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Testing	L372
Certification	C577

Report Type	Evaluation and Certification
Report Date	30 October 2019
Issuing Laboratory	GLI Europe B.V.
Evaluating Laboratory	GLI Europe B.V.
Recipient	Realistic Games Limited 8th Floor North, Reading Bridge House Reading Bridge, George Street Reading, Berkshire, RG1 8LS United Kingdom
Tested against Requirements	Gaming Act (2018:1138) Lottery Inspectorate's Regulation and General Guidelines on the technical requirements and accreditation of bodies performing the inspection, testing and certification of gaming activities (LIFS 2018_8) Guidance on the Lottery Inspectorate's Regulation and General Guidelines on the technical requirements and accreditation of bodies performing the inspection, testing and certification of gaming activities (LIFS 2018:8) and on Articles 1 and 4 of the Lottery Inspectorate's Regulation and General Guidelines on the State lottery and lotteries for public purposes (LIFS 2018:4)
Jurisdiction	Sweden iGaming
Manufacturer	Realistic Games Limited 8th Floor North, Reading Bridge House Reading Bridge, George Street Reading, Berkshire, RG1 8LS United Kingdom
Submitter	Realistic Games Limited 8th Floor North, Reading Bridge House Reading Bridge, George Street Reading, Berkshire, RG1 8LS United Kingdom
Product Name	**Random Number Generator**
Description of the Product Tested	**rgl-rng-api-1.4.0.jar and rgl-rng-java-1.4.1.jar** As requested per submitter's letter received 17 October 2019.
Evaluation Period	18 October 2019 / 24 October 2019
Internal Reference	RN-556-REG-19-01
Result	Pass (See Comments and Conditions on the following pages)
Internal methods used reference	Random Number Generator (RNG) Analysis WI-MA-006, PC-TC-001

Technical Evaluation authorized by:

Martin Britton
Managing Director

Worldwide Locations

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Lakewood, New Jersey

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GLI Africa
GLI Asia
GLI Australia Pty Ltd
GLI Austria GmbH
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GLI Italy
GLI South America

U.S. Regional Offices
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RNG ANALYSIS

RANDOMNESS REPORT FOR THE BONUS RNG

The intent of this report is to indicate that **Gaming Laboratories International**, **LLC** (GLI) has completed its evaluation of the Random Number Generator random number generator (RNG), provided by Realistic Games Limited.

SECTION I — SCOPE OF TESTING

Realistic Games Limited submitted the required materials to GLI in order to conduct a random number generator analysis on the Random Number Generator RNG. The scope of this analysis was limited to software verification, source code review, and data analysis. The RNG was tested for its ability to randomly produce outcomes for the Slot, Roulette, and Blackjack games.
The Random Number Generator RNG was evaluated against the RNG-specific requirements of the following technical standards:

Sweden iGaming:

- Gaming Act (2018:1138).
- Lottery Inspectorate's Regulation and General Guidelines on the technical requirements and accreditation of bodies performing the inspection, testing and certification of gaming activities (LIFS 2018_8).
- Guidance on the Lottery Inspectorate's Regulation and General Guidelines on the technical requirements and accreditation of bodies performing the inspection, testing and certification of gaming activities (LIFS 2018:8) and on Articles 1 and 4 of the Lottery Inspectorate's Regulation and General Guidelines on the State lottery and lotteries for public purposes (LIFS 2018:4).

SECTION II — SOFTWARE VERIFICATION

Verify+ by Kobetron™ signatures for the Random Number Generator RNG are as follows:

File	Type	Signature
rgl-rng-api-1.4.0.jar	Kobe4	0F3C
	MD5	ECED596F8DFF66B588FD7602DE30A0F2
	SHA-1	4838933ACD4F540E9AD08243244F6AC7B3FF6DBA
rgl-rng-java-1.4.1.jar	Kobe4	39F8
	MD5	57E2E9296A4A09A2B68AC2B7326F1BBD
	SHA-1	08A780F3EEA738339B92F20A88A08E97A5ED87DD

Table 1. Digital Signatures

SECTION III — SOURCE CODE REVIEW

Realistic Games Limited submitted appropriate documentation and full source code which pertains to the generation of random numbers. GLI reviewed the source code provided by tracing the path of the RNG application from the initiation of the draw to the selected output of random numbers. GLI inspected the source code, where practicable, in an attempt to find any undisclosed switches or parameters having a possible influence on randomness and fair play. GLI assessed the ability of the RNG to produce all numbers within the desired range.

