eGAMING COMPLIANCE SERVICES LIMITED

RANDOM NUMBER GENERATOR EVALUATION REPORT

FOR

THUNDERKICK (MALTA) LTD

REPORT REFERENCE NUMBER: 21108TLKGB001

REPORT ISSUE DATE: 12 JUNE 2020

CONFIDENTIAL

IMPORTANT DISCLAIMER

This report is supplied on the basis that it is for the sole use of the parties listed and to whom it is addressed, and exclusively for the objectives set out herein.

No party, other than those specified, may rely on this report for any purpose whatsoever.

eGaming Compliance Services Limited ('eCOGRA') does not accept any liability or responsibility towards any third party to whom this report is shown or into whose hands it may fall.

This report should not be relied upon for any assurances in relation to third parties and/or activities which are not covered by the certifiable regulatory requirements or compliance standards of the jurisdiction, regulatory authority or compliance entity or system for whose purposes this report is stated to have been prepared. All such other parties and activities are outside the scope of this report and have therefore not been reviewed by eCOGRA.

The nature, timing and extent of testing conducted for the purpose of the certification is considered sufficient and appropriate based on the applicable certifiable regulations and professional judgement applied to the associated risk of non-compliance. The certification of compliance should not be construed to imply any warranty over the functionality, quality or performance of the subject of certification. eCOGRA reserves the right to withdraw this certificate if any non-compliances are subsequently detected by or reported to eCOGRA.

CONFIDENTIALITY NOTICE

This document is proprietary to eCOGRA and contains confidential information of commercial value to eCOGRA, the disclosure of which to third parties could adversely affect the business affairs of eCOGRA.

This information is supplied in confidence to you, on the strict condition that no part of it is disclosed to any third party, in particular to any person or organisation that may be in competition with eCOGRA without the prior written approval of eCOGRA.

TABLE OF CONTENTS

Section 1. General Information

Client name:	Thunderkick (Malta) Ltd
Client Address:	The Bastions Office No. 2, Emvin Cremonia Street, Floriana, FRN 1281, Malta
Product name:	Random Number Generator (RNG)
Supplier:	Thunderkick (Malta) Ltd
Product description:	The Random Number Generator is software based, developed in-house, and written in the Java language.
Product version:	1.0.0
RNG type:	Software
Jurisdiction:	Great Britain
Scope of testing:	Remote Gambling and Software Technical Standards ("RTS") – June 2017, Level 1 testing against RTS 7A and 7B
Testing laboratory:	eGaming Compliance Services Limited, trading as 'eCOGRA' 2/F Berkeley Square House, Berkeley Square, London W1J 6 BD, United Kingdom
Testing laboratory accreditation:	A UKAS accredited testing laboratory No. 4656 ISO/IEC 17025:2017, issued by the United Kingdom Accreditation Service (Issue: 016, Issue date: 27 March 2020, Certificate number: 4656)
Test engineers:	Sphamandla Langa, Sikhumbuso Mzobe, Janine Odayan, Dario Pillay Pooveshan Gounden
Test supervisor:	Gary Lupton-Smith
Testing Period:	18 May – 21 May 2020
Certificate date:	12 June 2020
Certificate number:	21108TLKGB001
Result of testing:	Compliant (Refer to Test Results under Schedule 1)

I hereby certify that the abovementioned RNG complies with the requirements of RTS 7A and RTS 7B of the UKGC's Remote Gambling and Software Technical Standards – June 2017, as described in Section 4 of this report.

Gary Lupton-Smith

Technical Services Manager, eCOGRA

SECTION 2. INTRODUCTION

eCOGRA has been appointed by Thunderkick (Malta) Ltd to evaluate and certify the Random Number Generator product against compliance with the relevant Remote gambling and software technical standards – June 2017, and to highlight any exceptions identified during testing.

