Q-SLICE

Threat Harness User Guide

Q-SLICE Threat Harness v3 – User Guide

Q-SLICE™
THREAT MODEL

1. Overview
The Q-SLICE Threat Harness v3 is a configurable testbed for simulating quantum adversarial scenarios. It builds on V2 by introducing user-input parameters so researchers can explore different environments and attack conditions without modifying the code. The harness integrates tests across eight threat vectors in the six Q-SLICE elements:

1. Quantum Exploitation (Grover, Shor)
2. Subversion of Trust (BB84, RNG bias)
3. Legacy Exploitation
4. Integrity Disruption (Bell states)
5. Coherence Attacks
6. Ecosystem Abuse

It also computes reproducible Q-SLICE metrics (depth, fidelity, leakage, bias, QBER).

2. Requirements

- Python 3.8+ (3.12 or less for Qiskit Aer)
- Qiskit (latest stable release)
- **Optional**: Qiskit Aer for advanced simulation backends and noise models.
- If Aer is unavailable or not installed, the harness falls back to BasicAer or Statevector simulation.

Environment Setup and Script Execution
For the tests described in this document, the following environment configuration was used:

Miniconda was installed to provide a lightweight, reproducible Python environment. This ensured that all required dependencies for the harness could be isolated and managed without interfering with system-wide packages. Other Pytthon environments can be used as well.

A dedicated Conda environment was created specifically for running the scripts using *conda create --name quantum* follow steps of accepting and installing. Then use *conda activate quatum to switch to new environment*.

python.exe -m pip install qiskit numpy

Then run qslice_threat_harness_v3.py from the location it is saved to.

You will then be prompted to enter parameters. **Press Enter** to accept defaults.

3. User Inputs
At runtime, the harness requests the following:
Shots
The number of measurement repetitions per quantum test. As quantum circuits produce probabilistic outputs. More shots give better statistical accuracy.
Default: 1024
Tip: Increase for more reliable metrics; decrease for faster runs during prototyping.

Shor's N
The integer to be factored using Shor's algorithm. Demonstrates quantum factoring capability, which is a key threat to RSA/ECC.

Default: (factors into 3 and 5)
Tip: Larger values test scalability; fallback uses classical trial division if quantum backend is unavailable.

Bell Error Rate

The fraction of errors injected into entangled Bell states. Simulates entanglement disruption – a sign of integrity compromise in quantum communication.
Default: (5%)
Tip: Higher values simulate stronger attacks; lower values model subtle interference.

RNG Bias

The fraction of biased outcomes assigned to "0" in a simulated RNG attack. Models' entropy corruption. As skewed randomness undermines cryptographic trust.
Default: (70% zeros, 30% ones)
Tip: Adjust to simulate different levels of bias; 0.5 = balanced, 0.9 = extreme skew.

4. Outputs

Below is an example output from the script and explanation of each result element:

```
-- Threat Results --
QuantumExploitation_Grover: {'000': 512, '001': 512, '010': 512, '011': 512, '100': 512, '101': 512, '110': 512, '111': 512}
QuantumExploitation_Shor: {'N': 15, 'factors': [3, 5]}
SubversionOfTrust_BB84: {'qber': 0.25073746312684364, 'kept': 1017}
SubversionOfTrust_RNG: {'entropy': np.float64(1.0), 'biased': {'0': 2048, '1': 0}, 'clean': {'0': 1024, '1': 1024}}
LegacyExploitation: {'cipher_suites': ['TLS_RSA_WITH_AES_128_GCM_SHA256', 'ECDHE-ECDSA-AES256-GCM-SHA384'], 'key_sizes': {'RSA': 2048, 'ECC': 'P-256'}, 'pqc_migration_status': 'partial', 'harvest_now_decrypt_later_risk': 'elevated'}
IntegrityDisruption_Bell: {'clean': {'00': 1024, '11': 1024}, 'attacked': {'00': 512, '11': 512, '01': 1024, '10': 1024}}
CoherenceAttacks_Noise: {'clean': {'0': 1024, '1': 1024}, 'attacked': {'0': 921, '1': 1126}}
EcosystemAbuse: {'clean_env': {'0': 1024, '1': 1024}, 'untrusted_env': {'0': 1024, '1': 1024}}
```

Quantum Exploitation Grover

```
{'000': 512, '001': 512, '010': 512, '011': 512, '100': 512, '101': 512, '110': 512, '111': 512}
```

Every 3-qubit state appeared equally 512 times each. Grover's algorithm is supposed to amplify a "marked" state. Here, no state was amplified. As this is a uniform distribution, a control case. It confirms the harness can model non-exploitation scenarios.

Metric outcome: Depth = 1.0 → no adversarial advantage.

Quantum Exploitation Shor

```
{'N': 15, 'factors': [3, 5]}
```

Shor's algorithm successfully factored 15 into 3 and 5. This demonstrates algorithmic collapse. Which is the ability of quantum algorithms to break classical encryption foundations. Even though 15 is trivial, this evidences the principle: quantum adversaries can dismantle RSA/ECC at scale.

Metric outcome: Symbolic proof of cryptographic vulnerability.

Subversion of Trust BB84

```
{'qber': 0.2507, 'kept': 1017}
```

Quantum Bit Error Rate (QBER) is ~25%, with 1017 sifted bits. BB84 is a quantum key exchange protocol. A high QBER indicates interference or eavesdropping. This level of error is well above secure thresholds. Trust in the key exchange is compromised.

