Cowboy Secrets: CBSS

Technical Whitepaper

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Abstract

This document specifies the **Cowboy Secret Service (CBSS)**: the chain-native subsystem that lets account owners store API keys, model credentials, webhook tokens, and other application secrets on Cowboy and have them released, on demand, into the address space of a runner dispatched to execute a specific job for a specific actor. The authorized runner and its host can observe plaintext during execution; the chain, dispatcher, and any individual proxy cannot decrypt it on their own.

CBSS is a **threshold identity-based encryption (IBE)** scheme over BLS12-381, operated by a permissioned set of staked **CBSS Proxies** (the `cbssd` daemon). Each account has a per-account **release key** generated by a Distributed Key Generation (DKG) ceremony. To wrap a secret, the owner's CLI computes an identity from the secret's `(chain_id, account, key_hash, version, wrap_epoch, mpk_g2)` tuple, samples a fresh Boneh-Franklin encryption ephemeral `r` (publishing `U = r · G2_gen` in the envelope), derives a one-time AES key from `e(I, MPK)^r`, and AES-256-GCM-encrypts a fresh Data Encryption Key (DEK) into a chain-anchored `WrappedDek`. The plaintext payload itself is encrypted under the DEK and stored as a CBFS object. To unwrap, a runner constructs a signed release request, fans out partial-sign RPCs to `t` of `n` committee proxies, Lagrange-combines the partial BLS signatures into the threshold signature σ `= MSK · I`, and recovers the same AES key via `e(`σ`, U)` to decrypt the DEK and (separately) the CBFS payload. The ephemeral `^r` is what makes `K` secret: without it, `K` would be a public function of the (public) `MPK` and identity, and the threshold release would gate availability but not confidentiality.

Together with CBFS and the runner marketplace, CBSS gives Cowboy three properties: (1) **chain-derived authorization** for release requests (proxies check the responsible runner, actor, job, and policy against current chain state); (2) **off-chain plaintext** (no validator, dispatcher, or single proxy sees the DEK or payload); (3) **runner-scoped delivery** (secrets are rendered for one runner and one job without a shared secret cache). The critical release path requires no runner transaction, but participating proxies asynchronously attempt receipt transactions after serving. Receipt submission is currently best-effort and is not a completeness guarantee. This specification is a complement to the **Cowboy Technical Whitepaper** and the **Cowboy Storage Whitepaper**; where this document and the Technical Whitepaper conflict, the Technical Whitepaper prevails.

Introduction

Autonomous agents on Cowboy call model providers, search APIs, payment services, observability backends, and MCP tool servers that authenticate by bearer token. Without CBSS, a Cowboy

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actor can get that bearer token in front of a runner only by putting it in calldata, which exposes it to every validator and block-explorer scraper for the rest of consensus history. An actor that puts it in plaintext in CBFS trusts the runner not to leak it.

Smart-contract platforms have no native mechanism for conditional plaintext release. Ethereum's storage is public; even private rollups make every encrypted byte equally available to whoever decrypts the rollup. Validators can read any plaintext secrets in replicated state. Conversely, off-chain secret stores (Hashicorp Vault, AWS Secrets Manager, doppler.com) do release plaintext conditionally, but their authorization model is "an HTTPS bearer token from a long-lived service account," which has no link to the chain's notion of who is dispatched to do what.

The **authorization source** is chain state: an actor's manifest declares which secret keys it may read, the chain records the job and assigned runner, and the runner constructs and signs a release request against that state. The **plaintext path** lives off chain: the runner fans out partial signatures from a threshold committee, combines them locally, and decrypts the DEK and payload entirely in its own process. The **audit mechanism** is on chain when receipt submission succeeds: each participating proxy may submit a chain-verifiable receipt that pairs the partial signature against the proxy's published Verifiable Secret Sharing (VSS) commitment. Because daemon receipt work can be dropped when its worker pool is saturated, submission errors are only logged, and transaction admission is not execution confirmation, absence of a receipt is not proof that no release occurred. At no point during release does the chain or any single proxy hold the secret.

This document specifies the cryptographic construction, the on-chain instruction set (opcodes 68–84, 152–153, and 158), the `cbssd` proxy daemon, the runner-side `secrets-manager` client, the owner-facing CLI flows, the gas pricing, the slashing model, and the parameter table.

Architectural Overview

This Architectural Overview and **Related Work** are descriptive and non-binding. **Cryptographic Construction** and §§1–15 contain normative requirements. The key words **MUST**, **MUST NOT**, **REQUIRED**, **SHOULD**, **SHOULD NOT**, and **MAY** in this document are to be interpreted as described in RFC 2119 and RFC 8174 when, and only when, they appear in all capitals.

Terminology

- **Secret:** A named, account-owned, versioned byte string (e.g. `OPENAI_API_KEY`). The chain never sees the plaintext.

- **Owner:** The Cowboy account that owns one or more secrets. The owner's wallet key authorizes `SetSecret`, `UpdateSecretPolicy`, and `Delete*` transactions.
- **Actor / Runner / Job:** As in the Technical Whitepaper. An actor declares secrets it intends to read in its manifest; a job is dispatched to a specific runner; that runner is the one entitled to pull the declared secrets for the duration of the job.
- **CBSS Proxy:** A staked off-chain participant running the `cbssd` daemon. Proxies hold one BLS scalar share per release-key scope they serve and produce partial threshold signatures on demand.
- **Committee:** The ordered set of proxies serving a particular release key. The account default is 4-of-5, matching Commonware's `N3f1` quorum. The wire format carries override `n` and `t` values, but the production Commonware ceremony derives its polynomial quorum from `N3f1`; an override is usable only when its requested `t` equals that derived quorum.
- **DKG (Distributed Key Generation):** The multi-round protocol that produces the committee's Master Public Key (MPK), per-proxy shares, and per-proxy VSS commitments without any single proxy ever holding the Master Secret Key (MSK).
- **PSS Reshare:** Proactive Secret Sharing. A protocol that replaces every committee share with a fresh share for the same MSK, optionally over a different committee, without ever materialising the MSK.
- **Identity (`I`):** A point in `G1` derived deterministically from `(chain_id, account, key_hash, version, wrap_epoch, mpk_g2)`. Each secret version under each wrap epoch, on each chain, has a unique identity.
- **MPK / MSK:** Master Public Key (`MPK ∈ G2 = MSK · G2_gen`) and Master Secret Key (`MSK ∈ Scalar`, never instantiated). Preserved across reshares.
- **Wrapped DEK:** AES-256-GCM ciphertext of a Data Encryption Key, encrypted under the symmetric key derived from the IBE pairing `e(I, MPK)^r`, where `r` is the owner's per-wrap encryption ephemeral. The envelope (serialized format version 2) carries a leading 1-byte `version` tag, `ciphertext`, `nonce`, `ephemeral_u` (`U = r · G2_gen`, 96-byte compressed G2), and `aad`; readers reject unknown tag values.
- **CBFS pointer:** A CBFS object descriptor pointing to the AES-256-GCM ciphertext of the actual secret payload, encrypted under the DEK.
- **Release request:** `SignedReleaseRequestV4` contains a runner signature and a body with the release context, blinded identity and blinding-authorization proof. The context names the chain, secret/version, actor, runner, recipient, job, nonce, request block, serve epoch and optional CIP-33 hire. The signature binds the length-prefixed canonical body under `cbss/release-request/v4`.
- **Partial signature (σ_i):** `s_i · I` where `s_i` is a proxy's share. Verified individually via the pairing `e(`σ`_i, G2_gen) == e(I, S_i)` against the on-chain VSS commitment `S_i`.
- **Threshold signature (σ):** Lagrange combination of `t` partial signatures, equal to `MSK ·`

I.

- **Receipt:** A `SubmitReleaseReceiptArgsV4` submission containing `runner_request: SignedReleaseRequestV4` and `response: PartialSignResponseV4`. The response contains `request_hash`, `proxy_id`, the one-based `proxy_index`, `committee_epoch_at_serve`, `served_at_block`, blinded partial `tau` and `proxy_signature`. An accepted receipt earns the proxy a per-receipt fee and becomes a canonical audit record; missing receipts do not prove non-release.
- **CBSS System Actor (`0x04`):** The Cowboy system actor that owns secret metadata, release keys, proxy registry, DKG-pending records, release receipts, liveness challenges, and slashing.

Key Features

CBSS provides six core technical features:

- Off-chain plaintext data path. Wrap is local to the owner; unwrap is local to the runner. The chain stores ciphertext (`WrappedDek` and `cbfs_pointer`). DEKs and bundle entries use Rust `Zeroizing` wrappers, and mutable rendered strings are wiped after use. Checked codec containers are rebuilt and dropped rather than overwritten in place, so the implementation does not guarantee active zeroization of every plaintext allocation.
- Threshold IBE over BLS12-381. CBSS uses the same construction as drand for time-locked encryption: identity-based encryption where the "identity" is a per-version tuple, encryption uses only the public MPK, and decryption requires `t` of `n` proxies to produce partial BLS signatures on the identity. No single proxy holds enough information to decrypt; collusion requires $\geq$ `t` proxies.
- Per-account release keys with optional per-secret override. The default path generates one DKG per account and reuses its MPK for every secret the account wraps. High-value secrets can opt into a separate DKG and custom committee selection. The current production ceremony supports only the Commonware `N3f1` threshold for the selected committee size; arbitrary `T/N` ratios are not implemented safely.
- Chain-derived authorization. Every release is preceded by a runner-signed `SignedReleaseRequest`. Each proxy queries current chain state before serving, and an accepted receipt is revalidated at receipt-submission head. Receipt recording is asynchronous and best-effort, not a prerequisite for returning a partial.
- Proactive secret sharing. Reshares are scheduled (every `RESHARE_INTERVAL_BLOCKS`) and triggered by churn; PSS preserves MPK across reshares so historic ciphertexts remain decryptable, but replaces every share. The next reshare invalidates a previously-compromised

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share.

- Independent per-proxy receipt submission. No coordinator runs the receipt phase. Each participating proxy attempts a per-proxy receipt independently, with up to 10 blocks of jitter to smooth chain throughput. Accepted receipts emit `cbss.release.receipt_recorded`; `cbss.secret.released` is emitted when the accepted set reaches threshold. The daemon does not retry failed receipt submissions and may drop work when the receipt worker pool is saturated.

Differences vs. Existing Secret Stores

Aspect	Hashicorp Vault / AWS Secrets Manager	NuCypher / Lit Protocol	**CBSS**
Authorization root of trust	Service-account token	TaCo-style ABE / external policy	Cowboy chain (runner job dispatch)
Plaintext custodian	The vault server	Threshold KFrag holders	Owner at write, runner at read
Release latency	Single HTTPS RT	Multi-RT to KFrag holders	Parallel QUIC fanout; 5 s per-proxy timeout
Audit trail	Server logs	Off-chain	Best-effort chain receipts + daemon logs
Revocation	Token revoke; immediate	Re-encryption on policy change	Metadata-only; checked on each proxy authorization and accepted receipt
Re-wrap on policy change	None	Yes (by design)	Never (per-account release key + ACL at read)
Committee rotation	N/A	Manual	Block-scheduled PSS reshare
Proxy slashing	None	None	On-chain `SlashCbssProxy` evidence

Aspect	Hashicorp Vault / AWS Secrets Manager	NuCypher / Lit Protocol	**CBSS**
Native to actor model	No	No	Yes — `runner.secret(KEY)` slots on runner ops

CBSS combines the following properties:

1. No re-encryption on ACL change. CBSS uses a fixed per-account release key. Proxies validate `policy.actors` before serving, and the node validates it again for any submitted receipt. Adding or removing an actor is a metadata-only `UpdateSecretPolicy` instruction; no DEK is re-wrapped and no payload is re-uploaded.
2. Scope-locked request. A release request names one (actor, runner, job, secret, version, serve epoch) tuple with a release nonce. A successfully recorded receipt encodes that scope. If receipt submission fails, the daemon audit log is the only release-side record.
3. No chain transaction on the critical read path. The owner submits lifecycle transactions at write time; the runner submits zero transactions at read time. Participating proxies attempt receipt transactions asynchronously after serving, so chain inclusion is not on the runner's latency path.

Related Work

Centralised Secret Stores (Vault, AWS Secrets Manager, Doppler, 1Password Secrets Automation)

Hashicorp Vault stores ciphertext, authenticates clients via short-lived tokens, and releases plaintext over HTTPS. AWS Secrets Manager and Doppler use the same operational model. Integrating these stores with Cowboy actors raises these issues:

- Single point of compromise. A vault breach exposes every secret it holds.
- No on-chain authorization link. A Vault token says "this account has read access"; it has no way to say "this runner address is dispatched to this job at this block height."
- No native audit on the consumer chain. Vault audit logs live in the vault.
- Operationally Web2. A Cowboy actor that pulled secrets from Vault would need to bridge a service-account token into chain identity, defeating the point.

