 1
Initial State:	Inventory Wand select
Input:	Item select hotkey
Expected Output:	PlayState
Name:	Zap Wand Fire 2
Initial State:	Inventory wand select
Input:	Item select hotkey
Expected Output:	Wand with charges - 1
Name:	Game Quit
Initial State:	PlayState
Input:	Quit key and confirmation key
Expected Output:	RipScreen
Name:	Wand Construction 1
Initial State:	None
Input:	Coordinate
Expected Output:	Wand in valid initial state

Name:	Wand Construction 2
Initial State:	None
Input:	Coordinate, Item context value, type specifier
Expected Output:	Wand in valid initial state
Name:	Wand of Teleport Away
Initial State:	PlayerChar, nearby Monster
Input:	Wand of Teleport Away
Expected Output:	Monster has distance to PlayerChar ≥ 20
Name:	Wand of Slow Monster
Initial State:	PlayerChar, Monster without slowed flag
Input:	Wand of Slow Monster
Expected Output:	Monster has slowed flag
Name:	Wand of Invisibility
Initial State:	PlayerChar, Monster without invisible flag
Input:	Wand of Invisibility
Expected Output:	Monster with invisible flag
Name:	Wand of Polymorph
Initial State:	PlayerChar, Monster
Input:	Wand of Polymorph
Expected Output:	Different Monster at previous Monster's locations
Name:	Wand of Haste Monster
Initial State:	PlayerChar, Monster without haste flag
Input:	Wand of Haste Monster
Expected Output:	Monster with haste flag
Name:	Wand of Magic Missile
Initial State:	PlayerChar, Monster
Input:	Wand of Magic Missile
Expected Output:	Monster with reduced HP
Name:	Wand of Cancellation

Initial State:	PlayerChar, Monster without cancelled flag
Input:	Wand of Cancellation
Expected Output:	Monster with canceled flag
Name:	Wand of Do Nothing
Initial State:	PlayerChar, Monster
Input:	Wand of Do Nothing
Expected Output:	No exceptions
Name:	Wand of Drain Life
Initial State:	PlayerChar with reduced HP, Monster
Input:	Wand of Drain Life
Expected Output:	PlayerChar with increased HP, Monster with reduced HP
Name:	Wand of Cold
Initial State:	PlayerChar, Monster
Input:	Wand of Cold
Expected Output:	No exceptions
Name:	Wand of Fire
Initial State:	PlayerChar, Monster
Input:	Wand of Fire
Expected Output:	No exceptions
Name:	Weapon Construction 1
Initial State:	None
Input:	Coordinate
Expected Output:	Weapon in valid initial state
Name:	Weapon Construction 2
Initial State:	None
Input:	Coordinate, Item context value, type specifier
Expected Output:	Weapon in valid initial state
Name:	Weapon Identification Check
Initial State:	Identified Weapon

Input:	None
Expected Output:	Verification that Weapon is identified
Name:	Weapon Curse Check
Initial State:	Cursed Weapon
Input:	None
Expected Output:	Verification that Weapon is cursed
Name:	Weapon Name Check
Initial State:	Weapon
Input:	None
Expected Output:	Verification that Weapon has valid name
Name:	Weapon Enchantment Check
Initial State:	Cursed Weapon
Input:	None
Expected Output:	Verification that Weapon has expected enchantment values

8 Trace to Requirements

The following table maps each implemented test file to its corresponding set of functional and non-functional requirements.

Table 3: **Test-Requirement Trace**

File	**Related Requirement(s)**
test.amulet.cpp	FR.25
test.armor.cpp	FR.29, FR.34, FR.39,
test.coord.cpp	FR.17
test.feature.cpp	FR.5, FR.13, FR.14, FR.15, FR.25, FR.31
test.food.cpp	FR.5, FR.31
test.goldpile.cpp	FR.5
test.item.cpp	FR.5, FR.13, FR.14, FR.15, FR.25, FR.30 FR.31
test.itemzone.cpp	FR.5, FR.9, FR.26
test.level.cpp	FR.16-19
test.levelgen.cpp	FR.16-19
test.main.cpp	Runs Tests
test.mob.cpp	FR.37, FR.38, FR.39
test.monster.cpp	FR.35-39
test.playerchar.cpp	FR.9-15, FR.26-34, NFR.5
test.potion.cpp	FR.5, FR.13, FR.14, FR.15, FR.25, FR.31
test.ring.cpp	FR.5, FR.13, FR.14, FR.15, FR.25, FR.31
test.room.cpp	FR.17, FR.18, FR.19, FR.21
test.scroll.cpp	FR.5, FR.13, FR.14, FR.15, FR.25, FR.31
test.stairs.cpp	FR.18, FR.19
test.terrain.cpp	FR.13, FR.15, FR.18, FR.19, FR.23, FR.24
test.testable.cpp	Defines Test Structure
test.testable.h	Defines Test Structure
test.trap.cpp	FR.12, FR.15, FR.19, FR.20, FR.23, FR.24, FR.34
test.tunnel.cpp	FR.17, FR.19
test.uistate.cpp	FR.1-4, FR.6-10, NFR.1, NFR.3, NFR.5
test.wand.cpp	FR.5, FR.13, FR.14, FR.15, FR.25, FR.31
test.weapon.cpp	FR.5, FR.13, FR.14, FR.15, FR.25, FR.31