- RNG 1.0.0

This certification report highlights our key findings as a result of the evaluation conducted during the period 18 May 2020 to 21 May 2020

SECTION 3. SOFTWARE DETAILS

The scope of the RNG evaluation and certification applies solely to the RNG files, RNG file versions and associated hashes provided in the tables below:

RNG Components

File Name	File Version	MD5
gp-rng-fortuna-1.0.0-RELEASE.jar	1.0.0	3c22ea3b566d7fce256256bc35b354fa

SECTION 4. REVIEW FINDINGS

The key findings of our evaluation of the RNG for compliance with the relevant sections of the Remote Gambling and Software Technical Standards – June 2017, are as follows:

RTS Requirement	RTS Implementation Guidance	Testing Applied	Assessment	Comments
RTS 7 – Generation of random outcomes *(Aim: To ensure that games and other virtual events operate fairly)*				
RTS requirement 7A Random number generation and game results must be 'acceptably random'. Acceptably random here means that it is possible to demonstrate to a high degree of confidence that the output of the RNG, game, lottery and virtual event outcomes are random, through, for example, statistical analysis using generally accepted tests and methods of analysis. Adaptive behaviour (i.e. a	**RTS implementation guidance 7A** a. RNG's should be capable of demonstrating the following qualities: i. the output from the RNG is uniformly distributed over the entire output range and game, lottery, or virtual event outcomes are distributed in accordance with the expected/theoretical probabilities ii. the output of the RNG, game, lottery, and virtual event outcomes should be unpredictable, for	Refer to "1. Tests Performed" under "Schedule 1 – RNG Testing" below.	Compliant	

RTS Requirement	RTS Implementation Guidance	Testing Applied	Assessment	Comments
compensated game) is not permitted. Where lotteries use the outcome of other events external to the lottery, to determine the result of the lottery (for example, using numbers from the National Lottery) the outcome must be unpredictable and externally verifiable.	example, for a software RNG it should be computationally infeasible to predict what the next number will be without complete knowledge of the algorithm and seed value iii. random number generation does not reproduce the same output stream (cycle), and that two instances of a RNG do not produce the same stream as each other (synchronise) iv. any forms of seeding and re-seeding used do not introduce predictability v. any scaling applied to the output of the random number generator maintains the qualities above. 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			

RTS Requirement	RTS Implementation Guidance	Testing Applied	Assessment	Comments
	meeting the requirements in a. where applicable and in addition: i. the mechanical pieces should be constructed of materials to prevent decomposition of any component over time (e.g. a ball shall not disintegrate) ii. the properties of physical items used to choose the selection should not be altered iii. players should not have the ability to interact with, come into physical contact with, or manipulate the mechanics of the game. 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			

RTS Requirement	RTS Implementation Guidance	Testing Applied	Assessment	Comments
	implement a different set of rules, if they are based on the occurrence of random events.			
RTS requirement 7B As far as is reasonably possible, games and events must be implemented fairly and in accordance with the rules and prevailing payouts, where applicable, as they are described to the customer.	**RTS implementation guidance 7B** a. Games should implement the rules as described in the rules available to the customer before play commenced. b. The mapping of the random inputs to game outcomes should be in accordance with prevailing probabilities, pay tables, etc. c. When random numbers, scaled or otherwise, are received, e.g. following a game requesting a sequence of random numbers, they are to be used in the order in which they are received. For example, they may not be discarded due to adaptive behaviour. d. Numbers or sequences of	Refer to individual game certification.	Compliant (as stipulated in individual game certifications)	

RTS Requirement	RTS Implementation Guidance	Testing Applied	Assessment	Comments
	numbers are not to be discarded, unless they fall outside the expected range of numbers required by the virtual event – such an occurrence should result in an error being logged and investigated.			

SCHEDULE 1. RNG TESTING

1. TESTS PERFORMED

The scope of the evaluation consisted of an assessment of the following components:

- Documentation;
- Statistical and mathematical analysis;
- Seeding/re-seeding;
- RNG range; and
- RNG scaling.

The RNG evaluation was performed to ensure the following requirements were met:

- The data must be randomly generated;
- The data must be unpredictable; and
- The series cannot be reproduced.

The test suite used to perform the evaluation consisted of the following:

- Chi-Squared Tests;
- Wald-Wolfowitz (or Runs) Tests;
- Correlation and Serial Correlation;
- Expected probabilities for shuffle decks; and
- Diehard Test Suite.