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Threshold Cryptography for Decentralised Secrets (Lit Protocol, NuCypher / TACo, drand timelock)

NuCypher (now Threshold Network's TACo) and Lit Protocol both use threshold cryptography to release secrets contingent on policy. They are conceptually closest to CBSS:

- **Lit Protocol** uses a permissioned BLS threshold network. A user encrypts under the network's MPK with an attached "access control condition" (an EVM `eth_call`-style predicate); to decrypt, a client requests partial decryptions from `t` of `n` Lit nodes. Each Lit node independently evaluates the access condition against any chain it can read. The chain records no receipt of release.
- **NuCypher / TACo** uses proxy re-encryption (ECIES-based KFrags). Granting access requires generating new re-encryption keys and distributing them; revoking access requires re-encryption. The model is elegant for sharing-style workloads (Alice grants Bob access to a document) but expensive for autonomous-agent workloads where an actor's manifest may decide moment-to-moment which secrets it needs and the access list changes frequently.
- **drand timelock** uses tlock (Cryptology ePrint 2023/189, presented at Real World Crypto 2023) to encrypt to a future time through threshold IBE keyed on future round numbers. CBSS reuses the same construction (BLS12-381 hash-to-curve identity + pairing-based KEM + AEAD) but keys identities on per-version-tuple rather than future rounds, and adds chain-anchored authorization, audit, and slashing.

CBSS combines drand's threshold IBE construction with chain-policy authorization tied to Cowboy job dispatch and Runner stake. It also defines receipts and slashing.

Multi-Party Computation Secret Sharing (TSS Vaults, Pyrofex, ZenGo)

Threshold Signature Schemes (TSS) used by custody products like Fireblocks, ZenGo, and Coinbase MPC are mechanically related: they share a private key across nodes and produce signatures via threshold protocols. They sign messages. They do not encrypt or decrypt arbitrary payloads. Re-purposing a TSS vault for secret release would require either re-encrypting payloads under a derived symmetric key the TSS produces (equivalent to the CBSS construction) or signing each payload-release request individually (functionally equivalent but with worse parallelism, since signing requires interactive rounds where IBE decryption can pre-commit identities).

CBSS uses BLS-IBE rather than TSS-ECDSA because the algebra is simpler (single pairing equation per partial verification, non-interactive after DKG), the verification is one pairing per partial (vs. multi-round MPC for ECDSA), and resharing uses PSS on Shamir polynomials.

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Hardware-Rooted Approaches (TEE-Sealed Vaults, Intel SGX SealedData)

Sealing secrets in a TEE (Intel SGX, AMD SEV-SNP, AWS Nitro) gives strong custody guarantees: the secret is unsealed only inside attested hardware. Cowboy already supports TEE attestation and could combine it with a centralized vault. The reasons CBSS does not stop there:

- TEE attacks. Repeated side-channel breakthroughs against SGX (Foreshock, ÆPIC, Downfall, etc.) make any "TEE-only" custody model fragile. Compromising any `t-1` proxies still discloses zero plaintext.
- No vendor lock-in. A multi-vendor proxy fleet running pure software is a deliberate property; threshold IBE is hardware-agnostic.
- TEE composes additively. A secret may carry `policy.tee_required = true` to request a runner attestation gate; the proxies themselves are not required to run in TEEs. The current gate is hardware-rooted for Nitro but still has a self-asserted soft-fail binding path for SGX, TDX, and SEV-SNP (§12.9).

Tabular Summary

System	Custody model	Per-release chain action	Audit on chain	Re-wrap on ACL change	Native to L1 actor model
CBSS	Threshold IBE, t-of-n staked proxies	Best-effort proxy receipts after serve	Accepted per-proxy + threshold events	Never	Yes
Hashicorp Vault	Centralised	N/A (off-chain)	No	No	No
AWS Secrets Manager	Centralised	N/A (off-chain)	No (CloudTrail only)	No	No
Lit Protocol	Threshold BLS (PoA committee)	None enforced	Off-chain	No	No
NuCypher / TACo	Proxy re-encryption (KFrag holders)	KFrag generation per grant	Optional	Yes (re-encryption)	No

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System	Custody model	Per-release chain action	Audit on chain	Re-wrap on ACL change	Native to L1 actor model
drand timelock	Threshold IBE (round identities)	None	None	N/A	No
Fireblocks / ZenGo MPC	TSS (key sharded for signing)	None	Off-chain	N/A (signing primitive)	No
TEE-sealed vault	Single TEE	Attestation per release	Optional	Optional	No

Cryptographic Construction

CBSS implements the threshold IBE construction from drand's `tlock` paper, specialised to Cowboy's per-secret-version identities and bound to chain-anchored authorization. The following equations express standard threshold-BLS / Boneh-Franklin IBE in terms of CBSS objects.

Curve and Primitives

The curve is **BLS12-381**. We use:

- `G1`: 48-byte compressed points, used for identities `I` and partial / aggregate signatures σ`_i`, σ.
- `G2`: 96-byte compressed points, used for the generator `G2_gen`, the master public key `MPK`, and per-proxy VSS commitments `S_i`.
- `Gt`: target group of the pairing `e: G1 × G2 → Gt`.
- `Scalar`: `Fr` (the prime field of order `r`), used for shares `s_i` and the (notional) master secret `MSK`.

Hash-to-curve uses RFC 9380 with the suite tag `BLS12381G1_XMD:SHA-256_SSWU_RO_` and the CBSS domain `cbss/ibe/v1`. Symmetric encryption is **AES-256-GCM**; key derivation is **HKDF-SHA-256**.

Identity Construction

For a secret version `(account, key_hash, version, wrap_epoch)` on the chain `chain_id`:

```
canonical(SecretId)  = account || key_hash                          -- 52 bytes
base_aad             = u64_be(chain_id)
                     || canonical(SecretId)
                     || u64_le(version)
                     || u64_le(wrap_epoch)
                     || mpk_g2                                  -- 172 bytes total
I                    = hash_to_G1(base_aad, domain = "cbss/ibe/v1")
```

The identity derives from the 172-byte `base_aad` only. The trailing `mpk_g2 = compress(MPK)` is the 96-byte canonical release-key binding read from the selected on-chain release key. Resharing preserves MPK, so it does not change this identity; force rekeying changes MPK and strands the old ciphertext. All account-secret identity, payload AAD and wrapped-key AAD derivations below use that same committed MPK. The leading `u64_be(chain_id)` binds every identity and wrapped-DEK envelope to a single `chain_id`, so a secret wrapped under one `chain_id` can never be released under another. Note the boundary this does and does not draw: the preimage commits to the numeric `chain_id` only, not to a genesis or fork identity. Two deployments that reuse the same `chain_id` and the same key and committee state, including a clone or a fork that does not renumber, remain a single cryptographic domain and must be operated as one network. The AEAD AAD extends `base_aad` with the per-wrap encryption ephemeral: `aad = base_aad || compress(U)` (172 + 96 = 268 bytes; see Encryption below).

Notation: `U` denotes the G2 group element and `ephemeral_u = compress(U)` its stored 96-byte canonical compressed encoding; formulas over the stored field use `ephemeral_u` directly. In `base_aad`, `u64_le(version)` is the **secret version number** — not the envelope's leading 1-byte format-version tag, which is never part of the AAD or the key derivation.

`wrap_epoch` is the committee_epoch at the moment the secret version was wrapped. It is **immutable** once set on `SecretVersion` and ties the identity to the historical share polynomial under which it was encrypted.

The account-secret byte contract is CIP-24 §3.4.3 (`BASE_AAD_LEN = 172`, `EXTENDED_AAD_LEN = 268`, identity domain `IBE_DOMAIN = b"cbss/ibe/v1"`). The wrapped-DEK **format tag is 2**; it is separate from the `/v1` domain string. These rules apply to account secrets; time-lock and volume-DEK families keep their own CIP-24 AAD contracts.

Encryption (Owner Side)

Given `MPK`, identity `I`, plaintext DEK `dek` (256 bits, fresh CSPRNG), and `base_aad`:

```
r           ←$ Fr, r != 0                                  -- fresh per-wrap encryption ephemer
```

```
U           = r · G2_gen                                  -- 96-byte compressed G2, published
aad         = base_aad || compress(U)                     -- 268 bytes
gt          = e(I, MPK)^r                                 -- pairing in Gt
ikm         = serialize(gt)                               -- canonical compressed Gt encoding
K           = HKDF-SHA-256(salt = "cbss/ibe/v1",
                           ikm,
                           info = "cbss/ibe/v1" || aad,
                           L = 32)
nonce       ← CSPRNG(12)
WrappedDek  = AES-256-GCM(key = K,
                          nonce = nonce,
                          aad = aad,
                          plaintext = dek)
```

The ephemeral exponent keeps `K` secret. `MPK`, `I`, and `aad` are all public, so without `^r` anyone reading the chain could recompute `K` and decrypt the stored envelope. `r` MUST be sampled fresh per wrap and never reused.

The `WrappedDek` (version, ciphertext, nonce, ephemeral_u, aad — serialized format version 2, carried as a leading 1-byte tag on every serialization and rejected on unknown values; this is the only accepted wrapped-DEK format from genesis) is stored on chain. The tag is wire framing only — never part of the AEAD `aad` or the key derivation. The plaintext payload is separately AES-256-GCM-encrypted under `dek` and the **172-byte** `base_aad` — not the 268-byte extended `aad`, which only the `WrappedDek` AEAD and its HKDF `info` bind; the two layers must agree with the runner's decrypt path, which opens the payload under the base AAD — and uploaded to a CBFS volume; the resulting `cbfs_pointer` is also stored on chain.

DKG (Once Per Account / Per-Secret Override)

The production daemon uses Commonware's BLS12-381 Feldman–Desmedt DKG state machine with per-proxy Ed25519 DKG keys, signed dealer logs, player acknowledgements, and `N3f1` quorum selection. Each finalized player output contains its scalar share, the MPK, and the public-sharing commitments used to verify later partial signatures.

The chain records a requested `threshold`, but that value is not passed into Commonware's DKG API. Commonware derives the sharing quorum from committee size through `N3f1`. The default `(n=5, t=4)` is consistent. For overrides, callers MUST use the `N3f1`-derived threshold; other ratios can be accepted into `DkgPending` but do not produce a polynomial with the requested reconstruction threshold.

The DKG is bootstrapped by a `RequestAccountDkg` (default-path, owner-paid bond) or by `SetSecret` with `committee_override` (override-path, owner-paid bond). It commits via `RotateCommittee` (signed by $\geq$ `t` of the new committee) when the ceremony completes; if it does not complete within `DKG_FINALIZE_BLOCKS`, anyone may call `ExpireDkgPending` to refund the requester (minus a small slash) and clear the pending record.

Partial Sign and Threshold Combine (Runner Side)

A proxy holding share `s_i` for committee_epoch `e`, on receiving a runner-signed `PartialSignRequest`, validates the request (§5.3), reads `wrap_epoch` from the on-chain `SecretVersion`, derives `I = hash_to_G1(base_aad)` (the 172-byte identity input, never the extended AEAD `aad`), and computes:

```
σ_i = s_i · I                -- a G1 point, 48 bytes compressed
```

The proxy signs `(request_hash, proxy_id, sigma_i, committee_epoch_at_serve, served_at_block)` under its operator key (domain `cbss/partial-sign-response/v2`) and returns the response.

The runner verifies each σ_i via the pairing equation:

```
e(σ_i, G2_gen) == e(I, S_i)
```

where `S_i` is proxy `i`'s aggregate VSS commitment looked up on chain. With `t` valid partials, the runner computes Lagrange coefficients λ_i(0) over the chosen index set and combines:

```
σ = Σ (λ_i(0) · σ_i) over the t selected indices
```

By bilinearity, σ = `MSK · I`.

Decryption (Runner Side)

With the threshold signature σ, the runner derives the same `K` the owner used:

```
U           = decode(WrappedDek.ephemeral_u)            -- canonical, non-
identity, prime-order; rejected otherwise
aad         = base_aad || WrappedDek.ephemeral_u        -- must equal WrappedDek.aad EXACTLY
gt          = e(σ, U)
```

```
ikm         = serialize(gt)
K           = HKDF-SHA-256(salt = "cbss/ibe/v1",
                           ikm,
                           info = "cbss/ibe/v1" || aad,
                           L = 32)
dek         = AES-256-GCM-decrypt(K, nonce, aad, WrappedDek.ciphertext)
```

The bilinearity of the pairing guarantees the equality `e(`σ`, U) = e(MSK · I, r · G2_gen) = e(I, G2_gen)^(MSK · r) = e(I, MPK)^r`, so the runner's `K` matches the owner's `K` exactly. Recovering `K` from the public `(I, MPK, U)` without σ reduces to the co-BDH assumption on BLS12-381. The runner then fetches the CBFS object at `cbfs_pointer`, AES-256-GCM-decrypts under `(dek, base_aad)`, and wipes the DEK and plaintext buffers that expose mutable storage as described in §12.6.

