

# COMP 3850 Final Report

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## Data Results

### NIST Results of ALL Observations

	Test Name	Outcome	Outcome2	Outcome3	Outcome4	Outcome5	Outcome6
0	Frequency Test (Monobit)	Absolute	Random	Random	Random	Random	Absolute
1	Frequency Test within a Block	Non-Random	Non-Random	Random	Non-Random	Random	Random
2	Run Test	Non-Random	Non-Random	Random	Non-Random	Non-Random	Non-Random
3	Longest Run of Ones in a Block	Random	Non-Random	Random	Non-Random	Random	Non-Random
4	Binary Matrix Rank Test	Random	Random	Random	Random	Random	Error
5	Discrete Fourier Transform (Spectral) Test	Random	Non-Random	Random	Random	Random	Random
6	Non-Overlapping Template Matching Test	Non-Random	Non-Random	Random	Random	Random	Random
7	Overlapping Template Matching Test	Non-Random	Non-Random	Random	Random	Random	Error
8	Maurer's Universal Statistical Test	Error	Error	Error	Error	Error	Error
9	Linear Complexity Test	Random	Random	Random	Random	Random	Error
10	Serial Test A	Non-Random	Non-Random	Random	Non-Random	Random	Random
11	Serial Test B	Non-Random	Random	Random	Non-Random	Random	Random
12	Approximate Entropy Test	Non-Random	Non-Random	Random	Non-Random	Random	Absolute
13	Cumulative Sums (Forward) Test	Random	Random	Random	Non-Random	Random	Random
14	Cumulative Sums (Reverse) Test	Random	Random	Random	Non-Random	Random	Random
15	Random Excursions Test State -4	Random	Random	Random	Random	Non-Random	Random
16	Random Excursions Test State -3	Random	Non-Random	Random	Random	Random	Random
17	Random Excursions Test State -2	Random	Non-Random	Random	Random	Random	Random
18	Random Excursions Test State -1	Random	Random	Random	Random	Random	Random
19	Random Excursions Test State +1	Random	Random	Random	Random	Random	Random
20	Random Excursions Test State +2	Random	Random	Random	Random	Random	Random
21	Random Excursions Test State +3	Random	Random	Random	Random	Random	Random
22	Random Excursions Test State +4	Random	Random	Random	Random	Random	Non-Random
23	Random Excursions Variant Test State -9	Random	Random	Random	Random	Random	Random
24	Random Excursions Variant Test State -8	Random	Random	Random	Random	Random	Random
25	Random Excursions Variant Test State -7	Random	Random	Random	Random	Random	Random
26	Random Excursions Variant Test State -6	Random	Random	Random	Random	Random	Random
27	Random Excursions Variant Test State -5	Random	Random	Random	Random	Random	Random
28	Random Excursions Variant Test State -4	Random	Random	Random	Random	Random	Random
29	Random Excursions Variant Test State -3	Random	Random	Random	Random	Random	Random
30	Random Excursions Variant Test State -2	Random	Random	Random	Random	Random	Random
31	Random Excursions Variant Test State -1	Random	Random	Random	Random	Random	Random
32	Random Excursions Variant Test State +1	Random	Random	Random	Random	Random	Random
33	Random Excursions Variant Test State +2	Random	Random	Random	NaN	Random	Random
34	Random Excursions Variant Test State +3	Random	Random	Random	NaN	Random	Random
35	Random Excursions Variant Test State +4	Random	Random	Random	NaN	Absolute	Random
36	Random Excursions Variant Test State +5	Random	Random	Random	NaN	Random	Random
37	Random Excursions Variant Test State +6	Random	Random	Random	NaN	Random	Random
38	Random Excursions Variant Test State +7	Random	Random	Random	NaN	Random	Random
39	Random Excursions Variant Test State +8	Random	Random	Random	NaN	Random	Random
40	Random Excursions Variant Test State +9	Random	Random	Random	NaN	Random	Random

## NIST Results of Every5th and Pulsar4 Tenths

### Every5th

	Test Name	Outcome	Outcome2	Outcome3	Outcome4	Outcome5	Outcome6
0	Frequency Test (Monobit)	Random	Random	Random	Random	Random	Random
1	Frequency Test within a Block	Random	Random	Random	Non-Random	Random	Random
2	Run Test	Random	Random	Random	Non-Random	Random	Random
3	Longest Run of Ones in a Block	Random	Random	Random	Random	Random	Random
4	Binary Matrix Rank Test	Random	Random	Error	Error	Error	Error
5	Discrete Fourier Transform (Spectral) Test	Random	Random	Non-Random	Random	Random	Random
6	Non-Overlapping Template Matching Test	Random	Random	Random	Absolute	Absolute	Random
7	Overlapping Template Matching Test	Random	Random	Error	Error	Error	Error
8	Maurer's Universal Statistical Test	Error	Error	Error	Error	Error	Error
9	Linear Complexity Test	Random	Random	Error	Error	Error	Error
10	Serial Test A	Random	Random	Random	Non-Random	Random	Random
11	Serial Test B	Random	Random	Random	Non-Random	Random	Random
12	Approximate Entropy Test	Non-Random	Non-Random	Absolute	Absolute	Absolute	Absolute
13	Cumulative Sums (Forward) Test	Random	Random	Random	Non-Random	Random	Random
14	Cumulative Sums (Reverse) Test	Random	Random	Random	Non-Random	Random	Random
15	Random Excursions Test State -4	Random	Random	Random	Random	Random	Random
16	Random Excursions Test State -3	Random	Random	Random	Random	Random	Random
17	Random Excursions Test State -2	Random	Random	Random	Random	Random	Random
18	Random Excursions Test State -1	Random	Random	Random	Random	Random	Random
19	Random Excursions Test State +1	Random	Non-Random	Random	Non-Random	Random	Random
20	Random Excursions Test State +2	Non-Random	Non-Random	Random	Non-Random	Random	Random
21	Random Excursions Test State +3	Non-Random	Random	Random	Non-Random	Random	Random
22	Random Excursions Test State +4	Random	Random	Random	Non-Random	Random	Random
23	Random Excursions Variant Test State +1	Random	Random	Random	Random	Random	Random
24	Random Excursions Variant Test State +2	Random	Random	Random	Non-Random	Random	Random
25	Random Excursions Variant Test State +3	Random	Random	Random	Non-Random	Random	Random
26	Random Excursions Variant Test State +4	Non-Random	Random	Random	Non-Random	Random	Random
27	Random Excursions Variant Test State +5	Non-Random	Random	Random	Random	Random	Random
28	Random Excursions Variant Test State +6	Non-Random	Random	Random	Random	Random	Random
29	Random Excursions Variant Test State +7	Non-Random	Random	Random	Random	Random	Random
30	Random Excursions Variant Test State +8	Random	Random	Random	Random	Random	Random
31	Random Excursions Variant Test State +9	Random	Random	Random	Random	Random	Random