2. TEST RESULTS

Numerous recognised statistical and mathematical tests were performed to certify the RNG operated in compliance with RTS 7A and RTS 7B of the Remote Gambling and Software Technical Standards – June 2017, including tests for probability (to ensure the expected occurrences), randomness (so that one cannot predict the following occurrence with any degree of certainty) and uniformity (to determine that each possible outcome is equally likely over the long-term). The acceptance criteria for the statistical tests should pass the tests at a 95% confidence level.

1. OUTPUT BASED TESTING ON SCALED RANGES: 0-33, 0-36, 0-51, 0-66, 0-99, 0-500, 0-999

a. OUTPUT BASED TESTING ON SCALED RANGES RESULTS

OUTPUT BASED TESTING				CLIENT GENERATED DATA			eCOGRA GENERATED DATA		
				Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3
Test Number	Sample size	Test Range	DoF	P-value	P-value	P-value	P-value	P-value	P-value
1	3 000 000	0-33	33	0.3340	0.4415	0.1306	0.0316	0.9884	0.6217
2	3 000 000	0-36	36	0.7673	0.1785	0.1786	0.7043	0.9265	0.1430
3	3 000 000	0-51	51	0.8934	0.7177	0.0561	0.4588	0.3195	0.4572
4	3 000 000	0-66	66	0.4715	0.3992	0.7836	0.0375	0.6133	0.5455
5	3 000 000	0-99	99	0.0125	0.1076	0.5230	0.5976	0.9720	0.6765
6	3 000 000	0-500	500	0.4201	0.2639	0.8654	0.7122	0.3740	0.3758
7	3 000 000	0-999	999	0.6522	0.8282	0.5285	0.1401	0.4438	0.1180

b. SCALED DATA RANDOMNESS TEST SUCCESS (✓) OR FAILURE (×) SUMMARY

OUTPUT BASED TESTING				CLIENT GENERATED DATA			eCOGRA GENERATED DATA		
				Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3
Test Number	Sample size	Test Range	DoF	P-value	P-value	P-value	P-value	P-value	P-value
1	3 000 000	0-33	33	✓	✓	✓	✓	✓	✓
2	3 000 000	0-36	36	✓	✓	✓	✓	✓	✓
3	3 000 000	0-51	51	✓	✓	✓	✓	✓	✓
4	3 000 000	0-66	66	✓	✓	✓	✓	✓	✓
5	3 000 000	0-99	99	✓	✓	✓	✓	✓	✓
6	3 000 000	0-500	500	✓	✓	✓	✓	✓	✓
7	3 000 000	0-999	999	✓	✓	✓	✓	✓	✓

2. OUTPUT BASED TESTING ON SHUFFLED DECKS

a. OUTPUT BASED TESTING ON SHUFFLED DECKS RESULTS

OUTPUT BASED TESTING				CLIENT GENERATED DATA			eCOGRA GENERATED DATA		
				Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3
Tests Number	Sample size	Test Range	DoF	P-value	P-value	P-value	P-value	P-value	P-value
1	3 000 000	5 Card Hands	8	0.5357	0.6372	0.4113	0.3492	0.2680	0.6661
2	3 000 000	7 Card Hands	9	0.1926	0.5900	0.6874	0.5440	0.2847	0.5507
3	3 000 000	5-7 Card Multiples Combinations	17	0.4243	0.5898	0.6588	0.3102	0.3325	0.6622
4	3 000 000	5-7 Card Suit Combinations	29	0.5941	0.7854	0.4794	0.3397	0.3164	0.5137

b. SHUFFLED DECKS RANDOMNESS TEST SUCCESS (✓) OR FAILURE (×) SUMMARY

OUTPUT BASED TESTING				CLIENT GENERATED DATA			eCOGRA GENERATED DATA		
				Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3
Tests Number	Sample size	Test Range	DoF	P-value	P-value	P-value	P-value	P-value	P-value
1	3 000 000	5 Card Hands	8	✓	✓	✓	✓	✓	✓
2	3 000 000	7 Card Hands	9	✓	✓	✓	✓	✓	✓
3	3 000 000	5-7 Card Multiples Combinations	17	✓	✓	✓	✓	✓	✓
4	3 000 000	5-7 Card Suit Combinations	29	✓	✓	✓	✓	✓	✓

