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RvA Registration Number of Accreditation applicable to this Report:	
Testing	L372

Report Type	Evaluation
Report Date	10 February 2020
Issuing Laboratory	GLI Europe B.V.
Evaluating Laboratory	GLI Europe B.V.
Recipient	GMS Entertainment Limited Fort Anne, South Quay, Douglas, Isle of Man IM1 5PD
Tested against Requirements	UK Remote • Remote Gambling and Software Technical Standards (June 2017). • Testing Strategy for Compliance with Remote Gambling and Software Technical Standards November 2018. Malta Online • L.N. 243 of 2018 - GAMING ACT(CAP. 583) Gaming Authorisations Regulations, 2018. • Directive 2 of 2018 - Player Protection Directive. Isle of Man • Gambling Supervision Commission's Statutory Document Number 731/07 Online Gambling (Systems Verification) (No.2) Regulations 2007, laid before Tynwald 16 October 2007, coming into operation 31 August 2007. Gibraltar • Remote Technical and Operating Standards for the Gibraltar Gambling Industry - v1.1.0. • Gambling Commissioner's Guidelines - v.1.0.2012. • Gambling Act 2005 - Act. No. 2005-72 Commencement (LN. 2006/114) except for s. 55(b) 26.10.2006 Assent 22.12.2005.
Jurisdiction	UK Remote Malta Online Isle of Man Gibraltar
Manufacturer	GMS Entertainment Limited Fort Anne, South Quay, Douglas, Isle of Man IM1 5PD
Submitter	GMS Entertainment Limited Fort Anne, South Quay, Douglas, Isle of Man IM1 5PD
Product Name	**PariPlay CSRNG, Version 1.0**
Description of the Product Tested	**Debug\Pariplay.GamesEngine.Common.Analyst.dll** **Debug\Pariplay.GamesEngine.Common.Logic.dll** **Debug\Pariplay.GamesEngine.Common.RandomGeneratorAlgorithm.dll** **Release\Pariplay.GamesEngine.Common.Analyst.dll** **Release\Pariplay.GamesEngine.Common.Logic.dll** **Release\Pariplay.GamesEngine.Common.RandomGeneratorAlgorithm.dll** As requested per submitter's letter received on 3 February 2020.

Evaluation Period	3 February 2020 / 4 February 2020
Internal Reference	RN-401-PAY-20-01-246
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

RANDOMNESS REPORT FOR THE PARIPLAY CSRNG, VERSION 1.0 RNG

The intent of this report is to indicate that **Gaming Laboratories International**, **LLC** (GLI) has completed its evaluation of the PariPlay CSRNG random number generator (RNG), Version 1.0, provided by GMS Entertainment Limited.

SECTION I - SCOPE OF TESTING

GMS Entertainment Limited submitted the required materials to GLI in order to conduct a random number generator analysis on the PariPlay CSRNG, Version 1.0 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 online games.

The PariPlay CSRNG, Version 1.0 RNG was evaluated against the RNG specific requirements listed in the first page.

SECTION II - SOFTWARE Verification

Verify+ by Kobetron™ signatures for the PariPlay CSRNG, Version 1.0 RNG are as follows:

File	Version	Type	Signature
Debug\Pariplay.GamesEngine.Common.RandomGeneratorAlgorithm.dll	1.0.0.0	Kobe4	H2AU
		MD5	290664A42EEC549DCB41C2DFFB21D2A2
		SHA-1	EBB43D5271BA34DF705BA1966E734868A99AE125
		Kobe40	47UU6P3P1UAF0CU7U4634221431062P02A3268U8
		CDCK	B46F
Debug\Pariplay.GamesEngine.Common.Logic.dll	1.0.0.0	Kobe4	40HA
		MD5	807585D956CC4A4A2B197B1C8F147458
		SHA-1	B18DC762B8D133940948C75B1A81515D59960E95
		Kobe40	0414896H4UFPHC3P5A6UUP271A0HU29068FP39P9
		CDCK	F0A5
Debug\Pariplay.GamesEngine.Common.Analyst.dll	1.0.0.0	Kobe4	H543
		MD5	EF696EF54F1B98473B16C00DB78409A4
		SHA-1	82A5EC1AE39717D932915E7A362F81618D237B0A
		Kobe40	050A1533P31U2CHP6C1P8AU6U14C9144PHF7686F
		CDCK	3A6F
Release\Pariplay.GamesEngine.Common.RandomGeneratorAlgorithm.dll	1.0.0.0	Kobe4	4F4P
		MD5	97938DD88579B35CBB4DA7BB4DB77B7D
		SHA-1	AF1591B2756C7145F5D2087C570D3EF3AACDCE53
		Kobe40	27PH1P76828886PCA341682P837F99PC58H96UH8
		CDCK	1446
Release\Pariplay.GamesEngine.Common.Logic.dll	1.0.0.0	Kobe4	341F
		MD5	1F52891B7CAF2DEF5F1E7221415073C6
		SHA-1	8EB3B3CFE1DFA82E59E0437BAADEC14B14BCEE22
		Kobe40	80F63886PF5724H2U36080H3FCA5H64AAUFH1HAU
		CDCK	689B
Release\Pariplay.GamesEngine.Common.Analyst.dll	1.0.0.0	Kobe4	UA0P
		MD5	6B9CBBFC78B6F1E20501884969150A71
		SHA-1	8C0C166E37557707DA034348A5CB1CB80FA2B71F
		Kobe40	1HF7CC93996413AU0FHUH28F51214247C6C2433F
		CDCK	4695

Table 1. Digital Signatures

RANDOMNESS REPORT FOR THE PariPlay CSRNG, VERSION 1.0 RNG

SECTION III- Source code review

GMS Entertainment 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.