# Pulsar4 10ths

	Test Name	Outcome
0	Frequency Test (Monobit)	Random
1	Frequency Test within a Block	Random
2	Run Test	Non-Random
3	Longest Run of Ones in a Block	Random
4	Binary Matrix Rank Test	Error
5	Discrete Fourier Transform (Spectral) Test	Random
6	Non-Overlapping Template Matching Test	Absolute
7	Overlapping Template Matching Test	Error
8	Maurer's Universal Statistical Test	Error
9	Linear Complexity Test	Error
10	Serial Test A	Non-Random
11	Serial Test B	Non-Random
12	Approximate Entropy Test	Absolute
13	Cumulative Sums (Forward) Test	Random
14	Cumulative Sums (Reverse) Test	Random
15	Random Excursions Test State -4	Random
16	Random Excursions Test State -3	Random
17	Random Excursions Test State -2	Random
18	Random Excursions Test State -1	Random
19	Random Excursions Test State +1	Random
20	Random Excursions Test State +2	Random
21	Random Excursions Test State +3	Random
22	Random Excursions Test State +4	Random
23	Random Excursions Variant Test State -3	Random
24	Random Excursions Variant Test State -2	Random
25	Random Excursions Variant Test State -1	Random
26	Random Excursions Variant Test State +1	Absolute
27	Random Excursions Variant Test State +2	Random
28	Random Excursions Variant Test State +3	Random
29	Random Excursions Variant Test State +4	Random
30	Random Excursions Variant Test State +5	Random
31	Random Excursions Variant Test State +6	Random
32	Random Excursions Variant Test State +7	Random
33	Random Excursions Variant Test State +8	Random
34	Random Excursions Variant Test State +9	Random

## RandTest Results

	RandTestAll	RandTest5ths	RandTestElse
0	True	True	Null
1	True	True	Null
2	True	True	Null
3	True	True	True
4	True	True	Null
5	True	True	Null

## Interpretation of Data results

### RandTest Results Interpretation

The RandTest suite uses an algorithm called “exponentially-decaying moment prediction” to determine the net deviation between predicted and actual elements in sequences. It evaluated whether or not a sequence of numbers is random or not. It has a stated accuracy of 99.85% for nonrandom sequences and 96.82% for random sequences. This means the test will typically sustain a high degree of accuracy especially at a 0.05 cut off. But does falter at meeting the cyber security standard of 0.01. This means we will use this in conjunction with the overall statement from the NIST suite on the specific tests as extra evidence to prove or disprove randomness. In the case above we can clearly see that RandTest labels all binary sequences as random with no prediction this means we can confidently say with 96% certainty of this truth, this meets most standards of prediction. But fails to meet the industry standard of 99% accuracy with cybersecurity.

### Focusing on the primary 5 NIST Results

The first five tests are interpreted as the most important.

1. The Frequency (Monobit) Test is the first test in the NIST suite, and the remainder of the tests are dependent upon this test retaining the null hypothesis. The test determines the closeness of the fraction of 1's to  $1/2$ . For the test to pass, the number of 1's and 0's in the sequence should be similar. For the datasets containing every observation, the binary sequence has been created based on the median of the dataset, so by the nature of median (the middle value), the number of 0's and 1's will be equal (or different by 1 in the case of an odd number of observations), hence running the test on these sequences will return a p-value of 1 (or very close to 1 for odd number of observations), providing strong evidence to retain the null hypothesis, the expected outcome. Of more interest is the same test on the datasets of every 5th observation (pulsars 1, 2, 3, 4, 5, 6) and the test on every 10th observation (pulsar 4), where there isn't the same guarantee of an equal amount of 0's and 1's. Analyzing the results of each test, every number sequence passes. The lowest p-value observed is 0.096872 for pulsar 1 for every 5th observation, however it is still well above the 0.01 significance level. Now that each dataset has passed this test, further testing can be undertaken.

2. The next test, Frequency Test within a Block, applies a similar logic to the previous test, but instead tests the proportion of 1's in a bit block of length  $M$ , expecting the frequency of 1's to be close to  $M/2$  for the test to pass. For the datasets with every observation, pulsars 1,2 and 4 fail this test (extremely small p-values). On the other hand, pulsars 3 and 6 provide extremely strong evidence (high p-value) that the fraction of 1's with the  $M$  length bit blocks is close to  $1/2$ . While pulsar 5 has provides moderate evidence, p-value = 0.0398, just over the alpha of 0.01, that there is an equal proportion of 1's and 0's. Looking to the datasets with every 5th observation, pulsars 1,2,3,5 and 6 pass with fairly strong evidence, while pulsar 4 fails. Then for pulsar 4 with every 10th observation it just passes with a p-value of 0.0216.

3. The Runs Test focuses on the number of runs in a sequence, where a run is the number of identical bits in a row. E.g., a run of length 25 is a sequence of 25 zeroes (or ones) in a row. The test determines if the number of runs is as would be expected in a random sequence. For datasets containing every observation, pulsar 1,2,4,5 and 6 fail to pass this test, while pulsar 3 passes. For the datasets on every 5th observation, there is a large shift in the number of sequences that pass, pulsar 1, 2, 3, 5 and 6 all pass, while only pulsar 4 fails. For every 10th observation on pulsar 4 the test also fails.