3. DIEHARD TESTS

a. DIEHARD TEST RESULTS

DIEHARD TEST		CLIENT GENERATED DATA			eCOGRA GENERATED DATA		
Test Name	**Sample Size**	**Sample 1**	**Sample 2**	**Sample 3**	**Sample 1**	**Sample 2**	**Sample 3**
BIRTHDAY SPACINGS TEST	48 000 000	0.1056	0.0320	0.0776	0.3561	0.0782	0.0575
OVERLAPPING 5-PERMUTATION TEST	48 000 000	0.1839	0.0592	0.1001	0.0051	0.0464	0.0065
THE BITSTREAM TEST	48 000 000	0.0354	0.0921	0.0048	0.0021	0.0123	0.0519
COUNT-THE-1's TEST bytes	48 000 000	0.0226	0.0343	0.0457	0.0371	0.0102	0.0045
MINIMUM DISTANCE TEST	48 000 000	0.2037	0.7028	0.1616	0.2168	0.4892	0.4779
SQEEZE TEST	48 000 000	0.5631	0.9132	0.3752	0.5125	0.3864	0.8227
RUNS TEST	48 000 000	0.2219	0.1784	0.2261	0.0069	0.4231	0.3137
CRAPS TEST	48 000 000	0.1452	0.1763	0.4083	0.3834	0.5178	0.1343

b. DIEHARD TESTS SUCCESS (✓) OR FAILURE (×) SUMMARY

DIEHARD TEST		CLIENT GENERATED DATA			eCOGRA GENERATED DATA		
Test Name	**Sample Size**	**Sample 1**	**Sample 2**	**Sample 3**	**Sample 1**	**Sample 2**	**Sample 3**
BIRTHDAY SPACINGS TEST	48 000 000	✓	✓	✓	✓	✓	✓
OVERLAPPING 5-PERMUTATION TEST	48 000 000	✓	✓	✓	✓	✓	✓
THE BITSTREAM TEST	48 000 000	✓	✓	✓	✓	✓	✓
COUNT-THE-1's TEST bytes	48 000 000	✓	✓	✓	✓	✓	✓
MINIMUM DISTANCE TEST	48 000 000	✓	✓	✓	✓	✓	✓
SQEEZE TEST	48 000 000	✓	✓	✓	✓	✓	✓
RUNS TEST	48 000 000	✓	✓	✓	✓	✓	✓
CRAPS TEST	48 000 000	✓	✓	✓	✓	✓	✓

4. SERIAL CORRELATION TESTS

a. SERIAL CORRELATION TEST RESULTS:

	DECK 3					DECK 1				
	Col 1	**Col 2**	**Col 3**	**Col 4**	**Col 5**	**Col 1**	**Col 2**	**Col 3**	**Col 4**	**Col 5**
LAG 1	0.4492	0.9378	0.9673	0.7182	0.4029	0.6881	0.8230	0.5791	0.9569	0.4262
LAG 2	0.2573	0.9543	0.9951	0.0519	0.5867	0.4602	0.7424	0.1508	0.9445	0.5070
LAG 3	0.2308	0.9880	0.9822	0.1078	0.7833	0.4493	0.8678	0.2225	0.3162	0.7058
LAG 4	0.1825	0.9774	0.8953	0.1636	0.8693	0.5151	0.7288	0.2905	0.4719	0.5515
LAG 5	0.1017	0.9935	0.9082	0.0692	0.9217	0.6597	0.8053	0.3718	0.5892	0.5557
LAG 6	0.1622	0.9983	0.7516	0.0920	0.6885	0.5908	0.8083	0.1070	0.6724	0.3921
LAG 7	0.2133	0.9996	0.8326	0.1235	0.7881	0.7038	0.8607	0.1084	0.7443	0.5044
LAG 8	0.2944	0.9975	0.8832	0.1567	0.8159	0.6720	0.9148	0.1097	0.8154	0.5108
LAG 9	0.3541	0.8004	0.8632	0.2199	0.6656	0.5294	0.9404	0.1596	0.8329	0.1030
LAG 10	0.4333	0.8642	0.9129	0.1895	0.4754	0.2830	0.9665	0.2195	0.8722	0.1253