Reshare via Proactive Secret Sharing

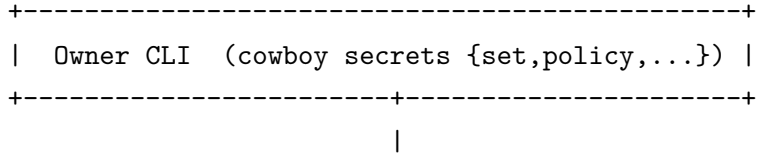
A reshare replaces all proxy shares with fresh shares for the same `MSK`. Each old-committee participant `j` (with old share `s_j`) selected as a dealer constructs a polynomial:

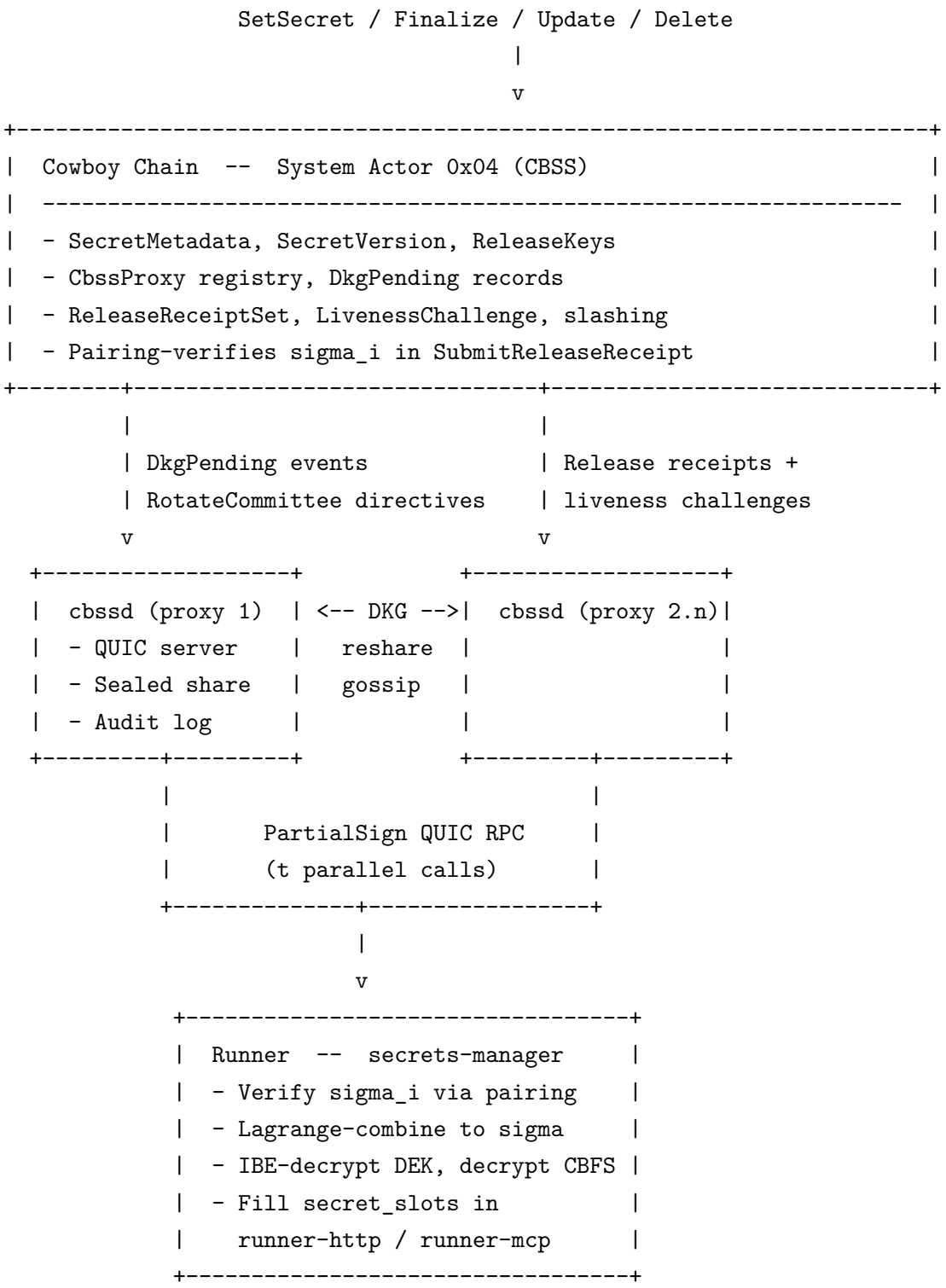
```
g_j(0)   = s_j · L_j              -- L_j is the Lagrange coefficient at zero for the chosen
g_j(x)   = g_j(0) + r_j(x)        -- r_j is a fresh degree-(t-1) polynomial with r_j(0) = 0
```

Each new-committee recipient `k` receives `g_j(k)` from every dealer (HPKE-encrypted), verifies it against published commitments, and sets its new share to `s'_k = Σ_j g_j(k)`. Because `Σ_j g_j(0) = Σ_j (s_j · L_j) = MSK`, the new shares lie on a polynomial whose constant term is MSK; MPK is preserved.

The chain enforces `args.new_mpk == old.mpk` and `args.new_committee_epoch == old.committee_epoch + 1` on `RotateCommittee`. It also retains the prior committee's commitments in `prior_committee_epochs` for `RESHARE_GRACE_BLOCKS`, so receipts under the prior epoch remain acceptable during the grace window.

System Architecture




SetSecret / Finalize / Update / Delete
Cowboy Chain -- System Actor 0x04 (CBSS)
- SecretMetadata, SecretVersion, ReleaseKeys
- CbssProxy registry, DkgPending records
- ReleaseReceiptSet, LivenessChallenge, slashing
- Pairing-verifies sigma_i in SubmitReleaseReceipt
DkgPending events
RotateCommittee directives
Release receipts +
liveness challenges
cbssd (proxy 1)
- QUIC server
- Sealed share
- Audit log
<-- DKG -->
reshare
gossip
cbssd (proxy 2.n)
PartialSign QUIC RPC
(t parallel calls)
Runner -- secrets-manager
- Verify sigma_i via pairing
- Lagrange-combine to sigma
- IBE-decrypt DEK, decrypt CBFS
- Fill secret_slots in
runner-http / runner-mcp

On-Chain Component (System Actor `0x04`)

The CBSS system actor occupies address `0x04` (per Technical Whitepaper §9). It owns the storage shapes in §2, dispatches the 20 CBSS instructions in §3, and emits the events in §4. It performs all pairing verifications for `SubmitReleaseReceipt` and validates committee co-signatures for `RotateCommittee`. It does **not** hold any plaintext, any DEK, or any share scalar. TEE verifier handler semantics are logically allocated to `0x05`, but their state is currently co-located under `0x04`.

Off-Chain Component (`cbssd` Daemon)

Each CBSS proxy operator runs `cbssd`, a Tokio-based binary that:

- Maintains a `secp256k1` operator identity, an X25519 HPKE key, an Ed25519 Commonware DKG key, and a pinned TLS SPKI, all registered on chain.
- Listens on a QUIC endpoint multiplexing four logical streams (`PartialSign`, `Health`, `DkgRound`, `ReshareRound`) on a single port (default 9601).
- Watches the chain for `DkgPending` records and `RotateCommittee` directives that name this proxy and orchestrates the corresponding ceremonies.
- Stores per-scope sealed shares at rest, sealed via AES-256-GCM under a key derived from the operator key.
- On `PartialSign`, validates the request against current head, computes $\sigma_i = s_i \cdot I$, signs the response, and returns it before asynchronously attempting a `SubmitReleaseReceipt` transaction after 0–10 blocks of jitter.
- Maintains a process-local FIFO set of the most recent 65,536 successful request hashes. It is neither time-based nor persistent across restart.
- Bounds transport and receipt worker concurrency. Partial-sign scalar and pairing work currently executes inline in the async request task; there is no per-actor partial-sign rate limiter.
- Submits `LivenessChallengeResponse` for any chain-recorded challenge against this proxy.

`cbssd` is a separate process from `cbfsd` and `runnerd`. Operators MAY co-locate these processes, but SHOULD isolate their keys, logs, and configuration. CBSS proxy stake is registered independently from other service roles.

Ingest ciphertext retention

When optional ingest is enabled, `cbssd` stores the full encrypted envelope body in its disk-backed `pending` fanout queue before the first CBFS relay POST. Write-quorum success can leave lagging

targets pending; the pending row is removed only after every configured target acknowledges. If targets remain unacknowledged after the retry deadline has passed, the retry worker moves the full row, including metadata and body, to `failed`. Failed rows have no automatic purge path in the current queue implementation.

The ingest path does not decrypt submitted payloads. Failed rows retain their ciphertext after retries stop; this upload queue is separate from release-receipt publication.

Runner-Side Client (`secrets-manager` Crate)

The runner-side client is a Rust crate consumed by `runner-node`, `runner-http`, `runner-mcp`, and `runner-llm`. It exposes a single trait:

```
#[async_trait]
pub trait SecretsClient: Send + Sync {
    async fn fetch_for_op(
        &self,
        ctx: &JobContext,
        actor: ActorAddress,
        keys: &[SecretRef],
    ) -> Result<SecretBundle, SecretsError>;
}
```

Production implementations fan out partial-sign QUIC RPCs to `t` of `n` committee proxies, with a 5-second per-proxy timeout, verify each σ_i via the pairing equation, Lagrange-combine into σ, IBE-decrypt the DEK, fetch and AES-decrypt the CBFS payload, and return a `SecretBundle` whose entries are `Zeroizing<Vec<u8>>`. The bundle fills the job's `secret_slots` in runner-http/mcp at request-construction time. Mutable rendered string fields are wiped after execution. Checked `HeaderMap` and `CanonicalJsonBytes` values lack mutable accessors, so their cleared replacements do not actively overwrite the old freed allocations.

1. Identifiers and Canonical Forms

1.1 An account is a `secp256k1`-derived 20-byte Cowboy address (Technical Whitepaper §1.1).

1.2 A key name is non-empty and $\leq$ **128 bytes**. Ordinary names MUST begin with `A`–`Z`; remaining bytes MUST be uppercase ASCII letters, digits, or `_`. The reserved Trading Post form is `tradingpost/{32-byte declaration id hex}/{u32 version}/{u32 artifact id}`. The hash on chain is `key_hash = keccak256(account || key_name)`. Plaintext key names MUST NOT appear in storage paths or events, only `key_hash`.

1.3 SecretId. `(account, key_hash)`. Canonical encoding is the 52-byte concatenation `account || key_hash`.

1.4 Versioning. Versions are monotonic `u64` integers per `SecretId`. Quotas: `MAX_SECRETS_PER_ACCOUNT = 256`, `MAX_VERSIONS_PER_SECRET = 32`, `MAX_ACL_ACTORS = 64`.

1.5 Release nonce and ID. Each `fetch_for_op` samples a 32-byte CSPRNG nonce. The consensus release ID is domain-separated and chain-bound: `keccak256("cbss-release-id/v4" || u64_be(chain_id) || canonical(SecretId) || u64_le(version) || actor || runner_id || job_id || release_nonce || u64_le(serve_epoch))`. Binding `chain_id` prevents a release ID minted under one `chain_id` from colliding with one minted under another (a clone or fork that keeps the same `chain_id` is not separated; see Identity Construction); binding `serve_epoch` prevents a pre-reshare receipt set from colliding with a request under the new committee.

1.6 Wrap epoch. The `committee_epoch` of the release key at the moment a secret version is wrapped. Stored on `SecretVersion`. **IMMUTABLE** once set.

1.7 Serve epoch. The `committee_epoch` the runner pinned in the request body when fanning out partial-sign RPCs. Equal to the `committee_epoch` of the release key at that block height. May differ from `wrap_epoch` after one or more reshares.

1.8 Domain separators. The implementation uses the following strings as message prefixes, hash-to-curve domain-separation tags, HKDF salt/info prefixes, or protocol contexts as indicated by the construction:

- `cbss/ibe/v1` — identity `I` and IBE key derivation (chain-bound AAD).
- `cbss-release-id/v4` — consensus release-ID preimage (§1.5).
- `cbss/release-request/v4` — runner signature over the length-prefixed canonical `ReleaseRequestBodyV4`.
- `cbss/blinded-partial-response/v4` — proxy signature over the 133-byte V4 response core, including the blinded partial and proxy index.
- `cbss/rotate-committee/v1` — committee co-signature over `RotateCommitteeArgs`.
- `cbss/liveness-challenge/v4` — runner signature over the V4 request hash and challenged proxy ID.
- `cbss/liveness-response/v1` — proxy signature over a liveness response.
- `cbss/share-storage/v1` — at-rest seal of operator share material.
- `cbss/operator-storage-key/v1` — derivation of the operator-local share-storage key.
- `cbss/dkg-share-hpke/v1` — HPKE info for inter-proxy DKG share envelopes.
- `cbss/dkg-round1/v1` and `cbss/dkg-round2/v1` — signed DKG dealer material.
- `cbss/dkg-round-msg/v1` and `cbss/reshare-round-msg/v1` — authenticated ceremony transport messages.

