

Hypurrliquid Yellow Paper

Reverse-Engineered Hyperliquid Reimplementation

April 4, 2026

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The protocol-truth reference for the Hyperliquid L1 reimplementation. Every claim here is tagged with its evidence level.

Evidence levels: CONFIRMED = verified from binary RE or official docs. OBSERVED = seen in runtime/snapshots. IMPLEMENTED = coded in hlx. INFERRED = deduced from behavior.

Use the White Paper for narrative architecture. Use the Hypurrliquid Paper for the full RE reference with Mermaid diagrams. Use the Action Inventory for the current action-family and sub-variant tables. Use the Truth Register when you want the compact fact ledger instead of the full chapter narrative. For the denser subsystem splits, use Hashing, Staking & Validators, Bridge2, and Outcomes.

0. Truth Surfaces

This paper is the technical narrative, not the only truth surface. Read it together with:

- Truth Register for the compact confirmed/active fact ledger
- Open Claims for unresolved work
- Protocol Scope Matrix for protocol vs testnet_impl vs local_impl
- Action Inventory for action-family and sub-variant tables

1. Block Lifecycle (46 Hook Points)

CONFIRMED from binary VA 0x01e748e0 and string at 0x539f8a.

1.1 Pipeline

RecoverUsers -> BeginBlock (9+5 effects) -> DeliverSignedActions (97 types)
-> ProcessFills -> EVM Block -> EndBlock -> Commit -> VoteAppHash

1.2 BeginBlock — 9 Named Effects

#	Effect	Guard Interval	Evidence
1	update_oracle	—	CONFIRMED
2	distribute_funding	8000ms	CONFIRMED
3	apply_bole_liquidations	—	CONFIRMED
4	update_funding_rates	8000ms	CONFIRMED
5	refresh_hip3_stale_mark_pxs	from snapshot	CONFIRMED
6	prune_book_empty_user_states	60000ms	CONFIRMED
7	update_staking_rewards	—	CONFIRMED
8	update_action_delayer	—	CONFIRMED

#	Effect	Guard Interval	Evidence
9	update_aligned_quote_token	—	CONFIRMED

1.3 Supplementary Effects

Effect	Guard	Evidence
check_trigger_orders	—	IMPLEMENTED
cancel_aggressive_orders_at_oi_cap	1000ms	CONFIRMED
validator_l1_vote_tracker_prune_expired	60000ms	CONFIRMED
reset_recent_ois	1000ms	CONFIRMED
update_stale_mark_guards	per-book	CONFIRMED

Current local main matches the widened 9-effect note on this ordering. What remains open on ActionDelayer is control semantics (enabled, delayer_mode, status_guard, vty_trackers), not the named drain slot.

1.4 EndBlock

Mark prices updated from book mid-prices: mark_prices[asset]=book.mid_price().

1.5 VoteAppHash

Every 2000 blocks. Quorum at 2/3+ stake. Final app_hash is first_16(SHA-256(L1_combined))||first_16(SHA-256(EVM_combined)), where each half comes from the rmp_serde->blake3XOF(2048B)->paddwu16 LtHash pipeline rather than one flat 14-category digest.

1.6 Consensus / Topology Surface

Current confirmed testnet-facing networking and consensus facts:

- ingress is concentrated through a broadcaster layer
- proposer rotation uses stake-weighted RoundRobinTtl
- QC and TC certificates drive the two-chain commit rule
- validator/sentry admission checks gate the transport layer
- ports 4001 and 4002 split block-streaming and peer/RPC verification traffic

Treat the exact operator deployment shape as still chain-scoped, but keep these surfaces aligned across lifecycle, gossip, and consensus notes.