4. The Test for the Longest Run of Ones in a Block provides a similar approach as the previous Runs Test; however, it instead focuses on the longest run of ones within  $M$ -bit blocks and compares it with what would be expected of a random sequence. For the datasets containing all observations, pulsar 1, 3 and 5 passes pulsar 2, 4 and 6 fails. When we look at the datasets containing every 5th observation, all six pulsars pass. In addition, the test on every 10th observation of pulsar 4 also passes.

5. The fifth test is the Binary Matric Rank Test; this test breaks the binary sequence down into  $32 \times 32$  matrices. Then it tests for linear dependence within the matrices. Given the nature of this test, the datasets need to be quite large for the test to be able to run, some of the datasets, especially those with every 5th or 10th observation may not have had enough data to run. If this situation occurs, the test will return a p-value of  $-1$ , which is an indicator that the test was unable to run, based on too little data. For pulsars with every observation included pulsars 1, 2, 3, 4 and 5 pass and pulsar 6 doesn't have enough data to run (hence p-value = -1). For the datasets containing every 5th observation, 1 and 2 pass while pulsars 3, 4, 5 and 6 can't run due to too little data

## Summary Tables of Results

### Pulsar 1

Every Observation	
Frequency Test (Monobit)	Pass
Frequency Test within a Block	Fail
Run Test	Fail
Longest Run of Ones in a Block	Pass
Binary Matrix Rank Test	Pass
<b>Total Passes</b>	<b>3</b>

Every <u>5th</u> Observation	
Frequency Test (Monobit)	Pass
Frequency Test within a Block	Pass
Run Test	Pass
Longest Run of Ones in a Block	Pass
Binary Matrix Rank Test	Pass
<b>Total Passes</b>	<b>5</b>

### Pulsar 2

Every Observation	
Frequency Test (Monobit)	Pass
Frequency Test within a Block	Fail
Run Test	Fail
Longest Run of Ones in a Block	Fail
Binary Matrix Rank Test	Pass
<b>Total Passes</b>	<b>2</b>

Every <u>5th</u> Observation	
Frequency Test (Monobit)	Pass
Frequency Test within a Block	Pass
Run Test	Pass
Longest Run of Ones in a Block	Pass
Binary Matrix Rank Test	Pass
<b>Total Passes</b>	<b>5</b>

### Pulsar 3

Every Observation	
Frequency Test (Monobit)	Pass
Frequency Test within a Block	Pass
Run Test	Pass
Longest Run of Ones in a Block	Pass
Binary Matrix Rank Test	Pass
<b>Total Passes</b>	<b>5</b>

Every <u>5th</u> Observation	
Frequency Test (Monobit)	Pass
Frequency Test within a Block	Pass
Run Test	Pass
Longest Run of Ones in a Block	Pass
Binary Matrix Rank Test	N/A
<b>Total Passes</b>	<b>4</b>



Pulsar 4

Every Observation	
Frequency Test (Monobit)	Pass
Frequency Test within a Block	Fail
Run Test	Fail
Longest Run of Ones in a Block	Fail
Binary Matrix Rank Test	Pass
<b>Total Passes</b>	<b>2</b>

Every <u>10th</u> Observation	
Frequency Test (Monobit)	Pass
Frequency Test within a Block	Pass
Run Test	Fail
Longest Run of Ones in a Block	Pass
Binary Matrix Rank Test	N/A
<b>Total Passes</b>	<b>3</b>

Every 5th Observation	
Frequency Test (Monobit)	Pass
Frequency Test within a Block	Fail
Run Test	Fail
Longest Run of Ones in a Block	Pass
Binary Matrix Rank Test	N/A
<b>Total Passes</b>	<b>2</b>

## Pulsar 5

Every Observation		Every <u>5th</u> Observation	
Frequency Test (Monobit)	Pass	Frequency Test (Monobit)	Pass
Frequency Test within a Block	Pass	Frequency Test within a Block	Pass
Run Test	Fail	Run Test	Pass
Longest Run of Ones in a Block	Pass	Longest Run of Ones in a Block	Pass
Binary Matrix Rank Test	Pass	Binary Matrix Rank Test	N/A
<b>Total Passes</b>	<b>4</b>	<b>Total Passes</b>	<b>4</b>

## Pulsar 6

Every Observation		Every <u>5th</u> Observation	
Frequency Test (Monobit)	Pass	Frequency Test (Monobit)	Pass
Frequency Test within a Block	Pass	Frequency Test within a Block	Pass
Run Test	Fail	Run Test	Pass
Longest Run of Ones in a Block	Fail	Longest Run of Ones in a Block	Pass
Binary Matrix Rank Test	N/A	Binary Matrix Rank Test	N/A
<b>Total Passes</b>	<b>2</b>	<b>Total Passes</b>	<b>4</b>

## Final Complete analysis

We can see here that most of the tests passed the first 2 most crucial tests except for Pulsar 4 which immediately disqualifies it from further evaluation. The same expectation can be said for the Pulsar binary datasets that do fail the Runs Test. However, Pulsar 5 is seen as a bit of an exception since it is the only pulsar that fails the Runs test but none of the other tests outside of the Random Excursions test at state -4. We pass 5 as random due to the sheer weighting of all the other evidence stacked against the runs test, this strongly indicates that the pulsar 5 should be more deeply investigate for a true determination. We can come to the summary conclusion that for all emissions, only Pulsar 3 is truly random, and Pulsar 5 is seen to be random pending further investigation. For Auto-Correlated observations at every 5th we can determine that the random pulsars are all of them except for 4 so this means Pulsars 1,2,3,5,6 at every 5th emission is random. At ACF 10th lags we find that the Pulsar 4 observations indeed become random, but due to the distance from the original emissions it is still seen as a non-random pulsar with some underlying structure that makes it uniform.

## Complete Summary Table

Designation	Assignment	All Emissions	Every 5th Emission	Every 10th Emission
J0437-4715	Pulsar 1	No	Yes	N/A
J0953+0755	Pulsar 2	No	Yes	N/A
J0835-4510	Pulsar 3	Yes	Yes	N/A
J1243-6423	Pulsar 4	No	No	Yes
J1456-6843	Pulsar 5	Yes	Yes	N/A
J1644-4559	Pulsar 6	No	Yes	N/A

**Yes = Random | No = Non-Random**

## Recommendations

### Further Pulsar Research

There are many different approaches that would be beneficial in a secondary further study of the material covered in this project by Group 15. In list format we will explain.