RNG ANALYSIS

RANDOMNESS REPORT FOR THE BONUS RNG

SECTION IV — DATA ANALYSIS

The game configuration and parameters for the data obtained and tested are listed in Table 2. GLI performed a data format check on each data set listed in order to confirm that the game parameters were correctly represented in the data analyzed.
A set of numbers is said to be drawn *with replacement* if a number can be selected multiple times within the same draw. A set of numbers is said to be drawn *without replacement* if a number can only be selected once within the same draw.

Data Set	Range	Positions	Replacement	Draws
Data Set 1	0-29	5	Yes	31,000,000
Data Set 2	0-89	5	Yes	95,000,000
Data Set 3	0-33	3	Yes	36,000,000
Data Set 4	0-59	3	Yes	39,000,000
Data Set 5	0-7	8	No	8,000,000
Data Set 6	0-36	1	N/A	39,000,000
Data Set 7	0-2	1	N/A	3,000,000
Data Set 8	0-9	1	N/A	10,000,000
Data Set 9	0-99	1	N/A	106,000,000
Data Set 10	0-999	1	N/A	1,061,000,000
Data Set 11	0-9,999	1	N/A	2,038,500,000
Data Set 12	0-99,999	1	N/A	1,733,700,000
Data Set 13	0-311	312	No	11,100,000
Binary Data	0-4,294,967,295	3,096,775	Yes	3

Table 2. Game Parameters

For a summary of the statistical tests applied to each data set, see *Appendix A*. For a description of the overall test methodology and a description of each test used, see *Appendix B*.
Overall, the RNG passed the battery of tests for each configuration at the 95%, 98%, and 99% confidence levels.

RNG ANALYSIS

RANDOMNESS REPORT FOR THE BONUS RNG

SECTION V — SUMMARY

Overall Evaluation of the Random Number Generator
GLI's conclusion based upon the tests applied to the Random Number Generator RNG data is that this random number generator has exhibited random behavior and is suitable for the applications as described herein. If a game utilizes a different range or a different number of selections from the included ranges, the RNG should be resubmitted to test that set of parameters.

RNG ANALYSIS

APPENDIX A: Statistical Test Summary

Data Set	Range	Positions	Replacement	Draws	Test Names													
					Runs	Serial Corr.	Interplay Corr.	Adj. Max-Min	Adj. High-Low	Adj. Blocks	Coupon	Duplicates	Overlaps	Permutation	Tot. Dist.	Tot. Dist. by Pos.	Count of Counts	DieHard
Data Set 1	0-29	5	Yes	31,000,000	X	X	X	X	X		X	X	X		X	X		
Data Set 2	0-89	5	Yes	95,000,000	X	X	X	X	X		X	X	X		X	X		
Data Set 3	0-33	3	Yes	36,000,000	X	X	X	X	X		X	X	X		X	X		
Data Set 4	0-59	3	Yes	39,000,000	X	X	X	X	X		X	X	X		X	X		
Data Set 5	0-7	8	No	8,000,000	X	X	X	X	X	X	X	X	X	X	X	X		
Data Set 6	0-36	1	N/A	39,000,000	X	X					X	X	X		X			
Data Set 7	0-2	1	N/A	3,000,000	X	X					X	X	X		X			
Data Set 8	0-9	1	N/A	10,000,000	X	X					X	X	X		X			
Data Set 9	0-99	1	N/A	106,000,000	X	X					X	X	X		X			
Data Set 10	0-999	1	N/A	1,061,000,000	X	X						X			X		X	
Data Set 11	0-9,999	1	N/A	2,038,500,000	X	X						X	X		X		X	
Data Set 12	0-99,999	1	N/A	1,733,700,000	X	X						X			X		X	
Data Set 13	0-311	312	No	11,100,000	X	X	X	X	X	X		X	X	X	X	X		
Binary Data	0-4,294,967,295	3,096,775	Yes	3														X

Table A 1. Tests Applied

RNG ANALYSIS

APPENDIX B: Test Descriptions

B.1 **Definitions.** The following terms apply to the below test descriptions. Randomness Device or Random Number Generator (RNG) output may be collected multiple numbers at a time. Each set of numbers is called a draw. Each individual number has a particular order within the *draw*. This is referred to as the number *position*.

