

RFC-007: Threshold Signature Governance

Status: Implemented **Date:** January 2026 **Author:** Derrell Piper ddp@eludom.net **Implementation:** script.scm, cyberspace.scm

Abstract

This RFC specifies the threshold signature system for Cyberspace governance, enabling K-of-N multi-party authorization for critical operations. Democracy in code: no single point of failure, no rogue administrator.

Motivation

Critical operations require collective authorization:

- **Release signing:** Multiple maintainers must approve
- **Deployment:** Operations team quorum required
- **Key ceremonies:** Distributed trust for root keys
- **Emergency response:** Prevent unilateral action

Traditional approaches fail: – **Shared passwords:** Who has it? Who used it? – **Sudo access:** Root is root – **Approval workflows:** Soft controls, bypassable

Threshold signatures provide cryptographic enforcement:

K valid signatures required. Not K-1. Not bypass.
Mathematics.

Specification

Tiered Signing Model

SIGNING TIERS

| | | |
|-------------|--------|-------------------------------|
| Development | 1-of-1 | Single developer can iterate |
| Staging | 2-of-2 | Peer review required |
| Production | 3-of-5 | Governance council quorum |
| Emergency | 5-of-7 | Full council for critical ops |

Script Signature Record

```
(define-record-type <script-signature>
  (make-script-signature signer signature timestamp)
  script-signature?
  (signer signature-signer) ; Ed25519 public key (32 bytes)
  (signature signature-value) ; Ed25519 signature (64 bytes)
  (timestamp signature-timestamp)) ; Unix epoch seconds
```

Signing a Script

```
(define (sign-script script-content private-key #!optional public-key)
  "Sign script content with a private key"
  ...)
```

Process: 1. Convert content to blob if string 2. Derive public key from private (if not provided) 3. Sign content with Ed25519 4. Record timestamp 5. Return script-signature record

Verifying Single Signature

```
(define (verify-script script-content signature-record)
  "Verify a script signature"
  (ed25519-verify (signature-signer signature-record)
    content-blob
    (signature-value signature-record)))
```

Threshold Verification

```
(define (verify-threshold-script script-content signature-records threshold)
  "Verify threshold signatures on a script
  Returns: #t if at least K signatures are valid"
  (let* ((valid-sigs (filter (lambda (sig)
                                (verify-script script-content sig))
                                signature-records))
         (valid-count (length valid-sigs)))
    (>= valid-count threshold)))
```

Signature File Format

```
;; deploy.sig
((signature "hex-signature" "hex-pubkey" 1767685100)
 (signature "hex-signature" "hex-pubkey" 1767685200)
 (signature "hex-signature" "hex-pubkey" 1767685300))
```

Each entry contains: – Signature bytes (hex-encoded) – Signer public key (hex-encoded) – Timestamp (Unix epoch)

CLI Interface

cyberspace verify

```
$ cyberspace verify deploy.scm deploy.sig \
  --threshold 3 \
  --keys alice.pub bob.pub carol.pub dave.pub eve.pub

==== Cyberspace Script Verification ===

Script:      deploy.scm
Signatures:  deploy.sig
Threshold:   3
Keys:        5 provided

Found 3 signature(s) in file
  Signature 1: VALID (signer: cbc9b260da65f6a7...)
  Signature 2: VALID (signer: a5f8c9e3d2b1f0e4...)
  Signature 3: VALID (signer: 7d3e8b2c1a0f5e4d...)

SUCCESS: Script verified with 3-of-3 threshold
```

cyberspace run

```
$ cyberspace run deploy.scm deploy.sig \
  --threshold 3 \
  --keys alice.pub bob.pub carol.pub dave.pub eve.pub

==== Cyberspace Script Verification ===
...
  SUCCESS: Script verified with 3-of-5 threshold

==== Executing Script ===
(seal-release "2.0.0"
```

```
message: "Major release with new governance model"
preserve: #t)
```