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- `cowboy/cbss/commonware-dkg/v1` — Commonware DKG protocol context.
- `cbss/proxy-select/v1` — deterministic committee-selection sampling.
- `cbss/tlock/v1` — time-lock identity and IBE key derivation.

2. Storage Shapes

`0x04` owns the following actor-storage key families, including maintenance indexes and co-located TEE records. Values are JSON unless marked raw or binary. In the tables, `s` is `account[20] || key_hash[32]`, `v` and `e` are big-endian `u64` version and epoch bytes, and `r` is the canonical binary release-key recipient/scope. Suffixes concatenate directly onto the literal prefix; plaintext key names are never storage keys. The evidence-epoch key has one additional literal `:` between `r` and `e`.

The six binary collection rows below use version-1 bounded state codecs. Their complete encodings and maximum byte sizes are in CIP-24 §3.2; each fits the 65,536-byte actor-value limit at capacity.

Key family and suffix	Value	Created / updated by	Deleted by / retention
`secret:` + `s`	`SecretMetadata`	`SetSecret`; version teardown updates selection	Final-version deletion or override DKG expiry; `DeleteSecret`
`secret_version:` + `s` `||` `v`	`SecretVersion`, including policy and actor grants	`SetSecret`, finalization, policy updates and grants	Either delete instruction; override `ExpireDkgPending`
`secret_version_hwm:` + `s`	`u64` allocation floor	Every `SetSecret`	Never lowered or deleted
`secret_version_tombstone:` + `s` `||` `v`	`SecretVersionTombstone`	Either delete instruction	Permanent
`account_secret_index:` + account	`Vec<Bytes32>` key hashes	`SetSecret`; version teardown	Entry removed with final version; empty index deleted
`account_release_key:` + account	`AccountReleaseKey`	`RotateCommittee`; cadence updates scheduling state	Survives secret deletion
`secret_release_key:` + `s` `||` `v`	`SecretReleaseKey`	`RotateCommittee`; cadence updates scheduling state	Owning version's delete cascade
`rksweep:` + account or truncated identity hash	Raw account[20] or `s` `||` `v`[60]	Every account/secret release-key write	Override row removed by owning version's delete cascade; account row survives

Key family and suffix	Value	Created / updated by	Deleted by / retention
`cbss_reshare_outstanding:` + `keccak256(r)`	`ReshareOutstandingV1` (schema version 3)	Reshare request and cadence/recovery work	Completed reshare; override delete cascade; `ExpireDkgPending` only for a marker bound to that exact pending ceremony
`dkg_pending:` + `r`	`DkgPending`	Account/system DKG requests; override `SetSecret`	Successful `RotateCommittee` or `ExpireDkgPending`
`dkg_ceremony_record:` + `r || e`	`DkgCeremonyRecord`	DKG request, alongside pending state	Successful DKG installation; retained on expiry and overwritten by a new request for the same scope/epoch
`cbss_release_key_evidence:` + `r`	Sorted `Vec<u64>` epoch index	Rotation and override deletion retain public history	Rewritten with retained epochs when history is pruned
`cbss_release_key_evidence:` + `r || ':' || e`	`ReleaseKeyEvidenceEpoch`	Rotation and override deletion snapshot the committee	Expired epoch values are deleted when the recipient's history is next retained/pruned

The override sweep key suffix is `keccak256(s || v)[0..24]`; an account sweep key uses the raw account address. These rows enumerate release keys without scanning the longer point keys. Prior serving-grace committees are embedded in each release-key value as `prior_committee_epochs`, not stored in a separate key family.

`SecretVersionTombstone` contains `deleted_at_block`, `was_pending`, and optional public `evidence_context = {version, recipient, wrap_epoch}`. Pending versions have no evidence context. A `ReleaseKeyEvidenceEpoch` contains `mpk`, the ordered `committee`, `threshold`, `epoch`, `vss_commitments`, and the inclusive serving cutoff `last_served_at`. The index has at most 64 epochs, each in its own bounded value. Evidence history is retained through `last_served_at + CBSS_EVIDENCE_WINDOW_BLOCKS` (512 blocks); it never authorizes release. Before deletion, a live override key has at most 28 indexed historical epochs: override keys reject force-rekey, and normal rotation admits at most four prior committees within each inclusive 100-block serving-grace window. Deletion also snapshots the current epoch, so the retained evidence index can then contain 29 epochs.

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Key family and suffix	Value	Created / updated by	Deleted by / retention
`cbss_proxy:` + proxy ID	`CbssProxy`	Registration; deregistration, slashing and health updates	Retained, including deregistered proxies
`cbss:proxy_index`	Binary `Vec<ProxyId>` (≤512)	Registration	Retained
`cbss:proxy_selection_generation`	`u64`	Proxy-selection state changes	Retained
`cbss_operator_proxy:` + operator	`ProxyId`	Registration	Retained
`cbss_dkg_pubkey:` + DKG public key	`ProxyId`	Registration	Retained
`cbss_proxy_release_scopes:` + proxy ID	Binary `Vec<ReleaseKeyScope>` (≤256)	`RotateCommittee` adds membership	Retained; secret deletion does not reclaim reverse-index entries
`cbss_proxy_governance_review:` + proxy ID	`ProxyGovernanceReviewFlag`	Slashing or expired-challenge health review	Retained
`cbss_slash_tombstone:` + proxy ID, fault byte, evidence hash	`bool`	Successful `SlashCbssProxy`	Permanent replay guard
`rkdereg:` + proxy-ID hash prefix[24]	`DeregisterReshareWorkV1`	`DeregisterCbssProxy`; cadence advances its scope cursor	Cadence deletes completed work
`cbss:deregister_reshare_pending_count`	`u16`	Deregistration work enqueue/completion	Deleted when no work remains
`release_receipt:` + release ID	Binary `ReleaseReceiptSet` (≤90 members / entries)	`SubmitReleaseReceipt`	`GcNonces` after the liveness-challenge admission window
`rrg:` + height/hash text	Raw receipt storage key	First accepted receipt	`GcNonces`, together with receipt set
`liveness_challenge:` + challenge ID	`LivenessChallenge`	Challenge submission, response and expiry	Retained
`liveness_challenge_index:` + release ID and proxy ID	Raw challenge ID[32]	Challenge submission	Response or expiry
`actor_release_debt:` + actor	`ActorReleaseDebt`	Receipt overdraft; `FundActor` repays	Deleted on full repayment
`tlock_req:` + tlock ID	`TlockRequest`	Time-lock registration	`GcNonces` after time-lock retention
`tlock_parts:` + tlock ID	Binary `TlockPartialSet` (≤90 partials)	`SubmitTlockRelease`	`GcNonces` with request
`tlg:` + height/hash text	Raw tlock ID[32]	Time-lock registration	`GcNonces` with request and partials

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`tlock_regcount:`; `tlock_auction_regcount:`	Raw block `u64` BE and count `u64` BE	Standalone / auction time-lock registration respectively	Retained; a new block resets the effective count

The `rrg:`, `tlg:`, `tng:` and `tcg:` scan keys are 32 ASCII bytes: prefix, 16 lowercase hexadecimal height digits, and 12 lowercase hexadecimal digits from the first six bytes of a Keccak hash. The hash input is respectively the release ID, tlock ID, nonce storage key, or CAE storage key. Heights are respectively request block, `target_height + TLOCK_RETENTION`, nonce-recording block, or CAE-recording block. Garbage collection clamps caller-supplied cutoffs to chain-derived retention limits.

The TEE Verifier's logical allocation is `0x05`, but these TEE values share physical actor storage at `0x04`:

Key family and suffix	Value	Created / updated by	Deleted by / retention
`tee_trusted_key_index:` + type length `u32` BE, type bytes, measurement[32]	Binary `TeeTrustedKeyIndex` (≤640 keys)	Trusted-key registration/revocation	Revocation removes a public key; index retained
`tee_collateral:` + effective height `u64` BE	Raw collateral D-CBOR	Collateral publication	Retained
`tee_collateral_index`	Binary sorted `Vec<u64>` (≤8,191 heights)	Collateral publication	Retained
`tee_measurement_binding:` + service public key	`MeasurementBinding`	Verified binding registration/revocation	Retained with status
`tee_measurement_binding_runner:` + runner	`MeasurementBinding`	Same binding registration/revocation	Retained as runner lookup
`tee_seen_nonce:` + job ID and nonce; `tee_billing_nonce:` + billing ID and nonce	Raw seen height `u64` BE	Task / billing CAE verification respectively	`GcNonces` after quote freshness retention
`tng:` + height/hash text	Raw nonce storage key	CAE verification	`GcNonces` with nonce
`cae:task:` + job ID; `tcg:` + height/hash text	Raw digest[32]; raw digest storage key	Conditional Result-Verifier CAE audit recording	Conditional `GcNonces` after dispute retention; audit recording is disabled in the genesis configuration

The trusted-key cap counts distinct normalized keys per `(tee_type, measurement_hash)`; registering an existing key is allowed at capacity, and revocation frees a slot. The collateral cap counts distinct indexed effective heights; replacing an existing height is allowed at capacity, subject to the usual authority and delay checks. A new height beyond the cap is rejected before the snapshot is written. Collateral remains retained. See CIP-23 §3.8.

The common `MAX_CBSS_RELEASE_COMMITTEE_SIZE = 90` storage-fit bound covers current, prior, pending, receipt and tlock committees, including retained release-key evidence, with threshold and VSS-commitment shape checks. The default committee remains 5; CIP-24's 15-member override policy remains spec-only. The receipt-set ceiling derives from the 692-byte maximal receipt entry: `44 + 90 × (32 + 692) = 65,204` bytes fits the 65,536-byte actor-value limit, while `44 + 91 × (32 + 692) = 65,928` does not. The corresponding tlock partial set is `11 + 90 × (32 + 48) = 7,211` bytes. The tagged trusted-key index is `3 + 640 × 51 = 32,643` bytes; its largest entry is a compressed P-384 key with its algorithm and length tags.

`DeleteSecretVersion` removes the version, including its policy and grants, and writes its permanent tombstone. For an installed override key it first retains public evidence, then deletes the dedicated `SecretReleaseKey`, its `rksweep:` row, and its reshare-outstanding marker. A pending override without an installed key cannot be deleted; `ExpireDkgPending` is its cancellation path. Installed but unfinalized versions can be deleted. `DeleteSecret` applies the same cascade atomically to every active version and removes the metadata and account secret-index entry. Shared account release keys, their sweep/reshare state, per-proxy reverse indexes, evidence records and the version high-water mark survive the cascade; evidence pruning follows its own retention rule. Deletion removes the on-chain CBFS pointer with the version, without issuing a CBFS object-drop instruction.

`SecretMetadata.latest_version` selects the greatest surviving entry in `active_versions` for a versionless read. Both version deletion and override DKG expiry recompute it; if no versions remain, the metadata and account secret-index entry are removed. A surviving pending version remains subject to the pending-release rejection. This selection is independent of version allocation.

The per-secret `secret_version_hwm` is consensus state, not a reclaimable index. Every `SetSecret` MUST allocate `max(SecretMetadata.latest_version, secret_version_hwm) + 1` with checked `u64` arithmetic and persist the new high-water mark atomically with the version. An absent metadata record contributes zero; deleting a secret or version, force-rekeying, or expiring an override DKG MUST NOT lower or delete its high-water mark. Restoring `latest_version` for read selection never makes an allocated version reusable. This prevents reuse of an IBE identity.

CBSS also has durable consensus phase state under `StatePrefix::CbssPhaseState` (`0x21`), separate from the `0x04` actor-storage families above. Its keys include `system:cip24:reshare_sweep_cursor` (`CBSS_RESHARE_SWEEP_CURSOR_KEY`), `system:cip24:reshare_ovf_meta` and `system:cip24:reshare_ovf_c:` followed by a big-endian chunk index. The sweep persists its continuation cursor; reshare producers append outbox metadata/pages, and the bounded drain updates metadata and removes consumed pages. These records are committed through `set_cbss_phase_state`.