B.2 **Distribution Comparisons.** Many of the tests compare an observed numerical distribution with an expected distribution. Unless otherwise specified, this is done by means of a statistical chi-square goodness-of-fit test. The value chi-square is computed in the standard way. If *k* is a possible value, o_k is the observed count of that value, and e_k is the expected count:

$$\chi^2 = \sum_k \frac{(o_k - e_k)^2}{e_k}$$

In the case where expected counts are too small for accurate use of the above formula, values are 'binned' together to ensure an appropriate minimum expected count. The resultant value for chi-square is compared against the distribution for the appropriate number of degrees of freedom. Unusually high (distribution mismatch) or unusually low (insufficient randomness) chi-square values can be causes for data failure.

B.3 **Meta-testing**. Evaluation of groups of *p*-values may include a meta-test for extremity of high or low *p*-values, a meta-test for frequency of high or low *p*-values, and a meta-test for uniformity of *p*-values, as appropriate.

B.4 **Confidence Level**. The statistical tests conducted by GLI are done at a particular *confidence level*. Common confidence levels used include 95%, 98%, and 99%, depending on jurisdictional requirements, and intended use of the RNG. High confidence level testing has low risk of mistakenly failing a good RNG, but higher risk of passing a bad RNG. Lower confidence level testing has increased power of detecting bad RNGs, while also increasing the risk of false failures of good RNGs. Specifically, the confidence level represents the probability that an ideal source of randomness would pass the testing. If an RNG passes statistical tests at a given confidence level, passage at all *higher* confidence levels is implied.

B.5 **Tests**. Some tests are only applicable to certain types of data. Some tests may be applied only to a portion of the data. Some tests may require that the data be parsed, binned, or otherwise transformed, as necessitated by data format.

RNG ANALYSIS

APPENDIX C: Test Descriptions

Adjacency Blocks:
For each draw, the data is first sorted. Then the amount of contiguous blocks of numbers is counted. These statistics are then compared against the expected. For example, if a draw consists of the numbers $1, 5, 4, 2, 6, 9$ the data would be sorted and separated into blocks. The resulting statistic would be 3.

Adjacency High-Low:
For each draw, the number of local extrema (‘highs’ and ‘lows’) in the data is recorded and compared with the expected distribution. These are also referred to as ‘turning points’. For example, if a draw consists of the numbers $1, 3, 5, 7, 2, 9$ there would be one local maximum (7) and one local minimum (2). The resulting statistic would be 2.

Adjacency Max-Min:
For each draw, the difference between the maximum and minimum values is calculated and recorded. This is compared with the expected theoretical distribution. For example, if a draw consists of the numbers $2, 3, 6, 7, 4$ the resulting statistic would be 5, the difference between the maximum value (7) and the minimum value (2).

Count of Counts:
The Count of Counts test first counts the occurrences of each value in each position of the data. These counts are then tallied and compared with the expected distribution of counts for the draw size and range of values.

Coupon Collector's:
The Coupon Collector's Test is applied positionally. The data is parsed until all possible values have been observed, then the number of values checked is recorded and the count is restarted. This is compared with the expected distribution. For example, if the set of all possible values is {0, 1, 2} and the first position of each draw is $1, 0, 1, 0, 2, 0, 1, 2,$ then all values are observed in the first position by the fifth draw. All values are then observed within the next 3 draws, so the first two statistics for the first position would be 5 and 3.

DieHard:
The DieHard Battery of Tests is a standard assessment of the randomness in raw outcomes generated from an RNG. The collection, designed by George Marsaglia, tests for a variety of patterns in the individual binary bits of RNG output. GLI uses a custom implementation to conduct DieHard testing.

RNG ANALYSIS

APPENDIX D: Test Descriptions

Duplicates:
The Duplicates Test counts the number of times a draw is exactly duplicated in the data. In the case that a particular draw is repeated more than twice, every possible way to generate a duplicate is counted. This is compared against the theoretical distribution to verify that the number of duplicate draws falls within expected bounds. For example, consider the dataset consisting of the following draws of two numbers each.

$a)\ 1, 3$
$b)\ 4, 1$
$c)\ 1, 3$
$d)\ 1, 3$
$e)\ 4, 1$
$f)\ 3, 1$

The duplicate pairs are (*a,c*), (*a, d*), (*c, d*), and (*b, e*), for a total of 4 duplicates. *(f)* is not counted as a duplicate since the draw must match in order as well as values.