1.7 Validator Lifecycle / Jail Surface

Current confirmed validator-control facts:

- epochs are time-based via `epoch_duration_seconds`
- active validators are recomputed at epoch boundaries
- signer admission checks search `epoch_states[cur_epoch]`
- jailed signers are excluded from normal proposer / signing flow
- `CSignerAction` currently has `unjailSelf`, `jailSelf`, and `jailSelfIsolated`
- manual unjail is rate-limited by `signer_to_last_manual_unjail_time`

What remains open on this lane is threshold/trigger detail, not the existence of the lifecycle surface.

2. Exchange State (57 Fields)

CONFIRMED from `serde struct chain` at `.rodata offset 0x543428` in testnet binary `331bef9b` (2026-04-03).

#	Field	Type	Parsed	Evidence
0	<code>locus</code>	<code>Locus(15)</code>	Yes	CONFIRMED
1	<code>perp_dexs</code>	<code>Vec<PerpDex></code>	Yes	CONFIRMED
2	<code>spot_books</code>	<code>Vec<SpotBook></code>	Yes	CONFIRMED
3	<code>agent_tracker</code>	<code>AgentTracker(5)</code>	Yes	CONFIRMED
4	<code>funding_distribute_guard</code>	<code>BucketGuard</code>	Yes	CONFIRMED
5	<code>funding_update_guard</code>	<code>BucketGuard</code>	Yes	CONFIRMED
6	<code>sub_account_tracker</code>	<code>SubAccountTracker(2)</code>	Yes	CONFIRMED
7	<code>allowed_liquidators</code>	<code>Vec<Address></code>	Yes	CONFIRMED
8	<code>bridge2</code>	<code>Bridge2(10)</code>	Yes	CONFIRMED
9	<code>staking</code>	<code>Staking(6)</code>	Yes	CONFIRMED
10	<code>c_staking</code>	<code>CStaking(23)</code>	Yes	CONFIRMED
11	<code>funding_err_dur_guard</code>	<code>BucketGuard</code>	Yes	CONFIRMED
12	<code>max_order_distance_from_anchor</code>	<code>f64</code>	Yes	CONFIRMED
13	<code>scheduled_freeze_height</code>	<code>u64</code>	Yes	CONFIRMED
14	<code>simulate_crash_height</code>	<code>u64</code>	Yes	CONFIRMED
15	<code>validator_power_updates</code>	<code>Vec</code>	Skip	CONFIRMED
16	<code>cancel_oi_cap_guard</code>	<code>BucketGuard</code>	Yes	CONFIRMED
17	<code>last_hlp_cancel_time</code>	<code>f64</code>	Yes	CONFIRMED
18	<code>post_only_until_time</code>	<code>f64</code>	Yes	CONFIRMED
19	<code>post_only_until_height</code>	<code>u64</code>	Yes	CONFIRMED
20	<code>spot_twap_tracker</code>	<code>JSON</code>	Yes	CONFIRMED
21	<code>user_to_display_name</code>	<code>HashMap</code>	Yes	CONFIRMED
22	<code>book_empty_user_states_pruning_guard</code>	<code>BucketGuard</code>	Yes	CONFIRMED