Checkpoint and state-restore tooling MUST preserve all CBSS state, including these `0x21` phase-state families and all of the above `0x04` actor-storage records, including high-water marks, tombstones and their evidence contexts, evidence indexes and epoch values, sweep indexes, reshare-outstanding markers and DKG pending/ceremony records. An expired override DKG can leave no version or tombstone, so tooling MUST carry the allocation floor verbatim rather than reconstruct it from surviving versions. Producers MUST obtain the encryption version from `GET /cbss/secret-next-version/{account}/{key_hash}` (`next_version`), never infer `latest_version + 1` or assume version 1 after a metadata 404. This read does not reserve the version; a concurrent allocation requires fresh encryption for the newly returned version. See CIP-24 §3.2 for the complete allocation contract and node's `docs/access/CLIENT-LIMITS.md` for access rows.

The CBSS system actor is exempt from both the per-actor key-count cap and the byte quota as a reserved system actor, like every actor below `RESERVED_SYSTEM_ADDRESS_LIMIT` (`0x100`). It holds network-wide custody state; growth is bounded by CBSS charges, stakes, bonds and deletion/garbage collection, while durable tombstones and high-water marks remain retained. Payerless CBSS phase work abandons a storage-capacity failure and rolls back its affected writes/events instead of failing the block; other storage errors remain fatal.

The principal value shapes:

```
struct SecretMetadata {
    id: SecretId,
    latest_version: u64,
    active_versions: Vec<u64>,
    created_at: BlockHeight,
    last_updated_at: BlockHeight,
}

struct SecretVersion {
    version: u64,
    pending: bool,                    // true between override SetSecret and
 ↪  FinalizeSecretVersion
    recipient: ReleaseKeyRef,         // Account(_) or SecretSpecific{...}
    policy: SecretPolicy,             // actors allowlist + tee_required
    wrap_epoch: Option<u64>,          // immutable once set; None iff pending
    cbfs_pointer: Option<CbfsPointer>, // None iff pending
    wrapped_dek: Option<WrappedDek>,  // None iff pending
    created_at: BlockHeight,
}

struct AccountReleaseKey {
    account: Address,
```

```
    mpk: G2Bytes,
    committee: Vec<ProxyId>,
    committee_operators: Vec<Address>, // operator snapshot parallel to committee
    threshold: u8,
    committee_epoch: u64,
    last_reshare_block: BlockHeight,
    vss_commitments: Vec<G2Bytes>,
    prior_committee_epochs: Vec<PriorCommitteeEpoch>, // capped at
↪   MAX_PRIOR_COMMITTEE_EPOCHS
}

struct SecretReleaseKey {
    secret_id: SecretId,
    version: u64,
    mpk: G2Bytes,
    committee: Vec<ProxyId>,
    committee_operators: Vec<Address>,
    threshold: u8,
    committee_epoch: u64,
    last_reshare_block: BlockHeight,
    vss_commitments: Vec<G2Bytes>,
    prior_committee_epochs: Vec<PriorCommitteeEpoch>,
}

struct PriorCommitteeEpoch {
    epoch: u64,
    committee: Vec<ProxyId>,
    committee_operators: Vec<Address>, // operator snapshot for the prior epoch
    vss_commitments: Vec<G2Bytes>,
    expires_at: BlockHeight,           // last_reshare_block + RESHARE_GRACE_BLOCKS
}

struct ReleaseReceiptSet {
    quorum_epoch: u64,                 // pinned to first accepted receipt's
↪   serve_epoch
    threshold: u8,
    entries: Vec<ReleaseReceipt>,      // capped at threshold
}

struct DkgCeremonyRecord {
    scope: ReleaseKeyScope,
    committee: Vec<ProxyId>,
    threshold: u8,
```

```
    committee_epoch: u64,
}

struct ActorReleaseDebt {
    actor: Address,
    outstanding: u64,
    delinquent_since: BlockHeight,
    last_updated_block: BlockHeight,
}
```

The invariant `pending == true` ⇔ `wrap_epoch.is_none()` ⇔ `cbfs_pointer.is_none()` ⇔ `wrapped_dek.is_none()` MUST hold for every `SecretVersion`. Once `wrap_epoch` is set on a non-pending version, it MUST NOT change.

3. System Instructions (Opcodes 68–84, 152–153, 158)

The protocol codec implements 20 CBSS instructions, encoded as `SystemInstruction` variants per Technical Whitepaper §3 dispatch.

Op	Name	Caller	Purpose
68	`SetSecret`	Owner	Set or override-intent a secret version
69	`UpdateSecretPolicy`	Owner	Mutate `policy` only; never re-wraps
70	`DeleteSecretVersion`	Owner	Tombstone one version
71	`DeleteSecret`	Owner	Tombstone all versions; drop release key if scoped
72	`RegisterCbssProxy`	Operator	Stake and register operator, HPKE, DKG, TLS, and network identity
73	`DeregisterCbssProxy`	Operator	Mark unbonded at current height and enqueue reshare
74	`RotateCommittee`	Committee co-sign	Commit a DKG or reshare result
75	`SlashCbssProxy`	Anyone (with evidence)	Apply per-class slash + suspend
76	`SubmitReleaseReceipt`	Proxy	Anchor a partial signature on chain, earn fee
77	`RequestAccountDkg`	Owner	Bond a default-path account DKG
78	`FinalizeSecretVersion`	Owner	Attach `cbfs_pointer` + `wrapped_dek` after override DKG commits

Op	Name	Caller	Purpose
79	`SubmitLivenessChallenge`	Runner	Bond a non-response challenge against a proxy
80	`LivenessChallengeResponse`	Proxy operator	Respond to a chain-recorded challenge
81	`ExpireDkgPending`	Anyone	Permissionless cleanup of expired DKG bonds
82	`ExpireLivenessChallenge`	Anyone	Permissionless transition of an expired challenge to `Unanswered`
83	`RequestReshare`	Owner / scheduler	Trigger a PSS reshare of an existing release key
84	`ForcedDeregisterCbssProxy`	Governance	Forced deregister via approved governance proposal
152	`RegisterTlockRelease`	Anyone	Register a height-gated threshold release identity
153	`SubmitTlockRelease`	Committee proxy	Post a verified partial after the target height
158	`GovRequestSystemDkg`	Governance	Bootstrap or rekey a keyless system-actor scope

3.1 `SetSecret` (default path). Owner has an existing `AccountReleaseKey`. Args carry `(key_hash, recipient = Account(self), policy, wrap_epoch, cbfs_pointer, wrapped_dek)`. Chain checks `wrap_epoch == release_key.committee_epoch`, that `wrapped_dek.ephemeral_u` is a canonical non-identity G2 point, and `wrapped_dek.aad == aad_for(chain_id, secret_id, version, wrap_epoch, mpk_g2) || wrapped_dek.ephemeral_u` (full equality); writes a non-pending `SecretVersion`.

3.2 `SetSecret` (override path). Args carry `(key_hash, recipient = SecretSpecific{...}, policy, committee_override = {t, n, preferred_proxies?})` and NO ciphertext. Chain validates `0 < t` $\leq$ `n`, validates or selects the committee, locks `DKG_BOND` from the owner, enqueues a `DkgPending` record, and writes a *pending* `SecretVersion` with `wrap_epoch = None`. The chain does not enforce that `t` equals Commonware's `N3f1` quorum; callers must observe the restriction in the DKG section.

3.3 `FinalizeSecretVersion`. Once the per-secret DKG commits via `RotateCommittee`, the owner calls `FinalizeSecretVersion(key_hash, version, wrap_epoch, cbfs_pointer, wrapped_dek)`. Chain checks `wrap_epoch == new_release_key.committee_epoch`, that `wrapped_dek.ephemeral_u` is a canonical non-identity G2 point, `wrapped_dek.aad == aad_for(chain_id, secret_id, version, wrap_epoch, mpk_g2) || wrapped_dek.ephemeral_u` (full equality), clears `pending`, and attaches the ciphertext.

3.4 `UpdateSecretPolicy`. Pure metadata. Args name an explicit `(key_hash, version)` and replace that version's `policy`, including while it is pending. No `WrappedDek` is touched. Proxies query the chain authorizer on each request; successfully submitted receipts are revalidated against submission-time state.

3.5 `DeleteSecretVersion` / `DeleteSecret`. Apply the deletion cascade and release-selection rule in §2. Both retain a permanent tombstone and emit the deletion events in §4; override deletion also emits bounded, best-effort per-epoch zeroization hints. The tombstone is authoritative even when a hint is omitted.

3.6 `RegisterCbssProxy`. Args: `(pubkey, hpke_pubkey, dkg_pubkey, tls_spki, network_addr, stake_amount)`. Chain requires `stake_amount` $\geq$ `MIN_PROXY_STAKE`, snapshots all key material, sets `eligible_after = block_height + PROXY_SOAK_PERIOD_BLOCKS`, and inserts the proxy plus operator and DKG-key reverse indexes. The proxy is not selection-eligible until `eligible_after` is reached.

3.7 `DeregisterCbssProxy`. Sets `unbond_at = block_height`. The proxy is removed from new committee selections immediately and the handler enqueues reshare events for scopes that contain it. There is no delayed unbond period in the current implementation.

3.8 `RotateCommittee`. Args: `(scope, new_committee, new_committee_epoch, new_mpk, vss_commitments, new_committee_sigs, prior_committee_sigs)`. Chain computes `rotate_committee_hash` and verifies:

- $\geq$ `t` signatures from the new committee under domain `cbss/rotate-committee/v1`.
- If updating an existing release key: $\geq$ `t` signatures from the *prior* committee, and `new_mpk == old.mpk`, and `new_committee_epoch == old.committee_epoch + 1`.
- Threshold reused from `old.threshold` (or, on first DKG, from `DkgPending.threshold`).
- `vss_commitments` valid: `vss_commitments[0] == new_mpk`, length is at least threshold, and every point decodes; the MPK itself must be non-identity.

On success, the prior committee's epoch is appended to `prior_committee_epochs`, capped at `MAX_PRIOR_COMMITTEE_EPOCHS` and pruned of expired entries.

3.9 `SlashCbssProxy`. Args: `(proxy_id, fault_class` $\in$ `{InvalidPartialReencrypt, DkgSabotage, Equivocation}, evidence)`. The chain re-derives the offence from `evidence`, rejecting any embedded release request whose `chain_id` is not the node's own, charges the per-class slash percentage (5 % / 5 % / 50 %), and suspends the proxy. A permanent evidence tombstone prevents replay of the same `(proxy_id, fault_class, evidence_hash)`.

3.10 `SubmitReleaseReceipt`. Args: `SubmitReleaseReceiptArgsV4 { runner_request: SignedReleaseRequestV4, response: PartialSignResponseV4 }`. Here `body` denotes the request body's `ReleaseRequestContextV4`; proxy fields are in `response`. Chain validates:

- `body.chain_id == chain_id` (the node's own chain).
- `body.request_block ∈ [head − REQUEST_FRESHNESS_BLOCKS, head]`.
- `response.committee_epoch_at_serve == body.serve_epoch`; both match a current or grace-window release key view.
- `runner_request.runner_signature` recovers to `body.runner_id` from the V4 request hash (§5.1).
- `response.proxy_signature` recovers to `proxy.operator` under `cbss/blinded-partial-response/v4`, signing the canonical response core.
- `SecretVersion` exists, is non-pending, has `recipient == body.recipient`, and yields the `wrap_epoch` for identity derivation.
- `policy.actors` (if set) contains `body.actor`; `policy.tee_required` validates against the runner's TEE attestation at submission-time current head.
- The request's blinding-authorization proof verifies against the committed identity, wrap epoch and MPK. The pairing equation `e(response.tau, G2_gen) == e(runner_request.body.blinded_identity, S_i)` holds, with `S_i = Σ_k vss_commitments[k] · response.proxy_index^k` evaluated from the release-key view; the index must match the proxy's one-based committee position.
- The `(release_id, proxy_id)` pair has not already been recorded; the `ReleaseReceiptSet` has not yet reached `threshold` entries.

On success, the receipt is appended to the set, the actor is charged `RELEASE_FEE_PER_RECEIPT`, and the proxy is credited the same. If the charge uses the permitted overdraft, the chain records `ActorReleaseDebt` and may mark the actor delinquent. The chain emits `cbss.release.receipt_recorded` per accepted receipt and `cbss.secret.released` when the accepted set reaches threshold.

3.11 `SubmitLivenessChallenge`. Args: `(runner_request, proxy_id, challenge_sig)`. Chain enforces `body.chain_id == chain_id`, `block_height ≥ body.request_block + MIN_CHALLENGE_DELAY_BLOCKS` and `block_height ≤ body.request_block + LIVENESS_CHALLENGE_MAX_AGE`. `challenge_sig` MUST recover to the runner address in the V4 request context under `cbss/liveness-challenge/v4`, binding the V4 request hash and challenged proxy ID. The chain checks for an existing receipt: if present, the challenge admits as `Resolved` immediately and the bond transfers to the proxy. Otherwise it admits as `Pending` with `deadline = block_height + LIVENESS_RESPONSE_BLOCKS`.