Interplay Correlation:
The Interplay Correlation Test measures statistical correlation between different positions of the same draw. For each pair of positions, statistical correlation is calculated as in the Serial Correlation Test. In the case of without replacement data, an adjustment is made to account for the expected resulting negative correlation.

Overlaps:
The Overlaps Test compares consecutive draws for overlapping values. The number of overlapping values is recorded for each pair of draws. This observed distribution of overlaps is then compared against the expected distribution. For example, if the following draws are observed consecutively,
$a)\ 1, 4, 5, 6$
$b)\ 4, 1, 7, 6$ the number of overlaps would be 3, representing the values 1, 4, and 6.

Permutation:
The Permutation Test is a test applicable to data that represents a reordering of numbers. Each draw can be considered as a permutation of the original ordering. Every permutation can be decomposed into disjoint cycles, which represent the possible positions a number would occupy if the same permutation is applied repeatedly. For each draw, three statistics are collected based on the cycle decomposition:

The number of cycles.
The size of the smallest cycle.
The size of the largest cycle.

Each of these statistics generates a distribution of observations which are compared with their respective expected distributions. For example, if the following draw were observed as a reordering of the numbers from 1 to 6,
$1, 3, 5, 4, 2, 6$ the cyclic decomposition would be (1)(2 3 5)(4)(6). 1, 4, and 6 remain in their original positions, so they form their own cycles. The values 2, 3, and 5 are shuffled, so they form a single cycle together. The total number of cycles is 4, the smallest cycle has size 1, and the largest cycle has size 3.

RNG ANALYSIS

APPENDIX E: Test Descriptions

Runs:
The Wald-Wolfowitz Runs Test is applied to each position within the draw. A center is established, typically the data median, and the number of 'runs' above and below the center are tallied. Values exactly equal to the center are discarded. This is compared to the expected distribution, which depends on the number of values above and below the center. For example, if the numbers drawn at a particular position were

$$2, 3, 1, 5, 4, 7, 3, 2, 3, 2, 3, 2, 6, 7, 3, 5$$

and the established center were the data median of 3, the data would be parsed for runs above 3 and runs below 3.

$$\underbrace{2, 3, 1}, \overbrace{5, 4, 7, 3}, \underbrace{2, 3, 2, 3, 2}, \overbrace{6, 7, 3, 5}$$

This would be counted as 4 runs.

Serial Correlation:
The Serial Correlation Test measures statistical correlation between consecutive draws of the same position. For each position, the sample Pearson correlation coefficient is calculated. If *X* represents the first number, and *Y* the number that follows, then the coefficient is

$$r = \frac{cov(X, Y)}{s_X s_Y}$$

where *s* denotes the sample standard deviation. The coefficients are used to generate a *p*-value for each position.

Total Distribution:
The Total Distribution Test is a simple tally of all observed values throughout the data. This is compared with the expected distribution. Typically the expected distribution is a uniform distribution. In the case of unequal weighting of values, an appropriate discrete distribution is used.

Total Distribution by Position:
The Total Distribution by Position Test tallies the observed distribution of values for each position within the draw. Each of these distributions is then compared with the expected.