#	Field	Type	Parsed	Evidence
23	user_to_scheduled_cancel	HashMap	Yes	CONFIRMED
24	hyperliquidity	2 fields	Yes	CONFIRMED
25	spot_disabled	bool	Yes	CONFIRMED
26	prune_agent_idx	u64	Yes	CONFIRMED
27	max_hlp_withdraw_ fraction_per_day	f64	Yes	CONFIRMED
28	hlp_start_of_day_ account_value	f64	Yes	CONFIRMED
29	register_token_gas_auction	GasAuction(4)	Yes	CONFIRMED
30	perp_deploy_gas_auction	GasAuction(4)	Yes	CONFIRMED
31	spot_pair_deploy_gas_ auction	GasAuction(4)	Yes	CONFIRMED
32	hyper_evm	HyperEvmState(13)	Yes	CONFIRMED
33	vtg	JSON	Yes	CONFIRMED
34	app_hash_vote_tracker	3 fields	Yes	CONFIRMED
35	begin_block_logic_guard	BucketGuard	Yes	CONFIRMED
36	user_to_evm_state	HashMap (778K)	Skip	CONFIRMED
37	multi_sig_tracker	1 field	Yes	CONFIRMED
38	reserve_accumulators	JSON	Yes	CONFIRMED
39	partial_liquidation_ cooldown	f64 (30.0)	Yes	CONFIRMED
40	evm_enabled	bool	Yes	CONFIRMED
41	validator_l1_vote_tracker	3 fields	Yes	CONFIRMED
42	staking_link_tracker	JSON	Yes	CONFIRMED
43	action_delayer	ActionDelayer(9)	Yes	CONFIRMED
44	default_hip3_limits	JSON	Yes	CONFIRMED
45	hip3_stale_mark_px_ guard	BucketGuard	Yes	CONFIRMED
46	disabled_precompiles	Vec	Yes	CONFIRMED
47	lv	JSON	Yes	CONFIRMED
48	hip3_no_cross	bool	Yes	CONFIRMED
49	initial_usdc_evm_system_ balance	f64	Yes	CONFIRMED
50	validator_l1_stream_ tracker	JSON	Yes	CONFIRMED
51	last_aligned_quote_token_ sample_time	f64	Yes	CONFIRMED
52	user_to_evm_to_l1_wei_ remaining	HashMap	Yes	CONFIRMED
53	dex_abstraction_enabled	bool	Yes	CONFIRMED
54	hilo	HyperliquidityImpactLimiter(3)	Yes	CONFIRMED
55	oh	Vec<OracleSnapshot>(100)	Yes	CONFIRMED
56	hpt	AlignedQuoteTokenTracker	Yes	DISCOVERED

57/57 fields declared. 55/57 deeply parsed from snapshots. 2 skipped (user_to_evm_state, validator_power_updates).

3. Action Surface (97 Variants, 126 Sub-Types)

CONFIRMED from binary dispatcher at VA 0x0272a320. 90 mainnet + 7 testnet.

Category	Count	Key Types
Trading	9	order, cancel, cancelByCloid, modify, batchModify, TWAP, liquidate
Margin	3	updateLeverage, updateIsolatedMargin, topUpIsolatedOnlyMargin
Transfers	6	usdSend, spotSend, sendAsset, withdraw3, sendToEvmWithData
Sub-Accounts	3	createSubAccount, subAccountTransfer, subAccountSpotTransfer
Vaults	6	createVault, vaultTransfer, vaultDistribute, vaultModify, netChildVaultPositions, setVaultDisplayName
Staking	5	tokenDelegate, claimRewards, linkStakingUser, registerValidator, extendLongTermStaking
Account	7	approveAgent, setDisplayName, setReferrer, convertToMultiSigUser, approveBuilderFee, startFeeTrial, userPortfolioMargin
DeFi	5	borrowLend, userDexAbstraction, userSetAbstraction, agentSetAbstraction, agentEnableDexAbstraction
Governance	3	govPropose, govVote, voteGlobal (22 sub-types)
HIP-3/4	3	SetGlobal (6 sub), perpDeploy (8 sub), spotDeploy
Validator	9	CValidator, CSigner, validatorL1Vote, validatorL1Stream, bridge votes (5)
System	11	SystemBole, SystemSpotSend, CWithdraw, CUserModify, EvmUserModify, etc.
Special	7	evmRawTx, multiSig, noop, VoteAppHash, ForceIncreaseEpoch, userOutcome (4 sub), settleFraction
Additional	8	priorityBid, registerSpot, disableDex, cancelAllOrders, quarantineUser, etc.

Current testnet notes widen the action surface to 97 variants. The local engine has broad typed coverage, but parity work remains active and this page should not be read as a blanket “zero gaps” claim.

4. Funding Rate

CONFIRMED from binary assertions.