b. SERIAL CORRELATION TEST SUCCESS (✓) OR FAILURE (×) SUMMARY

	DECK 3					DECK 1				
	Col 1	**Col 2**	**Col 3**	**Col 4**	**Col 5**	**Col 1**	**Col 2**	**Col 3**	**Col 4**	**Col 5**
LAG 1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
LAG 2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
LAG 3	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
LAG 4	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
LAG 5	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
LAG 6	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
LAG 7	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
LAG 8	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
LAG 9	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
LAG 10	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

5. CORRELATION TESTS

a. CORRELATION TEST RESULTS: Sample 1

	CLIENT GENERATED DATA							eCOGRA GENERATED DATA						
Range	**0-33**	**0-36**	**0-51**	**0-66**	**0-99**	**0-500**	**0-999**	**0-33**	**0-36**	**0-51**	**0-66**	**0-99**	**0-500**	**0-999**
LAG 1	0.4609	0.8204	0.6402	0.3098	0.0950	0.2991	0.2599	0.7379	0.2945	0.8062	0.3048	0.3798	0.2627	0.1801
LAG 2	0.3167	0.8035	0.0996	0.3750	0.1961	0.4951	0.3051	0.6420	0.3475	0.9080	0.2802	0.2328	0.2587	0.4072
LAG 3	0.4486	0.9283	0.1970	0.3863	0.0326	0.3632	0.3693	0.6722	0.3323	0.8191	0.4644	0.3482	0.2732	0.5993
LAG 4	0.4034	0.9755	0.0546	0.5473	0.0572	0.3535	0.5318	0.8091	0.4757	0.1173	0.3235	0.4987	0.3365	0.7539
LAG 5	0.5405	0.9897	0.0501	0.6382	0.0434	0.4919	0.6739	0.0735	0.2480	0.1759	0.2186	0.5410	0.4527	0.8540
LAG 6	0.6647	0.9917	0.0192	0.7459	0.0667	0.5791	0.3444	0.0710	0.2901	0.1926	0.3020	0.5021	0.5014	0.8356
LAG 7	0.7690	0.7874	0.0057	0.7638	0.0139	0.1308	0.0754	0.1103	0.3899	0.2051	0.3537	0.5495	0.6120	0.8822
LAG 8	0.8251	0.8387	0.0058	0.8426	0.0171	0.1743	0.0781	0.0265	0.2200	0.1023	0.4567	0.6214	0.4587	0.9310
LAG 9	0.7611	0.6714	0.0059	0.8975	0.0285	0.1645	0.0626	0.0405	0.2677	0.0740	0.5364	0.7074	0.5516	0.9620
LAG 10	0.8318	0.7481	0.0083	0.9152	0.0429	0.2193	0.0937	0.0388	0.2100	0.0849	0.6298	0.7525	0.4617	0.9790

b. CORRELATION TEST SUCCESS (✓) OR FAILURE (×) SUMMARY

	CLIENT GENERATED DATA							eCOGRA GENERATED DATA						
Range	**0-33**	**0-36**	**0-51**	**0-66**	**0-99**	**0-500**	**0-999**	**0-33**	**0-36**	**0-51**	**0-66**	**0-99**	**0-500**	**0-999**
LAG 1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
LAG 2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
LAG 3	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
LAG 4	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
LAG 5	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
LAG 6	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
LAG 7	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
LAG 8	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
LAG 9	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
LAG 10	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

3. CONCLUSION

Our test results together with the individual Level 3 game testing certifications produced statistically acceptable outcomes that were free of any significant statistical bias or predictability. Based on the testing conducted, the RNG is compliant with the requirements of RTS 7A and RTS 7B of the UKGC's Remote gambling and software technical standards – June 2017.