9 Trace to Modules

The table below re-iterates the modules of the project (for the convenience of the reader), along with their respective domain and module ID; the module IDs are used to refer to modules in the trace. More information about the modules can be found in the Module Guide.

Table 4: **Module Hierarchy**

Level 1	**Level 2**	
Hardware-Hiding Module	BasicIO	**M1**
	Doryen	**M2**
	Input Format	**M3**
Behaviour-Hiding Module	External	**M4**
	Item	**M5**
	Level	**M6**
	LevelGen	**M7**
	MainMenu	**M8**
	Mob	**M9**
	Monster	**M10**
	PlayerChar	**M11**
	RipScreen	**M12**
	PlayState	**M13**
	SaveScreen	**M14**
	UIState	**M15**
Software Decision Module	Coord	**M16**
	Feature	**M17**
	ItemZone	**M18**
	MasterController	**M19**
	Random	**M20**
	Terrain	**M21**

The following table maps test files, which implement unit tests, to their specific modules (denoted by their IDs).

Table 5: **Test-Module Trace**

File	**Related Module(s)**
test.amulet.cpp	M7, M13, M15
test.armor.cpp	M5, M9, M11
test.coord.cpp	M2, M5, M6, M7, M16, M20
test.feature.cpp	M5, M11, M17, M18
test.food.cpp	M5, M6, M7, M11, M13
test.goldpile.cpp	M5, M6, M7, M10, M11, M17, M18
test.item.cpp	M5, M17
test.itemzone.cpp	M5, M6, M16, M17, M18
test.level.cpp	M5, M6, M10, M11, M16, M17, M20
test.levelgen.cpp	M5, M6, M10, M16, M17, M20, M21
test.main.cpp	None (Runs Tests)
test.mob.cpp	M9, M10, M11, M13, M15, M16
test.monster.cpp	M9, M10, M16
test.playerchar.cpp	M5, M6, M9, M11, M12, M13, ↩ M15, M16, M17, M18, M19
test.potion.cpp	M5, M6, M7, M10, M11, M17, M18
test.ring.cpp	M5, M6, M7, M10, M11, M17, M18
test.room.cpp	M6, M7, M16, M20
test.scroll.cpp	M5, M6, M7, M10, M11, M17, M18
test.stairs.cpp	M7, M17, M19, M21
test.terrain.cpp	M6, M7, M20, M21
test.testable.cpp	Defines Test Structure
test.testable.h	Defines Test Structure
test.trap.cpp	M6, M7, M11, M15, M17
test.tunnel.cpp	M5, M6, M16
test.uistate.cpp	M4, M8, M12, M13, M15, M19
test.wand.cpp	M5, M6, M7, M10, M11, M17, M18
test.weapon.cpp	M5, M6, M7, M10, M11, M17, M18

10 Code Coverage Metrics

Given the Test-Requirements table, the Test-Module table, and the Module-Requirements trace given in the Module Guide, the referential transitivity property can be applied to determine exactly which functional and non-functional requirements were satisfied by the created test cases.

With the exception of a few non-functional requirements, the implemented tests offered almost **complete coverage** of all product functional and non-functional requirements. As the Rogue++ team discovered, several of the non-functional requirements were impractical to test in an automated fashion because computing the prevalence of certain subjective qualities in a product is extremely complicated (or at least well beyond the scope of Rogue Reborn). For example, NFR.2 states, "The Rogue Reborn game shall be fun and entertaining." While it is infeasible to test such characteristics with code, it can be trivially accomplished with human playtesters. Along with NFR.2, various other non-functional requirements that were too difficult to automatically assert in software were verified by other means, namely manual human labor.

Interestingly, the Rogue++ team also encountered a few requirements where the achievable target was difficult to materialize but still algorithmic and computational in nature. A prime example includes the luminosity constraint which ruled that no two consecutive frames may have a change in contrast greater than LUMINOSITY_DELTA. To measure this properly, the developer team wrote a Python script to analyze two static screenshots of the game. This program calculated the pixel-accurate luminosity of each screenshot and used the calculation proposed in the non-functional requirement to arrive at a final answer.

Static code coverage metrics were not utilized in Rogue Reborn due to the sheer volume of the code base and the state complexity of various modules.