3.12 `LivenessChallengeResponse`. Proxy operator submits with reason ∈ `{InvalidRequest, RateLimited, NeverReceived}`. Chain transitions the challenge to `Unverifiable` (terminal), refunds the bond to the runner, and leaves the proxy's health neutral.

3.13 Liveness deadline. A challenge that reaches `block_height > deadline` without a

response transitions to `Unanswered`, refunds the bond to the runner, and decrements the proxy's `health.score_bps`. The transition is performed permissionlessly via an `ExpireLivenessChallenge` instruction (mirroring `ExpireDkgPending`); a per-block tick is NOT used.

3.14 `ExpireDkgPending`. After the deadline, anyone may clean up an expired DKG bond; the requester may also self-cancel before the deadline. Both paths refund `max(bond_amount - DKG_TIMEOUT_SLASH, 0)` and clear the `DkgPending` record. A third-party timeout caller receives one token unit only when the slashed pool `min(bond_amount, DKG_TIMEOUT_SLASH)` can fund it; a zero-bond governance ceremony pays no tip. A zero refund performs no Account read or write, so a zero-bond ceremony can expire without a requester Account row; no Account is created. A nonzero refund still requires the requester Account. A requester self-cancel receives no caller tip. For override-path cleanup, the corresponding pending `SecretVersion` is erased without a tombstone.

4. Events

The CBSS system actor emits the following string topics with byte payloads. Payloads marked JSON are `serde_json` encodings; raw IDs are 32 bytes, actor addresses are 20 bytes, and integer fields in raw composite payloads are big-endian unless marked `_le`.

Topic	Body	When
`cbss.secret.created`	`account(20) || key_hash(32) || version(8)`	After every `SetSecret`, including creation of a pending override version
`cbss.secret.finalized`	`account(20) || key_hash(32) || version(8)`	After `FinalizeSecretVersion` makes a pending override version usable
`cbss.secret.policy_updated`	`account(20) || key_hash(32) || version(8)`	After `UpdateSecretPolicy`
`cbss.secret.version_deleted`	`account(20) || key_hash(32) || version(8)`	After `DeleteSecretVersion`
`cbss.secret.deleted`	`account(20) || key_hash(32) || latest_version(8)`	After `DeleteSecret`
`cbss.share.zeroization_requested`	`account(20) || key_hash(32) || version(8) || epoch(8)`	Override deletion; 68 bytes, ordered by version then epoch, at most 256 hints per transaction
`cbss.proxy.registered`	`proxy_id`	After `RegisterCbssProxy`
`cbss.proxy.deregistered`	`proxy_id`	After `DeregisterCbssProxy`
`cbss.proxy.forced_deregistered`	`proxy_id`	After governance-forced deregistration

Topic	Body	When
`cbss.proxy.slashed`	`proxy_id`	After `SlashCbssProxy`
`cbss.proxy.governance_review_required`	JSON `{proxy_id, reason, score_bps, flagged_at_block}`	After sustained low health crosses the review window
`cbss.committee.rotated`	JSON `{scope, epoch}`	After `RotateCommittee` succeeds
`cbss.dkg.requested`	JSON `{scope, epoch, force_rekey, threshold, committee_metadata}`	After account, override, or governance system DKG request
`cbss.dkg.expired`	canonical binary `ReleaseKeyScope`	After `ExpireDkgPending`
`cbss.reshare.requested`	JSON ceremony metadata, committees, signers, and old commitments	When cadence or committee churn enqueues a reshare
`cbss.release.receipt_recorded`	`release_id`	Per accepted `SubmitReleaseReceipt`
`cbss.secret.released`	`release_id`	Exactly once when the `t`-th receipt lands
`cbss.release_receipts.gc`	`upto_block(8) || removed_count(8)`	After each bounded permissionless receipt-GC pass
`cbss.actor.delinquent`	raw actor address	When receipt charging first exceeds the paid balance
`cbss.actor.debt_repaid`	`actor(20) || repaid_le(8) || remaining_le(8)`	When `FundActor` repays release-fee debt
`cbss.liveness.challenge`	JSON `{challenge_id, proxy_id, release_id, deadline}`	After `SubmitLivenessChallenge` admits
`cbss.liveness.response`	`challenge_id`	After `LivenessChallengeResponse`
`cbss.liveness.expired`	`challenge_id`	After `ExpireLivenessChallenge`
`cbss.tlock.registered`	`tlock_id`	After `RegisterTlockRelease`
`cbss.tlock.partial_recorded`	`tlock_id`	Per accepted `SubmitTlockRelease`
`cbss.tlock.released`	`tlock_id`	When the tlock partial set reaches threshold
`cbss.tlock.gc`	`upto_block(8) || removed_count(8)`	After each bounded permissionless tlock-GC pass

GC event bodies encode `upto_block` followed by the removed-record count as two big-endian `u64` values.

5. The Release Path

5.1 Construction. The V4 request and signing bytes have this shape:

```
context          = ReleaseRequestContextV4 {
                       chain_id, secret_id, version, actor, runner_id, recipient,
```

```
                    job_id, release_nonce, request_block, serve_epoch, cip33 }
body             = ReleaseRequestBodyV4 { context, blinded_identity, proof }
body_bytes       = codec(body)
request_hash     = keccak256("cbss/release-request/v4"
                             || u32_be(len(body_bytes)) || body_bytes)
runner_signature = ECDSA-sign(runner_sk, request_hash)
request          = SignedReleaseRequestV4 { body, runner_signature }
```

The canonical context begins with the V4 byte, followed by `chain_id` and the remaining context fields. The body adds the blinding-proof suite tag, the 48-byte compressed blinded identity and the proof `{r: G1Bytes, z: [u8; 32]}`. The exact encoded body is the body portion of the runner-signing preimage. `runner_signature` is the codec's fixed 65-byte recoverable secp256k1 signature; the V4 decoder rejects malformed or noncanonical signatures.

The V4 response contains `request_hash`, `proxy_id`, `proxy_index`, `committee_epoch_at_serve`, `served_at_block`, `tau` and `proxy_signature`. Its signed core is the 133-byte canonical response encoding without the final signature, including the leading V4 tag. The proxy signs `keccak256("cbss/blinded-partial-response/v4" || response_core)`.

`cip33` is the optional `Cip33ReleaseContext { hire_id }` in the signed context. Its presence is normative, and fails closed in both directions:

- When the released secret is a canonical Trading Post escrow label, `cip33` **MUST** be present and `cip33.hire_id` **MUST** equal the `hire_id` of the resolved `JobSpec.hire_binding`; the label's `(declaration_id, version, artifact_id)` **MUST** equal the binding's, the referenced hire **MUST** be `Active` with the same pins, and its term **MUST** be valid at the block at which the check runs: the proxy's current head when it serves, and the submission-time current head when the receipt is admitted (Identity/authorization state is revalidated at submission time; see §3.4 and §12.8). It is **not** evaluated at `body.request_block`, which bounds request freshness only. A request that omits `cip33`, names a different hire, or fails any of these checks **MUST** be rejected as unauthorized.
- When the released secret is **not** a Trading Post escrow label, `cip33` **MUST** be absent; a request that carries one **MUST** be rejected as invalid. This direction is enforced at receipt admission by consensus; the proxy's own validation (§5.3) does not currently check it, so a spurious context can be partial-signed and only fail later on chain (§14).

Hired-job authorization is therefore bound both by the on-chain `JobSpec.hire_binding` and by this signed context (CIP-33 §2.2/§2.5.1).

5.2 Fanout. The runner orders committee proxies by health and observed latency and sends requests with bounded concurrent fanout via QUIC until it obtains `t` valid partials or exhausts

the committee. The current per-proxy timeout is 5 seconds.

5.3 Proxy validation. In the field references below, `body` denotes `request.body.context`. On receipt of a `PartialSignRequest`, the daemon enforces:

1. `body.chain_id` **MUST** equal the proxy's own configured chain id, which **MUST** be a nonzero network identifier, and the chain id reported by the node the proxy resolves state from **MUST** equal the same value. A mismatch is rejected before any network access and before any chain-state lookup. The proxy derives the identity `I` from the *request body's* `chain_id` (§5.4), so a proxy that omits it will compute and return $\sigma_i = s_i \cdot I$ for a chain of the requester's choosing. On a cloned or forked network, which inherits the same committee shares and therefore the same `MSK`, that hands the other chain's threshold signature to a party authorized only here, defeating the chain separation of the Identity Construction section entirely.
2. The protocol version is supported and the canonical request hash is absent from the process-local 65,536-entry served-request FIFO.
3. `runner_signature` recovers to the runner address in the V4 context from the canonical V4 request hash (§5.1).
4. The secret/version/recipient resolution matches the request and `body.request_block` $\in$ `[head − REQUEST_FRESHNESS_BLOCKS, head]`.
5. The runner is currently assigned to `body.job_id`; the actor manifest declares the requested key; Trading Post labels additionally pass lease authorization.
6. `policy.actors` authorizes the actor and `policy.tee_required` passes the current TEE check when set.
7. The proxy is a member of the resolved committee and `body.serve_epoch == release_key.committee_epoch`.
8. The local share belongs to that proxy and epoch, is active at the served block, and matches the VSS commitments.

5.4 Signing. The proxy decrypts its share `s_i`, reads `wrap_epoch` from the on-chain `SecretVersion`, verifies the local share against the stored VSS commitments, computes `I = hash_to_G1(base_aad)` (the 172-byte identity input, never the extended AEAD `aad`), whose `chain_id` is the proxy's own chain id (equal to `body.chain_id` by §5.3.1) and whose `wrap_epoch` is the value just read from chain, computes $\sigma_i = s_i \cdot I$, signs the response payload, records the request hash after success, and returns. These cryptographic steps currently execute inline in the async handler.

5.5 Combine. The runner verifies each σ_i against the resolved release-key snapshot, Lagrange-combines `t` valid partials into σ, and IBE-decrypts the DEK. The DEK is wrapped in `Zeroizing<[u8; 32]>` for the duration of the operation.

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5.6 Payload. The runner fetches the CBFS object at `cbfs_pointer` from a configured CBFS-node HTTP endpoint, mounted path, or generic HTTP fallback, AES-256-GCM-decrypts under `(dek, base_aad)`, inserts the resulting `Zeroizing<Vec<u8>>` into the `SecretBundle` keyed on the original `KeyName`, and zeroes the DEK.

5.7 Substitution. Runner-host modules consume the bundle, filling exactly the job's `secret_slots` (§11.2); the runner never reads `${` out of text, so any other `${NAME}` is sent as written:

- `runner-http`: inserts each slot's secret at its byte offset in the URL, a header value (including `Authorization`), or a string in the JSON body.
- `runner-mcp`: inserts each slot's secret into a string in the MCP tool arguments (JSON-aware) and, for stdio MCP servers, spawns the child via `tokio::process::Command::env_clear().envs(env)` so the parent process environment is never mutated.
- `runner-llm`: fills nothing; a slot on an LLM job is refused, and no prompt is ever filled.

5.8 Drop. When the request completes (or panics), the bundle drops; entries are zeroized via `Zeroizing<Vec<u8>>::drop`. Rendered URL, prompt, and system-prompt strings are actively wiped. Header and canonical-JSON containers are replaced with cleared values, but their old allocations are freed without an overwrite because the checked codec types expose no mutable or consuming accessor. The PVM does not install a per-secret-key environment deny list. In deterministic mode it sets RustPython's `ignore_environment = true`, but that flag ignores Python configuration variables; RustPython's POSIX `os.environ` module still copies the host process environment.

5.9 Receipts. Asynchronously and independently, each participating proxy attempts `SubmitReleaseReceipt` with 0–10 blocks of jitter. The runner does not submit. The partial-sign response is returned before this work completes. A saturated receipt worker pool drops the attempt; a publication error is logged without retry; an accepted transaction hash is not followed through execution by the receipt path. Consequently, accepted receipt events form an auditable subset of releases, not a complete release ledger.

5.10 Release-ID interoperability. The node, `cbss-client`, and `cbssd` all derive the identical consensus `release_id` defined in §1.5. Daemon audit records and liveness lookups therefore resolve against the same ID a node-side receipt uses. The consensus formula is normative. The canonical namespace is `cbss-release-id/v4`, with the chain and serve epoch bound as specified in §1.5.

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6. The DKG and Reshare Path

6.1 DKG trigger. A `DkgPending` record exists for `(scope, threshold, deadline, requester)`. The committee is either selected by the chain (`select_eligible_proxies`) or named explicitly via `committee_override.preferred_proxies`. Each member discovers the others' `network_addr` and `hpke_pubkey` from the chain.

6.2 DKG ceremony. The committee establishes a full-mesh QUIC topology and runs the Commonware Feldman–Desmedt protocol described in the **Cryptographic Construction** section. Dealer messages, player acknowledgements, and signed dealer logs are routed using the registered Ed25519 DKG keys. Each recipient validates the transcript before finalizing its share; malformed signed dealer material can yield `DkgSabotage` evidence eligible for `SlashCbssProxy`.