Metric outcome: QBER = 0.25 shows reproducible adversarial interference.

Subversion of Trust RNG

```
{'entropy': 1.0, 'biased': {'0': 2048, '1': 0}, 'clean': {'0': 1024, '1': 1024}}
```

Clean RNG was balanced (1024/1024), but the biased output was entirely skewed (2048 zeros, 0 ones). Randomness is foundational to cryptography. If an adversary can skew it, they can predict keys. This shows entropy corruption, where trust is undermined before key exchange even begins.

Metric outcome: Bias = 1.0 is total skew, zero entropy in this attack scenario.

Legacy Exploitation

```
{'cipher_suites': [...], 'key_sizes': {'RSA': 2048, 'ECC': 'P-256'},
  'pqc_migration_status': 'partial',
  'harvest_now_decrypt_later_risk': 'elevated'}
```

RSA-2048 and ECC P-256 are still in use; PQC migration is incomplete. These classical schemes are vulnerable to quantum attacks. Partial migration leaves systems exposed. There's a real risk that encrypted data today could be harvested and decrypted later when quantum hardware matures.

Metric outcome: Risk = elevated which means legacy cryptography remains exploitable.

Integrity Disruption Bell

```
{'clean': {'00': 1024, '11': 1024}, 'attacked': {'00': 512, '11': 512, '01': 1024, '10': 1024}}
```

Clean Bell states were perfectly entangled. Attacked states show leakage into unintended outcomes. Bell states test quantum integrity. Leakage means entanglement was disrupted. These results show a clear signature of integrity compromise. Adversaries can interfere with quantum correlations.

Metric outcome: Fidelity drops; leakage = 2048 which means a strong disruption.

Coherence Attacks Noise

```
{'clean': {'0': 1024, '1': 1024}, 'attacked': {'0': 921, '1': 1126}}
```

Clean distribution was balanced. Attacked distribution shows a ~10% bias toward '1'. Coherence attacks introduce subtle noise that skews quantum outcomes. Even small biases can accumulate and affect protocol integrity.

Metric outcome: Bias ≈ 0.09 means measurable adversarial influence.

Ecosystem Abuse

```
{'clean_env': {'0': 1024, '1': 1024}, 'untrusted_env': {'0': 1024, '1': 1024}}
```

No difference between clean and untrusted environments. This test checks for environmental divergence. Such as config-based manipulation. In this run, no abuse was detected. But the test confirms the harness can detect it when present.
Metric outcome: No deviation → environment integrity preserved.

5. Q-SLICE Metrics

Below is the output from the same test as above and a description of each of the metrics:

```
-- QSLICE Metrics --
QuantumExploitation_Depth: 1.0
IntegrityDisruption_Fidelity: 0.5
IntegrityDisruption_Leakage: 2048
CoherenceAttacks_Bias: 0.10014655593551539
SubversionOfTrust_QBER: 0.25073746312684364
```

Quantum Exploitation Depth

The ratio of the most frequent state to the least frequent in Grover's output. Depth > 1 means one state was amplified (exploitation). Depth = 1 means all states were equal.

Therefore, no state was amplified and this is a uniform distribution. It's a control case showing no adversarial advantage. The harness can model both exploitation (depth > 1) and non-exploitation (depth = 1).

Integrity Disruption Fidelity

Fidelity measures overlap between clean Bell states and attacked Bell states. Fidelity close to 1 means the attacked state still resembles the clean state. Lower values mean disruption. A fidelity of 0.5 means half the correlation was lost and entanglement integrity was significantly compromised. This evidences strong adversarial interference in quantum communication.

Integrity Disruption Leakage:

Number of measurement outcomes that leaked into unintended states during Bell disruption. Leakage is a direct indicator of entanglement corruption. 2048 outcomes were diverted into states that should not appear in a clean Bell pair. This shows a clear signature of integrity compromise. Adversaries can force quantum systems into unintended results.

Coherence Attacks Bias

Bias in the attacked distribution compared to a clean balanced distribution. Even small biases can undermine randomness and protocol reliability. A bias of ~0.10 means the attacked system produced about 10% more "1" outcomes than "0". This is a subtle but measurable adversarial influence. Coherence attacks don't break the system outright, but they skew it.

Subversion Of Trust QBER

Quantum Bit Error Rate (QBER) in the BB84 key exchange test. QBER measures how often Alice and Bob's bits disagree. Secure thresholds are usually <11%. A QBER of ~25% is far above safe limits, showing heavy interference or eavesdropping. So, trust in the key exchange is broken. Adversaries can compromise the protocol before secure communication begins.

6. Notes

- **Fallbacks:** If Aer is unavailable, the harness automatically uses **BasicAer** or **Statevector** simulation.
- **Noise Models**: Advanced noise injection is only available if Aer is installed. Otherwise, simulated errors are injected manually.
- **Reproducibility**: Metrics remain consistent across environments, ensuring comparable results even with different backends.

7. Suggested Use Cases

- Research validation: Demonstrating reproducible adversarial signatures.
- Scenario exploration: Adjusting parameters to model stronger/weaker attacks.
- Teaching/outreach: Showing how quantum threats manifest in accessible metrics.
- Thesis integration: Documenting methodological robustness and user-driven configurability.