- More Pulsars and more observations of pulsars to both categorize and eliminate structure of the pulsars
- Analysis with more testing methods such as TestU01 and Ent Utility.
- Application of the uncertainty variable to eliminate and false categorizations or conclusions

### Other Avenues of Randomness

There are many areas that immutable randomness for humans may exist some avenues of research could be found by examining these 3 primary locations or systems.

- Stellar surface with sunspots and/or Coronal Mass Ejections
- Black hole accretion disks with the collision of matter and their emissions
- Radioactive decay in the stochastic process on what atom decays not the rate of decay.

## Appendix (Individual Pulsar Results)

Order goes

All Observations -> Every5th -> (where applied) Every10th

Pulsar 1

	Test Name	P-Value	Outcome
0	Frequency Test (Monobit)	1.000000e+00	Absolute
1	Frequency Test within a Block	9.050000e-08	Non-Random
2	Run Test	3.353164e-03	Non-Random
3	Longest Run of Ones in a Block	4.782901e-02	Random
4	Binary Matrix Rank Test	1.020085e-01	Random
5	Discrete Fourier Transform (Spectral) Test	5.765222e-01	Random
6	Non-Overlapping Template Matching Test	4.860000e-07	Non-Random
7	Overlapping Template Matching Test	5.365440e-04	Non-Random
8	Maurer's Universal Statistical Test	-1.000000e+00	Error
9	Linear Complexity Test	8.177284e-01	Random
10	Serial Test A	2.420000e-19	Non-Random
11	Serial Test B	1.600000e-06	Non-Random
12	Approximate Entropy Test	1.840000e-13	Non-Random
13	Cumulative Sums (Forward) Test	6.250000e-01	Random
14	Cumulative Sums (Reverse) Test	6.250000e-01	Random
15	Random Excursions Test State -4	1.210000e-01	Random
16	Random Excursions Test State -3	3.158609e-01	Random
17	Random Excursions Test State -2	3.590000e-01	Random
18	Random Excursions Test State -1	7.280000e-01	Random
19	Random Excursions Test State +1	2.730000e-01	Random
20	Random Excursions Test State +2	1.640000e-01	Random
21	Random Excursions Test State +3	3.070000e-01	Random
22	Random Excursions Test State +4	1.160000e-01	Random
23	Random Exursions Variant Test State -9	1.503674e-01	Random
24	Random Exursions Variant Test State -8	2.508288e-01	Random
25	Random Exursions Variant Test State -7	2.850494e-01	Random
26	Random Exursions Variant Test State -6	2.685964e-01	Random
27	Random Exursions Variant Test State -5	4.008621e-01	Random
28	Random Exursions Variant Test State -4	7.261831e-01	Random
29	Random Exursions Variant Test State -3	9.471395e-01	Random
30	Random Exursions Variant Test State -2	7.808785e-01	Random
31	Random Exursions Variant Test State -1	9.114677e-01	Random
32	Random Exursions Variant Test State +1	7.110000e-01	Random
33	Random Exursions Variant Test State +2	7.320000e-01	Random
34	Random Exursions Variant Test State +3	6.430000e-01	Random
35	Random Exursions Variant Test State +4	5.100000e-01	Random
36	Random Exursions Variant Test State +5	8.140000e-01	Random
37	Random Exursions Variant Test State +6	9.820000e-01	Random
38	Random Exursions Variant Test State +7	9.340000e-01	Random
39	Random Exursions Variant Test State +8	6.670000e-01	Random
40	Random Exursions Variant Test State +9	7.260000e-01	Random

	Test Name	P-Value
0	Frequency Test (Monobit)	0.096872
1	Frequency Test within a Block	0.273011
2	Run Test	0.295998
3	Longest Run of Ones in a Block	0.143727
4	Binary Matrix Rank Test	0.858290
5	Discrete Fourier Transform (Spectral) Test	0.453695
6	Non-Overlapping Template Matching Test	0.424735
7	Overlapping Template Matching Test	0.418207
8	Maurer's Universal Statistical Test	-1.000000
9	Linear Complexity Test	0.757153
10	Serial Test A	0.148533
11	Serial Test B	0.445237
12	Approximate Entropy Test	0.000145
13	Cumulative Sums (Forward) Test	0.072222
14	Cumulative Sums (Reverse) Test	0.193743
15	Random Excursions Test State -4	0.997903
16	Random Excursions Test State -3	0.995330
17	Random Excursions Test State -2	0.984748
18	Random Excursions Test State -1	0.849145
19	Random Excursions Test State +1	0.156236
20	Random Excursions Test State +2	0.000354
21	Random Excursions Test State +3	0.000475
22	Random Excursions Test State +4	0.369569
23	Random Excursions Variant Test State +1	0.317311
24	Random Excursions Variant Test State +2	0.386476
25	Random Excursions Variant Test State +3	0.013906
26	Random Excursions Variant Test State +4	0.000670
27	Random Excursions Variant Test State +5	0.007661
28	Random Excursions Variant Test State +6	0.000526
29	Random Excursions Variant Test State +7	0.002282
30	Random Excursions Variant Test State +8	0.038867
31	Random Excursions Variant Test State +9	0.015293