6.3 DKG commit. Once the Commonware canonical commit quorum finalizes and the daemon collects at least the chain threshold of rotate signatures, it queues `RotateCommittee`. The chain refunds the requester's recorded `bond_amount` on successful execution. If the ceremony remains pending until its deadline, a third party may submit `ExpireDkgPending`; the requester is refunded `max(bond_amount - DKG_TIMEOUT_SLASH, 0)` and the cleanup caller earns one token unit only when the slashed pool `min(bond_amount, DKG_TIMEOUT_SLASH)` can fund it. Zero-bond governance ceremonies pay no cleanup tip. Both commit and expiry skip Account access when the refund is zero, so zero-bond governance ceremonies need no requester Account row. A nonzero refund still requires that row.

6.4 Reshare trigger. Block-height scheduler (`now` $\geq$ `last_reshare_block + RESHARE_INTERVAL_BLOCKS`), churn detection (committee size near `t + RESHARE_SAFETY_MARGIN`), or owner-paid `RotateCommittee` request.

6.5 Reshare ceremony. A subset of $\geq$ `t` old-committee members run the PSS protocol of the **Cryptographic Construction** section. New-committee members verify each dealer's contribution against the on-chain old commitments. On success, the new committee submits `RotateCommittee` co-signed by $\geq$ `threshold` of itself AND $\geq$ `threshold` of the prior committee.

6.6 Old-share deletion. The intended safe boundary is confirmed execution of `RotateCommittee`, after which the old sealed share is deleted and an audit record is appended. The current daemon also deletes the old share earlier, when a signed rotation is merely queued for submission. If that transaction is rejected or never executes, the member may lose its old share before the chain changes epochs. Operators MUST treat queued-but-unconfirmed rotations as a recovery risk; deletion is not currently atomic with observing the on-chain rotation.

6.7 Grace window. For `RESHARE_GRACE_BLOCKS` after a rotation, receipts under the prior epoch remain acceptable: the chain looks up the receipt's `committee_epoch_at_serve` first against

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the current release key, then against `prior_committee_epochs`. The grace window is capped at `MAX_PRIOR_COMMITTEE_EPOCHS` simultaneously retained epochs.

7. Slashing

CBSS slashes for three on-chain-provable fault classes only. All other operational issues (non-response, slow proxies, miscalibrated stake) flow through the liveness-challenge audit trail and on-chain governance, not through automatic slashing.

Fault	Penalty	Evidence
`InvalidPartialReencrypt`	5 % of stake + suspend	A V4 runner request and authenticated proxy response with an invalid/malformed blinded partial, or an authenticated serve stamp outside the request freshness range.
`DkgSabotage`	5 % of stake + suspend	A round-2 message whose recipient share is inconsistent with the dealer's published round-1 commitments. The chain verifies `g_2 · share_scalar != Σ commitments[k] · recipient_index^k`.
`Equivocation`	50 % of stake + suspend	A signed V4 request and two authenticated responses with the same request hash, proxy, nonzero index and serve epoch but different validly encoded blinded partials. Verification needs no release-key history.

For invalid-partial evidence, let `R` be the runner-signed `request_block` and `anchor = clamp(served_at_block, R, R + 384)`. Admission runs from `R` through `anchor + 512`

inclusive, with saturating height addition. A deleted version requires `R ≤ deleted_at_block`, a non-pending tombstone and its public evidence context. Historical-epoch lookup additionally requires `R ≤ last_served_at` and submission at or before `last_served_at + 512`. The accused proxy's stamp cannot change either eligibility cutoff. Once request, blinding authorization, committee position and response are authenticated, a stamp outside `[R, R + 384]` is itself a fault in either direction, even with a valid pairing. A valid pairing with an in-range stamp is never slashable. Public history follows §2's retention rule and never extends serving grace.

The handler is `SlashCbssProxy`. The chain writes a permanent tombstone for `(proxy_id, fault_class, evidence_hash)` so the same evidence cannot slash twice. Plaintext leaks (off-chain disclosure) and persistent low health are not auto-slash; they route through governance (Technical Whitepaper §11) via `ForcedDeregisterCbssProxy`.

8. Gas Pricing

CBSS instructions consume gas under both meters (Cycles + Cells; Technical Whitepaper §4 / §17.1). Pricing:

Instruction	Cycles	Cells
`SetSecret` (default)	12,000	500
`SetSecret` (override)	38,000	500
`FinalizeSecretVersion`	8,000	500
`UpdateSecretPolicy`	6,000	500
`DeleteSecretVersion`	5,000	500
`DeleteSecret`	5,000 × active-version count	500
`RegisterCbssProxy`	15,000	500
`DeregisterCbssProxy` / forced variant	8,000	500
`RequestAccountDkg` / `GovRequestSystemDkg`	30,000	500
`RequestReshare`	30,000	500
`RotateCommittee`	25,000 + 1,000 × `new_committee.len()`	500
`ExpireDkgPending`	5,000	500
`SubmitReleaseReceipt`	8,500	500
`SubmitLivenessChallenge`	5,000	500

Instruction	Cycles	Cells
`LivenessChallengeResponse`	4,000	500
`ExpireLivenessChallenge`	5,000	500
`SlashCbssProxy`	20,000–22,000 by fault class	500
`RegisterTlockRelease`	6,000	500
`SubmitTlockRelease`	8,500	500

Every listed handler charges one flat `GasCosts::base_cells` value, currently 500. Cells are not dynamically proportional to encoded payload length in the current implementation.

9. Liveness, Health, and Slashing Fairness

9.1 Liveness challenge bond. `LIVENESS_CHALLENGE_BOND` (default 100 token units). Locked on `SubmitLivenessChallenge`, refunded on `Unverifiable` or `Unanswered`, transferred to the proxy on `Resolved`.

9.2 Health score. Each `CbssProxy` starts with `health.score_bps = 10,000`. An unanswered challenge subtracts 100 bps, capped at 1,000 bps per 7,200-block attrition window. A successful slash subtracts the fault penalty itself (500, 500, or 5,000 bps). Committee-selection weight floors the effective score at 500 bps. If actual score remains below 1,000 bps for 2,592,000 blocks, the chain records a governance-review flag and emits `cbss.proxy.governance_review_required`; it does not itself enact forced deregistration. There is no per-block health recovery in the current implementation.

9.3 Bond economics. Spam against responsive proxies is expensive: every challenge costs `LIVENESS_CHALLENGE_BOND` and resolves immediately to the proxy if the proxy already produced a receipt. The constraint `MIN_CHALLENGE_DELAY_BLOCKS > REQUEST_FRESHNESS_BLOCKS` ensures honest receipts have already landed (or can no longer land) before a challenge is admissible.

10. Owner-Side Flows (CLI)

10.1 **Default-path set:**

```
cowboy secrets set OPENAI_API_KEY --value-file -
```

`--value-file -` reads the value from standard input and avoids placing it in shell history or the process argument list; the CLI refuses an inline plaintext value when attached to a TTY. The CLI looks up the owner's `AccountReleaseKey`. If absent, it submits `RequestAccountDkg` and waits for `cbss.committee.rotated`. It generates a fresh DEK, samples a fresh `r != 0` with `U = r · G2_gen`, computes `aad = base_aad || compress(U)`, derives `K = HKDF(serialize(e(I, MPK)^r), "cbss/ibe/v1" || aad)`, AES-encrypts the value to a CBFS object, AES-encrypts the DEK under `K` into a `WrappedDek` (which carries `ephemeral_u = compress(U)`), and submits `SetSecret`.

10.2 **Override-path set:**

```
cowboy secrets set STRIPE_LIVE_KEY --value-file - \
  --committee-n 5 --committee-t 4
```

The CLI submits `SetSecret(committee_override = {t=4, n=5})` with no ciphertext and a recipient of `SecretSpecific{...}`. It waits for the per-secret DKG to commit, then submits `FinalizeSecretVersion` with the wrapped DEK and CBFS pointer. For any other committee size, `t` must equal Commonware's `N3f1` quorum; arbitrary ratios such as 5/9 do not match the production ceremony.

10.3 **Policy update:**

```
cowboy secrets policy --key-hash 0x... --version 3 --actor 0x...
```

This replaces the selected version's complete actor allowlist and `tee_required` flag; repeat `--actor` for multiple actors and pass `--tee-required` when required. It is a pure metadata update: no DEK is touched. Proxies query current chain state when authorizing a release.

10.4 **Versioning and deletion:**

```
cowboy secrets list --actor 0xOWNER
cowboy secrets delete-version --key-hash 0x... --version 3 --yes
cowboy secrets delete --key-hash 0x... --yes
```

10.5 **Operator flows:**

```
cowboy proxy register --pubkey 0x... --hpke-pubkey 0x... --dkg-pubkey 0x... \
  --tls-spki 0x... --network-addr quic://1.2.3.4:9601 --stake 1000
cowboy proxy list
cowboy proxy deregister --proxy-id 0x...
```

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11. SDK Integration

11.1 Manifest. Actors declare in their `ActorManifest`:

```
{
  "entitlements": [
    {
      "id": "secrets.read",
      "params": {
        "keys": [
          "OPENAI_API_KEY",
          "0x0123456789abcdef0123456789abcdef01234567:SLACK_API_KEY"
        ]
      }
    }
  ]
}
```

An unqualified key name refers to a secret owned by the actor's account; a cross-account reference uses `0x<40-hex-address>:KEY_NAME`. Manifest upgrades MAY shrink `secrets.read.keys` but MUST NOT expand them; the entitlement diff check is enforced when the actor's manifest is updated via the upgrade flow (Technical Whitepaper §3).

11.2 Python SDK. An http or mcp runner op marks the one string a secret fills with `runner.secret(key, prefix="", suffix="", account=None)`:

```
result = await runner.http(
    method="POST",
    url="https://api.openai.com/v1/chat/completions",
    headers={"Authorization": runner.secret("OPENAI_API_KEY", prefix="Bearer ")},
    body=payload,
)
```

A marked string is an http op's `url=`, a header value or a string inside a dict or list `body=`, or a string in an mcp op's tool arguments. The runner sends `prefix + <secret> + suffix` there and fills nothing else; any other `${NAME}` in the job is sent as literal text. `account` defaults to the actor's owner. The SDK adds each marked key's `[account, key]` grant to the job's `secrets` and writes its `secret_slots` (JobSpec v7): per slot an RFC 6901 pointer, the account, the key name and the byte offset the secret goes at. `validate()` allows at most 16 slots, strictly ascending by pointer, each granted and rooted at `/url`, `/headers/<name>` or `/body/...` of an Http job or `/arguments/...` of an Mcp job. Every marked key MUST be in the manifest's `secrets.read.keys`; an undeclared request is rejected by manifest and chain authorization and surfaces as secret-access denial. A slot on any other job type, `llm` included, is refused.

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A parallel `secrets.verify` entitlement (same `keys` shape and subset rule) grants **verify-only** use of a key as an inbound-MAC key via `runner.http(..., verify=VerifyInput(...))`: the runner MAC-checks an inbound webhook before any executor work and never fills the key into a request (`validate()` keeps it out of the job's grants, and the runner takes its name from the manifest's `secrets.verify` entry), so a key held only under `secrets.verify` cannot be exfiltrated through a `runner.secret()` slot.

11.3 PVM environment boundary. The PVM has no declared-key-specific environment filter. In deterministic execution it sets RustPython's `ignore_environment = true`, which suppresses environment-driven interpreter configuration such as `PYTHONPATH`; it does **not** clear `os.environ`. RustPython's POSIX module constructs `os.environ` from the host process environment, so actors can observe any variables inherited by the PVM host process. Deployments MUST therefore launch that process with an empty or explicitly allowlisted environment. `SecretBundle` debug formatting redacts values, and runner HTTP logging records a redacted URL origin rather than path, query, or user information; the implementation does not claim a general trace-wide scanner that removes every occurrence of an active secret value.

12. Security Considerations

12.1 Threshold IBE assumption. Security reduces to two assumptions on BLS12-381 plus the random-oracle model for `hash_to_G1`: the Computational co-Diffie-Hellman assumption (unforgeability of BLS partial/threshold signatures) and the co-Bilinear-Diffie-Hellman (co-BDH) assumption (confidentiality of the IBE wrap key — recovering `K` from the public `(I, MPK, U)` without σ; see Decryption). Standard threshold-BLS analysis (Boneh, Lynn, Shacham 2001; Boldyreva 2003) covers the partial signature combine. The IBE construction matches Boneh-Franklin's BasicIdent transformed to threshold form via a vetted t-of-n DKG; we follow the drand `tlock` paper's specialization with our chain-anchored identity tuple.