Governance Scenarios

Production Deployment (3-of-5)

```
; Governance Council: Alice, Bob, Carol, Dave, Eve
;; Threshold: 3 signatures required

(define deployment-script
  "(seal-release \"2.0.0\
    message: \"Major release\
    preserve: #t)")

;; Alice signs
(define sig-alice
  (sign-script deployment-script alice-private alice-public))

;; Carol signs
(define sig-carol
  (sign-script deployment-script carol-private carol-public))

;; Dave signs
(define sig-dave
  (sign-script deployment-script dave-private dave-public))

;; Verify threshold
(define verify-threshold-script
  (lambda (deployment-script)
    (list sig-alice sig-carol sig-dave)
    3))

;; => #t
```

Insufficient Signatures

```
; Only 2 signatures
(define insufficient-sigs
  (list sig-alice sig-carol))

(define verify-threshold-script
  (lambda (deployment-script)
    (list sig-alice sig-carol)
    3))

;; => #f (rejected: need 3, got 2)
```

Tampered Script Detection

```
;; Attacker modifies script
(define tampered-script
  "(seal-release \"2.0.0\""
  message: \"HACKED - deploying malware\""
  preserve: #t)")

(verify-threshold-script tampered-script sufficient-sigs 3)
;; => #f (signatures don't match modified content)
```

Multi-Signature vs Shamir

Two threshold approaches exist:

Multi-Signature (This RFC)

Each party: own keypair
Signing: each signs independently
Verify: count valid signatures K
Use case: governance, approvals

Advantages: – Each party maintains own key – Clear audit trail (who signed) – Simple revocation (by key) – No key reconstruction

Shamir Splitting (RFC-008)

Single key: split into N shares
Signing: K parties reconstruct, sign once
Verify: single signature
Use case: key backup, recovery

Advantages: – Single signature output – Key never fully assembled (in advanced schemes) – Smaller signature files

For governance, multi-signature is preferred: – Accountability (which individuals approved) – No reconstruction ceremony – Works asynchronously

Security Considerations

Threat Model

Protected against: – Single compromised key (need K) – Rogue administrator (need quorum) – Script tampering (signatures fail) – Replay of old scripts (timestamps, context)

Not protected against: – K compromised keys – All parties colluding – Side-channel on signing devices

Key Management

1. **Generation:** Secure random via libsodium
2. **Storage:** Hardware tokens preferred, encrypted files acceptable
3. **Distribution:** Out-of-band verification of public keys
4. **Rotation:** New ceremony, revoke old keys

Threshold Selection

| Scenario | Threshold | Rationale |
|-------------|-----------|-----------------|
| Development | 1-of-1 | Fast iteration |
| Staging | 2-of-2 | Peer review |
| Production | 3-of-5 | Majority quorum |
| Root key | 5-of-7 | Supermajority |
| Emergency | N-of-N | Full consensus |

Audit Integration

Every verified execution records:

```
(audit-append
  actor: (threshold-verifier-list)
  action: (list 'script-execute script-hash)
  motivation: "Production deployment authorized"
  context: (list 'threshold 3 'signatures 3))
```

Audit trail shows: – Which signers authorized – What script was executed – When authorization occurred – Threshold requirements met

Implementation Notes

Dependencies

- crypto-ffi – Ed25519 operations
- cert – SPKI integration
- audit – Trail recording

Performance

- Signature verification: $\sim 10\mu\text{s}$ per Ed25519 verify
 - Threshold check: $O(N)$ where $N = \text{signature count}$
 - No network round-trips (offline verification)
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References

1. Boneh, D., et al. (2001). Short Signatures from the Weil Pairing.
 2. Gennaro, R., et al. (2016). Threshold-optimal DSA/ECDSA signatures.
 3. NIST SP 800-57. Recommendation for Key Management.
 4. RFC-004: SPKI Authorization Integration
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Changelog

- **2026-01-06** – Initial specification
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Implementation Status: Complete **Test Status:** Passing
(`test-threshold-sig.scm`) **CLI Tool:** cyberspace verify/run