Pulsar 2

	Test Name	P-Value	Outcome2
0	Frequency Test (Monobit)	9.933346e-01	Random
1	Frequency Test within a Block	9.910000e-12	Non-Random
2	Run Test	3.200000e-94	Non-Random
3	Longest Run of Ones in a Block	3.810000e-36	Non-Random
4	Binary Matrix Rank Test	2.570000e-01	Random
5	Discrete Fourier Transform (Spectral) Test	6.140000e-05	Non-Random
6	Non-Overlapping Template Matching Test	3.830000e-26	Non-Random
7	Overlapping Template Matching Test	4.630000e-13	Non-Random
8	Maurer's Universal Statistical Test	-1.000000e+00	Error
9	Linear Complexity Test	5.807496e-01	Random
10	Serial Test A	2.350000e-17	Non-Random
11	Serial Test B	9.520000e-01	Random
12	Approximate Entropy Test	8.310000e-34	Non-Random
13	Cumulative Sums (Forward) Test	5.600000e-01	Random
14	Cumulative Sums (Reverse) Test	5.530000e-01	Random
15	Random Excursions Test State -4	2.050000e-01	Random
16	Random Excursions Test State -3	7.680000e-03	Non-Random
17	Random Excursions Test State -2	1.610000e-03	Non-Random
18	Random Excursions Test State -1	1.780000e-02	Random
19	Random Excursions Test State +1	3.980000e-01	Random
20	Random Excursions Test State +2	4.020000e-01	Random
21	Random Excursions Test State +3	1.520000e-01	Random
22	Random Excursions Test State +4	4.760000e-01	Random
23	Random Exursions Variant Test State -9	8.054226e-01	Random
24	Random Exursions Variant Test State -8	8.514120e-01	Random
25	Random Exursions Variant Test State -7	9.198637e-01	Random
26	Random Exursions Variant Test State -6	9.651054e-01	Random
27	Random Exursions Variant Test State -5	9.037602e-01	Random
28	Random Exursions Variant Test State -4	6.808479e-01	Random
29	Random Exursions Variant Test State -3	5.164123e-01	Random
30	Random Exursions Variant Test State -2	3.147768e-01	Random
31	Random Exursions Variant Test State -1	1.467931e-01	Random
32	Random Exursions Variant Test State +1	3.100000e-01	Random
33	Random Exursions Variant Test State +2	7.060000e-01	Random
34	Random Exursions Variant Test State +3	8.460000e-01	Random
35	Random Exursions Variant Test State +4	9.560000e-01	Random
36	Random Exursions Variant Test State +5	7.170000e-01	Random
37	Random Exursions Variant Test State +6	8.100000e-01	Random
38	Random Exursions Variant Test State +7	9.680000e-01	Random
39	Random Exursions Variant Test State +8	9.550000e-01	Random
40	Random Exursions Variant Test State +9	8.880000e-01	Random



	Test Name	P-Value	Outcome2
0	Frequency Test (Monobit)	0.736699	Random
1	Frequency Test within a Block	0.753000	Random
2	Run Test	0.018694	Random
3	Longest Run of Ones in a Block	0.092363	Random
4	Binary Matrix Rank Test	0.481248	Random
5	Discrete Fourier Transform (Spectral) Test	0.565809	Random
6	Non-Overlapping Template Matching Test	0.526000	Random
7	Overlapping Template Matching Test	0.248594	Random
8	Maurer's Universal Statistical Test	-1.000000	Error
9	Linear Complexity Test	0.543779	Random
10	Serial Test A	0.123000	Random
11	Serial Test B	0.224000	Random
12	Approximate Entropy Test	0.000025	Non-Random
13	Cumulative Sums (Forward) Test	0.604000	Random
14	Cumulative Sums (Reverse) Test	0.904000	Random
15	Random Excursions Test State -4	0.332000	Random
16	Random Excursions Test State -3	0.161000	Random
17	Random Excursions Test State -2	0.625000	Random
18	Random Excursions Test State -1	0.719000	Random
19	Random Excursions Test State +1	0.008430	Non-Random
20	Random Excursions Test State +2	0.000040	Non-Random
21	Random Excursions Test State +3	0.152000	Random
22	Random Excursions Test State +4	0.383000	Random
23	Random Excursions Variant Test State -5	0.226919	Random
24	Random Excursions Variant Test State -4	0.237548	Random
25	Random Excursions Variant Test State -3	0.263552	Random
26	Random Excursions Variant Test State -2	0.193931	Random
27	Random Excursions Variant Test State -1	0.133614	Random
28	Random Excursions Variant Test State +1	0.261000	Random
29	Random Excursions Variant Test State +2	0.516000	Random
30	Random Excursions Variant Test State +3	0.576000	Random
31	Random Excursions Variant Test State +4	0.450000	Random
32	Random Excursions Variant Test State +5	0.739000	Random
33	Random Excursions Variant Test State +6	0.792000	Random
34	Random Excursions Variant Test State +7	0.533000	Random
35	Random Excursions Variant Test State +8	0.561000	Random
36	Random Excursions Variant Test State +9	0.649000	Random

Pulsar 3

	Test Name	P-Value	Outcome3
0	Frequency Test (Monobit)	0.978133	Random
1	Frequency Test within a Block	0.843000	Random
2	Run Test	0.051600	Random
3	Longest Run of Ones in a Block	0.206000	Random
4	Binary Matrix Rank Test	0.694000	Random
5	Discrete Fourier Transform (Spectral) Test	0.655000	Random
6	Non-Overlapping Template Matching Test	0.771000	Random
7	Overlapping Template Matching Test	0.887000	Random
8	Maurer's Universal Statistical Test	-1.000000	Error
9	Linear Complexity Test	0.320837	Random
10	Serial Test A	0.876000	Random
11	Serial Test B	0.553000	Random
12	Approximate Entropy Test	0.767000	Random
13	Cumulative Sums (Forward) Test	0.943000	Random
14	Cumulative Sums (Reverse) Test	0.926000	Random
15	Random Excursions Test State -4	0.339000	Random
16	Random Excursions Test State -3	0.590000	Random
17	Random Excursions Test State -2	0.573000	Random
18	Random Excursions Test State -1	0.590000	Random
19	Random Excursions Test State +1	0.491000	Random
20	Random Excursions Test State +2	0.565000	Random
21	Random Excursions Test State +3	0.448000	Random
22	Random Excursions Test State +4	0.643000	Random
23	Random Excursions Variant Test State -9	0.215330	Random
24	Random Excursions Variant Test State -8	0.180652	Random
25	Random Excursions Variant Test State -7	0.150421	Random
26	Random Excursions Variant Test State -6	0.174968	Random
27	Random Excursions Variant Test State -5	0.232254	Random
28	Random Excursions Variant Test State -4	0.286278	Random
29	Random Excursions Variant Test State -3	0.322716	Random
30	Random Excursions Variant Test State -2	0.332797	Random
31	Random Excursions Variant Test State -1	0.541866	Random
32	Random Excursions Variant Test State +1	0.493000	Random
33	Random Excursions Variant Test State +2	0.509000	Random
34	Random Excursions Variant Test State +3	0.759000	Random
35	Random Excursions Variant Test State +4	0.863000	Random
36	Random Excursions Variant Test State +5	0.780000	Random
37	Random Excursions Variant Test State +6	0.629000	Random
38	Random Excursions Variant Test State +7	0.410000	Random
39	Random Excursions Variant Test State +8	0.288000	Random
40	Random Excursions Variant Test State +9	0.309000	Random