Jurisdictional Requirements

Chapter 13 – Functional requirements for random number generators		Determination	Result/Explanation
§ 1	The results of a random number generator shall be random, statistically independent, reflect a correct standard deviation and reflect the correct probability distribution.	PASS	Result of source code review and/or statistical analysis of collected data.
	The result from a random number generator shall not be predictable without knowledge of the algorithm's use, its implementation and seed values.	PASS	Result of source code review and/or statistical analysis of collected data.
	Several statistical tests can can be used to ensure the results of a random number generator. The Diehard battery of tests (Marsaglia) and the NIST battery of tests (National Institute of Standards and Technology – Statistical Test Suite) are two tests that can be used.	PASS	Result of source code review and/or statistical analysis of collected data.
§ 2	Reference to an established and accepted algorithm and any software code and conversion procedure for random number generator shall be documented.	PASS	Result of source code review and/or statistical analysis of collected data.
	If a random number generator is built into the software, this programme code, together with comments and documentation, should be able to be reported.	PASS	Result of source code review and/or statistical analysis of collected data.
	The algorithm on which a random number generator is based must be published in an internationally recognised publication. The outcome of tests that may be relevant to random number generators are, for example, the X2 test (chi-square test), serial correlation test and runs test. The licensee must allow verification of the defined paytable by allowing the accredited testing body or the Gaming Inspectorate to review the software, sheets, logs, check lists or other paytable documentation.	PASS	Result of source code review and/or statistical analysis of collected data.
§ 3	The random number generator must be able to handle the maximum load determined.	PASS	Result of source code review and/or statistical analysis of collected data.
§ 4	Features that do not generate game outcomes, but which depend on random elements shall be based on the random number generator results.	N/A	RNG Evaluation only
	Such features may include, for example, a random game or the positioning at a poker table in a poker tournament.	N/A	RNG Evaluation only
§ 5	The outcomes from a random number generator shall reflect the correct standard deviation and the correct probability distribution.	PASS	Result of source code review and/or statistical analysis of collected data.
	The random number generator's output of numbers, symbols or events must correspond to the game rules established for the game in question.	N/A	RNG Evaluation only
	If the random number is converted to, for example, cards, there should be four aces, four kings, etc. in a normal card deck if the game in question uses a normal card deck.	N/A	RNG Evaluation only
§ 6	The random number generator's calculations should be consistent with events logged in the game system.	N/A	RNG Evaluation only

Jurisdictional Requirements

Chapter 13 – Functional requirements for random number generators		Determination	Result/Explanation
§ 7	If, according to the game rules, a sequence of outcomes from a random number generator is determined in advance, new sequences may only be created if so stated in the game rules.	N/A	RNG Evaluation only
§ 8	Unless otherwise stated in the game rules, the outcome of a random number generator must always be independent of events in the current game or of previous games.	PASS	Result of source code review and/or statistical analysis of collected data.
	Drawing devices without a random number generator		
§ 9	The results of a drawing device shall be random, statistically independent, reflect the correct standard deviation and the correct probability distribution.	N/A	Not a drawing device
	The outcome of tests that may be relevant to random number generators are, for example, the X2 test (chi-square test), serial correlation test and runs test.	N/A	Not a drawing device
§10	A free-standing drawing device without a random number generator shall be locked and access to it restricted.	N/A	Not a drawing device
	Drawing devices in live casino games		
§11	Drawing devices in live casino games shall be monitored and logged.	N/A	Not a drawing device
	From the logged material it shall be clear that the game rules are complied with.	N/A	Not a drawing device
	Logging shall include logging date and time.	N/A	Not a drawing device
§12	Premises used for live casino games, including the associated facilities, shall be subject to physical access control.	N/A	Not a drawing device
	At a minimum, the segregation of access for persons with different occupational functions shall be in place.	N/A	Not a drawing device
	Dealers, floor managers, managers and monitoring staff are examples of different types of employees that shall be categorised into different access groups.	N/A	Not a drawing device

Chapter 16. Technical requirements		Determination	Result/Explanation
§ 5	A licensee shall, unless the gaming authority decides otherwise, retain all information on the operation of the gaming system for at least five years.	N/A	RNG Evaluation only

Jurisdictional Requirements

GLI's evaluation to the Technical Standards was limited only to the requirements applicable to the Random Number Generator RNG. In addition, the following sections of the applicable Technical Standards were excluded from the scope of work for this evaluation:

Technical Standard Section(s)	Reason for Exclusion
13.4 - Features that do not generate game outcomes, but which depend on random elements shall be based on the random number generator results. Such features may include, for example, a random game or the positioning at a poker table in a poker tournament.	RNG Evaluation only
13.5 - The random number generator's output of numbers, symbols or events must correspond to the game rules established for the game in question.	RNG Evaluation only
13.5 - If the random number is converted to, for example, cards, there should be four aces, four kings, etc. in a normal card deck if the game in question uses a normal card deck.	RNG Evaluation only
13.6 - The random number generator's calculations should be consistent with events logged in the game system.	RNG Evaluation only
13.7 - If, according to the game rules, a sequence of outcomes from a random number generator is determined in advance, new sequences may only be created if so stated in the game rules.	RNG Evaluation only
13.9 and 13.10 - Drawing devices without a random number generator	Not a drawing device
13.11 and 13.12 - Drawing devices in live casino games	Not a drawing device
Chapter 16. Technical requirements	
16.5 - A licensee shall, unless the gaming authority decides otherwise, retain all information on the operation of the gaming system for at least five years.	RNG Evaluation only