12.2 DKG implementation. Production `cbssd` uses Commonware's BLS12-381 `feldman_desmedt` dealer/player/log state machines with `N3f1` quorum selection. The older local DKG coordinator remains test-only. The requested chain threshold and Commonware's derived quorum are separate inputs today, which is why override callers must select the `N3f1` threshold described above. An expired ceremony's record remains available for `DkgSabotage` verification only until a same-scope retry starts: expiry does not advance the release-key epoch, so the retry reuses the storage key and overwrites the prior record. Evidence from the first ceremony can then become unverifiable.

Proxy registration rejects all-zero HPKE and DKG public keys, but it does not perform stronger point or small-subgroup validation. A nonzero but unusable key can therefore register and fail only when a ceremony first uses it.

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12.3 Reshare insider rotation. PSS preserves MSK; this means a post-reshare committee can re-sign any historical-`wrap_epoch` identity. Reshare provides *insider rotation* (a previously-compromised share is replaced) but NOT forward secrecy. Forward secrecy would require re-encrypting every chain-anchored ciphertext on every reshare, which is operationally infeasible. Owner accounts that want a fresh release key can create a new secret version with `--committee-n`, `--committee-t`, and a fresh committee selection.

12.4 Collusion of `t` proxies. `t` colluding proxies can reconstruct `MSK · I` for any identity they choose, decrypting any ciphertext under that release key. CBSS does not prevent or detect off-line collusion. Mitigation is limited to operator diversity through block-hash-seeded, health-weighted committee selection plus the soak period, and governance action based on evidence obtained outside the protocol. The `InvalidPartialReencrypt` slash proves an invalid partial; it does not prove or punish a valid off-line collusive decryption.

12.5 Owner key compromise. A compromised owner key can submit `UpdateSecretPolicy` to add an attacker actor and pull the secret. CBSS does not prevent this; it is a documented security boundary. Mitigations are wallet-level (hardware keys, multisig) and event-driven (chain emits `cbss.secret.policy_updated` for any change).

12.6 Memory hygiene. DEKs and secret-bundle values use `Zeroizing`; mutable rendered `String` fields are wiped after use. `HeaderMap` and `CanonicalJsonBytes` expose no in-place mutable buffer, so the runner clears them by replacement and the old plaintext allocation is freed without active overwrite. Network, allocator, and checked-codec copies therefore remain outside a strict every-allocation zeroization guarantee. Both AES-GCM layers bind `(chain_id, account, key_hash, version, wrap_epoch, mpk_g2)`, and the `WrappedDek` layer additionally binds `ephemeral_u`, so any field-level tamper fails authentication.

12.7 Replay protection. Three layers:

- Process-local 65,536-entry FIFO keyed on the canonical signed request hash; restart clears it and FIFO eviction is not time-based.
- Chain-side `release_receipt:{release_id}` map dedupes accepted receipts by `(release_id, proxy_id)` until receipt-set garbage collection.
- `request_block` freshness window `REQUEST_FRESHNESS_BLOCKS` constrains how far back a release request can target.

12.8 Revocation latency. Each proxy's HTTP authorizer fetches current secret, job, manifest, and TEE state for the request rather than consulting a documented TTL cache. A receipt that arrives later is revalidated at receipt-submission current head. Releases already served cannot be recalled, and failed receipt submission leaves no chain record.

12.9 TEE composition. When `policy.tee_required = true`, release authorization consults

TEE verifier state, whose handler role is allocated to `0x05` but whose records are currently persisted under `0x04`. AWS Nitro's full path verifies its COSE document and X.509 chain against active collateral. For SGX, TDX, and SEV-SNP, chip-root proof and complete TCB enforcement remain soft-fail: a failed or unavailable proof can create a self-asserted active measurement binding, and the release path accepts any active, unexpired binding. Consequently `tee_required` is not yet a hardware-rooted guarantee for non-Nitro runners.

12.10 Side channels and external review. Pairing operations and scalar arithmetic in `cbss-crypto` use `blstrs`'s constant-time primitives. Share scalars use `subtle::CtOption` for branch-free deserialization. HPKE and AES-GCM rely on RustCrypto's constant-time implementations. The repository contains an external-review packet and report template but no accepted external cryptographic review report; that review remains a pre-mainnet gate.

12.11 Runner trust boundary. Threshold IBE protects a secret before authorized release; it does not protect plaintext from the selected runner, its host administrator, a compromised runner process, or downstream libraries after substitution. A malicious authorized runner can exfiltrate any secret it is permitted to request. TEE policy is an additional gate with the enforcement limits in §12.9, not a substitute for runner accountability.

13. Parameters

Parameter	Default	Tunable by
`MIN_PROXY_STAKE`	1,000 token units	Consensus code constant
`PROXY_SOAK_PERIOD_BLOCKS`	100	Consensus code constant
Deregistration delay	0 (`unbond_at = current block`)	Consensus code behavior
`DEFAULT_N`	5	Consensus code constant
`DEFAULT_T`	4 (`N3f1` for n=5)	Consensus code constant
Override `n` wire range	1–255 (`u8`); execution storage-fit ceiling 90	Protocol codec / consensus validation
`MAX_CBSS_RELEASE_COMMITTEE_SIZE`	90	Consensus code constant; storage-fit ceiling, separate from default size 5 and CIP-24's spec-only override policy 15
`MAX_TEE_TRUSTED_KEYS_PER_MEASUREMENT`	640	Consensus code constant; per `(tee_type, measurement_hash)`
`MAX_TEE_COLLATERAL_SNAPSHOTS`	8,191	Consensus code constant; distinct indexed effective heights
`MAX_PRIOR_COMMITTEE_EPOCHS`	4	Consensus code constant
`RESHARE_INTERVAL_BLOCKS`	1,296,000 (≈ 15 days at 1 s/block)	Consensus code constant
`RESHARE_GRACE_BLOCKS`	100	Consensus code constant
`RESHARE_SAFETY_MARGIN`	1	Consensus code constant

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Parameter	Default	Tunable by
DKG_BOND	1,000 token units	Consensus code constant
DKG_FINALIZE_BLOCKS	7,200 (≈ 2 hours at 1 s/block)	Consensus code constant
DKG_TIMEOUT_SLASH	50 token units	Consensus code constant
Third-party DKG-expiry reward	1 token unit	Consensus code constant
REQUEST_FRESHNESS_BLOCKS	384	Consensus code constant
CBSS_EVIDENCE_WINDOW_BLOCKS	512	Consensus code constant
CBSS_MAX_EVIDENCE_EPOCHS	64	Consensus code constant
RELEASE_FEE_PER_RECEIPT	1 token unit	Consensus code constant
MAX_RELEASE_OVERDRAFT	16 token units	Consensus code constant
LIVENESS_CHALLENGE_BOND	100 token units	Consensus code constant
MIN_CHALLENGE_DELAY_BLOCKS	416	Consensus code constant
LIVENESS_RESPONSE_BLOCKS	64	Consensus code constant
LIVENESS_CHALLENGE_MAX_AGE_BLOCKS	480	Consensus code constant
LIVENESS_UNANSWERED_DECREMENT_BPS	100	Consensus code constant
HEALTH_ATTRITION_EPOCH_BLOCKS	7,200	Consensus code constant
MAX_HEALTH_LOSS_PER_EPOCH_BPS	1,000	Consensus code constant
Committee weight floor	500 bps	Consensus code constant
Governance review threshold	1,000 bps	Consensus code constant
GOVERNANCE_REVIEW_BLOCKS	2,592,000 (≈ 30 days)	Consensus code constant
MAX_SECRETS_PER_ACCOUNT	256	Consensus code constant
MAX_VERSIONS_PER_SECRET	32	Consensus code constant
MAX_ACL_ACTORS	64	Consensus code constant
Proxy request timeout	5,000 ms	Local runner configuration
Served-request replay cache	65,536 entries	Daemon code constant
MIN_TLOCK_LEAD_BLOCKS	16	Consensus code constant
MAX_TLOCK_REGISTRATIONS_PER_BLOCK	256	Consensus code constant
TLOCK_RETENTION	256 blocks	Consensus code constant

Evidence retention first removes expired epochs. If the retained history would still exceed CBSS_MAX_EVIDENCE_EPOCHS, rotation is rejected; unexpired evidence is not discarded to make room.

Except for local client/daemon settings, these values are compile-time constants in the current implementation. Changing one requires a consensus-compatible software upgrade; there is no generic on-chain parameter store that tunes this table at runtime.

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14. Implementation Status and Mainnet Gate

CBSS is not mainnet-ready. The mainnet gate requires completed DKG, release-path, CLI/liveness, full-network, TEE, stress, and adversarial review, and an accepted external cryptographic review.

The implementation includes threshold IBE, the Commonware-backed production DKG path, PSS reshare machinery, chain storage and handlers, pairing-verified receipt admission, runner threshold fanout/decryption, QUIC daemon plumbing, CLI transaction builders, liveness lifecycle, and slashing evidence handlers. These components do not establish mainnet readiness.

The current implementation also has material cross-component limits described normatively above: best-effort receipts are not a complete audit trail; non-`N3f1` threshold overrides do not match the production DKG polynomial; old shares can be deleted before rotation confirmation; non-Nitro `tee_required` accepts the soft-fail binding path; a same-scope DKG retry can overwrite expired-ceremony sabotage evidence; proxy registration only rejects all-zero HPKE/DKG keys; and the PVM exposes its host process environment through `os.environ` despite the interpreter configuration flag; checked-codec plaintext allocations cannot all be actively overwritten. No external cryptographic review has been accepted.

The wrapped-DEK codec accepts only format version 2 and rejects any other version tag. The daemon accepts only the V4 release protocol envelope, strictly decodes the signed request and authenticates the runner before proceeding with a release.

The rule in §5.1 that a non-Trading-Post release MUST NOT carry a `cip33` context is enforced at receipt admission by consensus, but not by the proxy: `cbssd` runs its lease gate only when a Trading Post label is present, and the client copies the job's hire context onto every release request it builds. A spurious context is therefore partial-signed and rejected only later, on chain. The signature covers `cip33` and consensus fails closed, so this costs work rather than safety: the release itself is authorized on every substantive ground, but because the receipt never lands, `RELEASE_FEE_PER_RECEIPT` is never charged or credited (§3.10) and the release leaves no chain audit record.

14.1 Out of Scope

- Forward-secret reshare (would require re-encryption of all anchored ciphertexts on every rotation).
- Plaintext leak slashing (handled by on-chain governance, not on-chain evidence).
- Zero-knowledge proofs of correct partial-sign computation (the pairing check on chain is sufficient for the threat model).

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- Hierarchical secrets (sub-keys, scoped namespaces beyond per-account).
- Push-based re-fetch on policy change (runners resolve authorization at operation time).

15. Relationship to the Technical Whitepaper

This document layers on, but never supersedes, the Technical Whitepaper. Specifically:

- Actors, messages, timers, reentrancy, and per-handler resource limits follow Technical Whitepaper §3. The current PVM does not clear `os.environ`; its host process must be launched with a scrubbed environment as described in §11.3.
- Fee markets (Cycles, Cells) and per-block basefee adjustment follow Technical Whitepaper §4 and §17. CBSS instructions consume both meters per §8 of this document.
- State rent for CBSS chain storage (metadata, release keys, receipts, challenges) follows the standard system-actor accounting at `0x04`. Off-chain plaintext incurs no rent (it does not exist on chain); CBFS objects holding wrapped payloads bill under CBFS storage rent.
- The Runner Marketplace (Technical Whitepaper §5) is the consumer of release requests. Job dispatch integrates with CBSS via the actor's `secrets.read` manifest entitlement; the assigned runner is the only eligible signer of release requests for the job's duration.
- CBFS (Storage Whitepaper) is the data plane for the encrypted payload. The current owner path sends an owner-signed ciphertext envelope to the `cbssd` ingest service, which fans it out to CBFS nodes with short-lived operator-signed blob capabilities. The runner resolves the content-addressed pointer through configured CBFS-node HTTP endpoints, a mounted path, or an HTTP fallback. The CBFS pointer on `SecretVersion` is the only chain-resident reference.
- Consensus, randomness, and networking follow Technical Whitepaper §6. Current committee selection derives a deterministic seed from the block hash, height, requested count, and scope, then performs health-weighted sampling over eligible proxies.
- Governance, upgrades, and system actor hot-code replacement follow Technical Whitepaper §11. CBSS mainnet enablement is a governance proposal contingent on external cryptographic review of `cbss-crypto`.
- Entitlements (Technical Whitepaper §15) gate `secrets.read` at the manifest level; CBSS is the second, fine-grained layer (per-key, per-version, per-actor).
- TEE state is consulted when `policy.tee_required = true`, subject to the Nitro versus non-Nitro enforcement boundary in §12.9; its records are currently persisted under `0x04` despite the logical `0x05` allocation.

Where this document and the Technical Whitepaper disagree on shared platform values or procedures, the Technical Whitepaper is the normative reference. CBSS wire formats and

consensus encodings are specified in CIP-24.

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