	Test Name	P-Value	Outcome3
0	Frequency Test (Monobit)	0.951201	Random
1	Frequency Test within a Block	0.925000	Random
2	Run Test	0.126000	Random
3	Longest Run of Ones in a Block	0.957000	Random
4	Binary Matrix Rank Test	-1.000000	Error
5	Discrete Fourier Transform (Spectral) Test	0.003660	Non-Random
6	Non-Overlapping Template Matching Test	1.000000	Random
7	Overlapping Template Matching Test	-1.000000	Error
8	Maurer's Universal Statistical Test	-1.000000	Error
9	Linear Complexity Test	-1.000000	Error
10	Serial Test A	0.499000	Random
11	Serial Test B	0.499000	Random
12	Approximate Entropy Test	1.000000	Absolute
13	Cumulative Sums (Forward) Test	0.763000	Random
14	Cumulative Sums (Reverse) Test	0.705000	Random
15	Random Excursions Test State -4	0.886000	Random
16	Random Excursions Test State -3	0.347000	Random
17	Random Excursions Test State -2	0.735000	Random
18	Random Excursions Test State -1	0.700000	Random
19	Random Excursions Test State +1	0.659000	Random
20	Random Excursions Test State +2	0.258000	Random
21	Random Excursions Test State +3	0.018600	Random
22	Random Excursions Test State +4	0.783000	Random
23	Random Exursions Variant Test State -9	0.490920	Random
24	Random Exursions Variant Test State -8	0.463355	Random
25	Random Exursions Variant Test State -7	0.410205	Random
26	Random Exursions Variant Test State -6	0.413686	Random
27	Random Exursions Variant Test State -5	0.438578	Random
28	Random Exursions Variant Test State -4	0.406813	Random
29	Random Exursions Variant Test State -3	0.603332	Random
30	Random Exursions Variant Test State -2	0.765594	Random
31	Random Exursions Variant Test State -1	0.605577	Random
32	Random Exursions Variant Test State +1	0.699000	Random
33	Random Exursions Variant Test State +2	0.502000	Random
34	Random Exursions Variant Test State +3	0.326000	Random
35	Random Exursions Variant Test State +4	0.262000	Random
36	Random Exursions Variant Test State +5	0.263000	Random
37	Random Exursions Variant Test State +6	0.259000	Random
38	NaN	NaN	NaN
39	NaN	NaN	NaN
40	NaN	NaN	NaN

Pulsar 4

	Test Name	P-Value	Outcome4
0	Frequency Test (Monobit)	9.812939e-01	Random
1	Frequency Test within a Block	3.910000e-53	Non-Random
2	Run Test	3.420000e-21	Non-Random
3	Longest Run of Ones in a Block	3.930000e-08	Non-Random
4	Binary Matrix Rank Test	6.940000e-01	Random
5	Discrete Fourier Transform (Spectral) Test	1.820000e-02	Random
6	Non-Overlapping Template Matching Test	7.120000e-02	Random
7	Overlapping Template Matching Test	2.960000e-01	Random
8	Maurer's Universal Statistical Test	-1.000000e+00	Error
9	Linear Complexity Test	4.620000e-01	Random
10	Serial Test A	0.000000e+00	Non-Random
11	Serial Test B	0.000000e+00	Non-Random
12	Approximate Entropy Test	2.100000e-12	Non-Random
13	Cumulative Sums (Forward) Test	1.040000e-09	Non-Random
14	Cumulative Sums (Reverse) Test	8.930000e-10	Non-Random
15	Random Excursions Test State -4	9.730000e-01	Random
16	Random Excursions Test State -3	9.450000e-01	Random
17	Random Excursions Test State -2	8.490000e-01	Random
18	Random Excursions Test State -1	3.060000e-01	Random
19	Random Excursions Test State +1	9.310000e-01	Random
20	Random Excursions Test State +2	5.080000e-01	Random
21	Random Excursions Test State +3	1.770000e-01	Random
22	Random Excursions Test State +4	1.180000e-02	Random
23	Random Excursions Variant Test State -1	5.637029e-01	Random
24	Random Excursions Variant Test State +1	3.860000e-01	Random
25	Random Excursions Variant Test State +2	6.170000e-01	Random
26	Random Excursions Variant Test State +3	6.990000e-01	Random
27	Random Excursions Variant Test State +4	8.270000e-01	Random
28	Random Excursions Variant Test State +5	8.470000e-01	Random
29	Random Excursions Variant Test State +6	7.280000e-01	Random
30	Random Excursions Variant Test State +7	8.100000e-01	Random
31	Random Excursions Variant Test State +8	8.810000e-01	Random
32	Random Excursions Variant Test State +9	8.340000e-01	Random