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.

GLI conducted a statistical analysis of sufficient scope to test the RNG for selecting as many as 416 winners from a pool size as large as 416, as many as 10 winners from a pool size as large as 1,000 both in weighted and unweighted cases, and as many as 1 winner from a pool size as large as 100,000,000, as described in the General Certifications listed in Table 2. The selection of test cases took into account broad coverage of range sizes and selections.

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
General Certification – Card Games	Up to and including 416	Up to and including 416	No	①
General Certification – Slot Games (unweighted)	Up to and including 1,000	From 3 up to and including 10	Yes	①
General Certification – Slot Games (weighted)	Up to and including 1,000	From 3 up to and including 10	Yes	①
General Certification – Single Outcomes	Up to and including 100,000,000	1	N/A	①
Binary for Diehard	0-2,147,483,647	1	N/A	3,096,775
Binary for Nist	0-2,147,483,647	1	N/A	33,032,258

Table 2. Game Parameters

① Data sets of different ranges and draw sizes were collected and analyzed to cover the scope of this general certification.

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 level.

SECTION V - SUMMARY

Overall Evaluation of the Random Number Generator

GLI's conclusion based upon the tests applied to the PariPlay CSRNG, Version 1.0 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 ranges included in General Certifications in Table 2, the RNG should be resubmitted to test that set of parameters

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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	NIST
General Certification – Card Games	Up to and including 416	Up to and including 416	No	①	X	X	X	X	X	X	X	X	X	X	X	X			
General Certification – Slot Games (unweighted)	Up to and including 1,000	From 3 up to and including 10	Yes	①	X	X	X	X	X		X	X	X		X	X	X		
General Certification – Slot Games (weighted)	Up to and including 1,000	From 3 up to and including 10	Yes	①	X	X									X	X			
General Certification – Single Outcomes	Up to and including 100,000,000	1	N/A	①	X	X					X	X	X				X		
Binary for Diehard	0-2,147,483,647	1	N/A	3,096,775														X	
Binary for Nist	0-2,147,483,647	1	N/A	33,032,258															X

Table 1. Tests Applied

① Data sets of different ranges and draw sizes were collected and analyzed to cover the scope of this general certification.

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.

APPENDIX B: 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

$$1, 0, 1, 0, 2, 0, 1, 2, \ldots$$

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.

APPENDIX B: 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.

NIST Test Suite:
The following "bitwise" tests from the NIST Test Suite were applied:

- Frequency (Monobits) Test
- Frequency Test within a Block
- Run Test
- Test for the Longest Run of Ones in a Block
- Binary Matrix Rank Test
- Discrete Fourier Transform (Spectral) Test
- Non-Overlapping Template Matching Test
- Maurer's "Universal Statistical" Test
- Linear Complexity Test
- Serial Test
- Approximate Entropy Test
- Cumulative Sums (Cumsum) Test
- Random Excursions Test
- Random Excursions Variant Test

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.

APPENDIX B: Test Descriptions

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.

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.

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

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

GLI's evaluation to the Technical Standard was limited only to the requirements applicable to the PariPlay CSRNG, Version 1.0. In addition, the following sections of the applicable Technical Standard were excluded from the scope of work for this evaluation:

Technical Standard Section(s)	Reason for Exclusion
CC UK 02_01 United Kingdom Remote Technical Standards - RNG	Remote Gambling and Software Technical Standards (June 2017). Testing Strategy for Compliance with Remote Gambling and Software Technical Standards November 2018.
7A - Where lotteries use the outcome of other events external to the lottery, to determine the result of the lottery the outcome must be unpredictable and externally verifiable.	Not a lottery
7A.a.iv - Any forms of seeding and re-seeding used do not introduce predictability	No Seeding/Reseeding methodology implemented
7A.b - For lotteries using external events - where it is not practical to demonstrate 7a.	Not a lottery
7A.c - For games or virtual events that use the laws of physics to generate the outcome of the game (mechanical RNGs), the mechanical RNG used should be capable of meeting the requirements in a. where applicable and in addition:	Not a mechanical RNG
7A.d - Restricting adaptive behaviour prohibits automatic or manual interventions that change the probabilities of game outcomes occurring during play. Restricting adaptive behaviour is not intended to prevent games from offering bonus or special features that implement a different set of rules, if they are based on the occurrence of random events.	RNG Evaluation only
CC MAL 02_01 Malta Remote - Gaming Conformance Criteria	L.N. 243 of 2018 - GAMING ACT(CAP. 583) Gaming Authorisations Regulations, 2018. Directive 2 of 2018 - Player Protection Directive.
All, except requirements directly referring to Random Numbers Generators.	RNG Evaluation only
CC IOM 01_01 Isle of Man Online Gaming and Lotteries Conformance Criteria	Gambling Supervision Commission's Statutory Document Number 731/07 Online Gambling (Systems Verification) (No.2) Regulations 2007, laid before Tynwald 16 October 2007, coming into operation 31 August 2007.
All, except requirements directly referring to Random Numbers Generators.	RNG Evaluation only
Gibraltar (#246) iGaming RNG Requirements	Remote Technical and Operating Standards for the Gibraltar Gambling Industry - v1.1.0 Gambling Commissioner's Guidelines - v.1.0.2012 and Gambling Act 2005 - Act. No. 2005-72 Commencement (LN. 2006/114) except for s. 55(b) 26.10.2006 Assent 22.12.2005.
11.2 – Mechanical RNGs	Not a Mechanical RNG