	Test Name	P-Value	Outcome4
0	Frequency Test (Monobit)	8.339354e-01	Random
1	Frequency Test within a Block	3.340000e-03	Non-Random
2	Run Test	3.350000e-03	Non-Random
3	Longest Run of Ones in a Block	4.350000e-01	Random
4	Binary Matrix Rank Test	-1.000000e+00	Error
5	Discrete Fourier Transform (Spectral) Test	3.120000e-01	Random
6	Non-Overlapping Template Matching Test	1.000000e+00	Absolute
7	Overlapping Template Matching Test	-1.000000e+00	Error
8	Maurer's Universal Statistical Test	-1.000000e+00	Error
9	Linear Complexity Test	-1.000000e+00	Error
10	Serial Test A	0.000000e+00	Non-Random
11	Serial Test B	0.000000e+00	Non-Random
12	Approximate Entropy Test	1.000000e+00	Absolute
13	Cumulative Sums (Forward) Test	3.970000e-03	Non-Random
14	Cumulative Sums (Reverse) Test	7.880000e-03	Non-Random
15	Random Excursions Test State -4	9.980000e-01	Random
16	Random Excursions Test State -3	9.950000e-01	Random
17	Random Excursions Test State -2	9.850000e-01	Random
18	Random Excursions Test State -1	8.490000e-01	Random
19	Random Excursions Test State +1	6.840000e-03	Non-Random
20	Random Excursions Test State +2	2.980000e-04	Non-Random
21	Random Excursions Test State +3	3.550000e-04	Non-Random
22	Random Excursions Test State +4	1.220000e-04	Non-Random
23	Random Excursions Variant Test State +1	1.240000e-02	Random
24	Random Excursions Variant Test State +2	1.490000e-05	Non-Random
25	Random Excursions Variant Test State +3	2.700000e-07	Non-Random
26	Random Excursions Variant Test State +4	1.570000e-04	Non-Random
27	Random Excursions Variant Test State +5	6.680000e-02	Random
28	Random Excursions Variant Test State +6	1.320000e-01	Random
29	Random Excursions Variant Test State +7	3.750000e-02	Random
30	Random Excursions Variant Test State +8	5.280000e-02	Random
31	Random Excursions Variant Test State +9	2.750000e-01	Random

	Test Name	Outcome
0	Frequency Test (Monobit)	Random
1	Frequency Test within a Block	Random
2	Run Test	Non-Random
3	Longest Run of Ones in a Block	Random
4	Binary Matrix Rank Test	Error
5	Discrete Fourier Transform (Spectral) Test	Random
6	Non-Overlapping Template Matching Test	Absolute
7	Overlapping Template Matching Test	Error
8	Maurer's Universal Statistical Test	Error
9	Linear Complexity Test	Error
10	Serial Test A	Non-Random
11	Serial Test B	Non-Random
12	Approximate Entropy Test	Absolute
13	Cumulative Sums (Forward) Test	Random
14	Cumulative Sums (Reverse) Test	Random
15	Random Excursions Test State -4	Random
16	Random Excursions Test State -3	Random
17	Random Excursions Test State -2	Random
18	Random Excursions Test State -1	Random
19	Random Excursions Test State +1	Random
20	Random Excursions Test State +2	Random
21	Random Excursions Test State +3	Random
22	Random Excursions Test State +4	Random
23	Random Excursions Variant Test State -3	Random
24	Random Excursions Variant Test State -2	Random
25	Random Excursions Variant Test State -1	Random
26	Random Excursions Variant Test State +1	Absolute
27	Random Excursions Variant Test State +2	Random
28	Random Excursions Variant Test State +3	Random
29	Random Excursions Variant Test State +4	Random
30	Random Excursions Variant Test State +5	Random
31	Random Excursions Variant Test State +6	Random
32	Random Excursions Variant Test State +7	Random
33	Random Excursions Variant Test State +8	Random
34	Random Excursions Variant Test State +9	Random



Pulsar 5

	Test Name	P-Value	Outcome5
0	Frequency Test (Monobit)	0.977150	Random
1	Frequency Test within a Block	0.039800	Random
2	Run Test	0.000020	Non-Random
3	Longest Run of Ones in a Block	0.085500	Random
4	Binary Matrix Rank Test	0.694000	Random
5	Discrete Fourier Transform (Spectral) Test	0.064800	Random
6	Non-Overlapping Template Matching Test	0.032300	Random
7	Overlapping Template Matching Test	0.296000	Random
8	Maurer's Universal Statistical Test	-1.000000	Error
9	Linear Complexity Test	0.029600	Random
10	Serial Test A	0.853000	Random
11	Serial Test B	0.963000	Random
12	Approximate Entropy Test	0.956000	Random
13	Cumulative Sums (Forward) Test	0.761000	Random
14	Cumulative Sums (Reverse) Test	0.761000	Random
15	Random Excursions Test State -4	0.000254	Non-Random
16	Random Excursions Test State -3	0.019100	Random
17	Random Excursions Test State -2	0.162000	Random
18	Random Excursions Test State -1	0.067300	Random
19	Random Excursions Test State +1	0.941000	Random
20	Random Excursions Test State +2	0.951000	Random
21	Random Excursions Test State +3	0.155000	Random
22	Random Excursions Test State +4	0.027100	Random
23	Random Exursions Variant Test State -9	0.867859	Random
24	Random Exursions Variant Test State -8	0.790482	Random
25	Random Exursions Variant Test State -7	0.668588	Random
26	Random Exursions Variant Test State -6	0.569494	Random
27	Random Exursions Variant Test State -5	0.331137	Random
28	Random Exursions Variant Test State -4	0.194835	Random
29	Random Exursions Variant Test State -3	0.145052	Random
30	Random Exursions Variant Test State -2	0.092327	Random
31	Random Exursions Variant Test State -1	0.229949	Random
32	Random Exursions Variant Test State +1	0.170000	Random
33	Random Exursions Variant Test State +2	0.166000	Random
34	Random Exursions Variant Test State +3	0.645000	Random
35	Random Exursions Variant Test State +4	1.000000	Absolute
36	Random Exursions Variant Test State +5	0.775000	Random
37	Random Exursions Variant Test State +6	0.642000	Random
38	Random Exursions Variant Test State +7	0.812000	Random
39	Random Exursions Variant Test State +8	0.965000	Random
40	Random Exursions Variant Test State +9	0.835000	Random

	Test Name	P-Value	Outcome5
0	Frequency Test (Monobit)	0.898120	Random
1	Frequency Test within a Block	0.860000	Random
2	Run Test	0.095800	Random
3	Longest Run of Ones in a Block	0.693000	Random
4	Binary Matrix Rank Test	-1.000000	Error
5	Discrete Fourier Transform (Spectral) Test	0.217000	Random
6	Non-Overlapping Template Matching Test	1.000000	Absolute
7	Overlapping Template Matching Test	-1.000000	Error
8	Maurer's Universal Statistical Test	-1.000000	Error
9	Linear Complexity Test	-1.000000	Error
10	Serial Test A	0.853000	Random
11	Serial Test B	0.932000	Random
12	Approximate Entropy Test	1.000000	Absolute
13	Cumulative Sums (Forward) Test	0.894000	Random
14	Cumulative Sums (Reverse) Test	0.786000	Random
15	Random Excursions Test State -4	0.728000	Random
16	Random Excursions Test State -3	0.900000	Random
17	Random Excursions Test State -2	0.755000	Random
18	Random Excursions Test State -1	0.968000	Random
19	Random Excursions Test State +1	0.383000	Random
20	Random Excursions Test State +2	0.542000	Random
21	Random Excursions Test State +3	0.568000	Random
22	Random Excursions Test State +4	0.796000	Random
23	Random Excursions Variant Test State -9	0.638822	Random
24	Random Excursions Variant Test State -8	8.415830	Random
25	Random Excursions Variant Test State -7	0.382103	Random
26	Random Excursions Variant Test State -6	0.500924	Random
27	Random Excursions Variant Test State -5	0.630192	Random
28	Random Excursions Variant Test State -4	0.655119	Random
29	Random Excursions Variant Test State -3	0.597154	Random
30	Random Excursions Variant Test State -2	0.820090	Random
31	Random Excursions Variant Test State -1	0.599426	Random
32	Random Excursions Variant Test State +1	0.237000	Random
33	Random Excursions Variant Test State +2	0.225000	Random
34	Random Excursions Variant Test State +3	0.159000	Random
35	Random Excursions Variant Test State +4	0.234000	Random
36	Random Excursions Variant Test State +5	0.294000	Random
37	Random Excursions Variant Test State +6	0.285000	Random
38	Random Excursions Variant Test State +7	0.382000	Random
39	Random Excursions Variant Test State +8	0.416000	Random
40	Random Excursions Variant Test State +9	0.390000	Random

Pulsar 6

	Test Name	P-Value	Outcome6
0	Frequency Test (Monobit)	1.000000	Absolute
1	Frequency Test within a Block	0.836000	Random
2	Run Test	0.000011	Non-Random
3	Longest Run of Ones in a Block	0.000178	Non-Random
4	Binary Matrix Rank Test	-1.000000	Error
5	Discrete Fourier Transform (Spectral) Test	0.218000	Random
6	Non-Overlapping Template Matching Test	0.087500	Random
7	Overlapping Template Matching Test	-1.000000	Error
8	Maurer's Universal Statistical Test	-1.000000	Error
9	Linear Complexity Test	-1.000000	Error
10	Serial Test A	0.356000	Random
11	Serial Test B	0.697000	Random
12	Approximate Entropy Test	1.000000	Absolute
13	Cumulative Sums (Forward) Test	0.679000	Random
14	Cumulative Sums (Reverse) Test	0.679000	Random
15	Random Excursions Test State -4	0.196000	Random
16	Random Excursions Test State -3	0.398000	Random
17	Random Excursions Test State -2	0.760000	Random
18	Random Excursions Test State -1	0.845000	Random
19	Random Excursions Test State +1	0.272000	Random
20	Random Excursions Test State +2	0.135000	Random
21	Random Excursions Test State +3	0.076700	Random
22	Random Excursions Test State +4	0.002160	Non-Random
23	Random Exursions Variant Test State -9	0.324324	Random
24	Random Exursions Variant Test State -8	0.338728	Random
25	Random Exursions Variant Test State -7	0.388747	Random
26	Random Exursions Variant Test State -6	0.449177	Random
27	Random Exursions Variant Test State -5	0.449063	Random
28	Random Exursions Variant Test State -4	0.366256	Random
29	Random Exursions Variant Test State -3	0.335979	Random
30	Random Exursions Variant Test State -2	0.407626	Random
31	Random Exursions Variant Test State -1	0.719918	Random
32	Random Exursions Variant Test State +1	0.720000	Random
33	Random Exursions Variant Test State +2	0.730000	Random
34	Random Exursions Variant Test State +3	0.364000	Random
35	Random Exursions Variant Test State +4	0.442000	Random
36	Random Exursions Variant Test State +5	0.605000	Random
37	Random Exursions Variant Test State +6	0.719000	Random
38	Random Exursions Variant Test State +7	0.947000	Random
39	Random Exursions Variant Test State +8	0.975000	Random
40	Random Exursions Variant Test State +9	0.908000	Random

	Test Name	P-Value	Outcome6
0	Frequency Test (Monobit)	0.498962	Random
1	Frequency Test within a Block	0.596000	Random
2	Run Test	0.835000	Random
3	Longest Run of Ones in a Block	0.833000	Random
4	Binary Matrix Rank Test	-1.000000	Error
5	Discrete Fourier Transform (Spectral) Test	0.698000	Random
6	Non-Overlapping Template Matching Test	1.000000	Random
7	Overlapping Template Matching Test	-1.000000	Error
8	Maurer's Universal Statistical Test	-1.000000	Error
9	Linear Complexity Test	-1.000000	Error
10	Serial Test A	0.499000	Random
11	Serial Test B	0.098400	Random
12	Approximate Entropy Test	1.000000	Absolute
13	Cumulative Sums (Forward) Test	0.473000	Random
14	Cumulative Sums (Reverse) Test	0.849000	Random
15	Random Excursions Test State -4	0.431000	Random
16	Random Excursions Test State -3	0.494000	Random
17	Random Excursions Test State -2	0.221000	Random
18	Random Excursions Test State -1	0.149000	Random
19	Random Excursions Test State +1	0.570000	Random
20	Random Excursions Test State +2	0.801000	Random
21	Random Excursions Test State +3	0.924000	Random
22	Random Excursions Test State +4	0.963000	Random
23	Random Excursions Variant Test State -9	0.845815	Random
24	Random Excursions Variant Test State -8	0.944984	Random
25	Random Excursions Variant Test State -7	0.766848	Random
26	Random Excursions Variant Test State -6	0.808976	Random
27	Random Excursions Variant Test State -5	0.929013	Random
28	Random Excursions Variant Test State -4	0.613505	Random
29	Random Excursions Variant Test State -3	0.473289	Random
30	Random Excursions Variant Test State -2	0.643429	Random
31	Random Excursions Variant Test State -1	0.422678	Random
32	Random Excursions Variant Test State +1	0.109000	Random