- **EMA:** DeterministicEma with fraction-based accumulation (num/denom). `assert!(decay<=1.), assert!(self.denom>0.)`.
- **Funding payment:** `payment=szixoracle_pxx(cum_funding_global-pos.cum_funding_entry)`
- **Direction:** Positive rate = longs pay shorts.
- **Guard interval:** 8000ms for both distribute and update.

- **Per-asset multiplier:** Set via SetFundingMultiplier VoteGlobal.
-

5. Liquidation & ADL

CONFIRMED from binary constants and docs.

- **Margin check:** $\text{margin_available} = \text{account_value} - \text{initial_margin_required}$. Liquidatable when < 0 .
 - **Isolated:** Per-position check with allocated margin.
 - **BOLE liquidation threshold:** Health factor < 0.8 .
 - **BOLE cooldown:** 30 seconds for partial liquidations.
 - **BOLE types:** Partial (50% seize), Market (full repay), Backstop (default liquidator).
 - **ADL:** Triggered when shortfall persists after liquidation. Counterparties ranked by ROE (highest first). Position reduced proportionally.
 - **ADL priority:** $\text{ROE} = \text{unrealized_pnl} / \text{margin_allocated}$.
-

6. State Hashing

CONFIRMED algorithm: $\text{rmp_serde} \rightarrow \text{blake3XOF}(2048\text{B}) \rightarrow \text{paddwu16}(\text{LtHash16}) \rightarrow \text{SHA-256}(32\text{B})$.

- **11 L1 categories + 3 EVM categories = 14 accumulators.**
- **L1 accumulators:** Running sums from genesis maintained in live state, not the stale BSS cache that earlier notes treated as canonical.
- **EVM accumulators:** accounts_hash , contracts_hash , storage_hash .
- **Heartbeat concise_lt_hashes:** EVM only. The traced heartbeat surface does not carry the full L1 accumulator state.

6.1 AppHash Split

Current repo truth is that the final app_hash is $\text{first_16}(\text{SHA-256}(\text{L1_combined})) || \text{first_16}(\text{SHA-256}(\text{EVM_combined}))$, not a single SHA-256 over one merged 14-accumulator buffer.

- **Encoding:** `abi.encodePacked(uint8(1),uint24(actionId),abi.encode(params...))`
 - **15 action types:** `LimitOrder`, `VaultTransfer`, `TokenDelegate`, `StakingDeposit`, `StakingWithdraw`, `SpotSend`, `UsdClassTransfer`, `FinalizeEvmContract`, `AddApiWallet`, `CancelByOid`, `CancelByCloid`, `ApproveBuilderFee`, `SendAsset`, `ReflectEvmSupplyChange`, `BorrowLend`.
 - **Delay:** `delay_scalex3000ms` (configurable). Actions fire in next block's `begin_block` Effect 8.
 - **In replay mode:** Raw tx calldata scanned via RLP parser without EVM execution.
-

8. Bridge Finalization and Validator-Set Updates

CONFIRMED from Bridge2 state naming, bridge action inventory, and the current control-plane notes.

- **Bridge2 state** includes `withdrawal_signatures`, `withdrawal_finalized_votes`, `finished_withdrawal_to_time`, `validator_set_signatures`, `validator_set_finalized_votes`, `bal`, `last_pruned_deposit_block_number`, and `oaw` (bool).
- **Withdrawal endpoint:** `withdraw3`.
- **Bridge signing action:** `ValidatorSignWithdrawal`.
- **Finalize actions:** `VoteEthFinalizedWithdrawal` and `VoteEthFinalizedValidatorSetUpdate`.
- **Validator-set update signing:** `SignValidatorSetUpdate`.
- **Signer model:** current repo truth keeps bridge signing on validator signer keys, not an unrelated bridge-only signer family.

What remains open is exact dispute-period closure and some Ethereum-side operational details, not whether bridge finalization is a first-class staged state machine.

9. Aligned Quote Token (HPT)

DISCOVERED from Hyperliquid docs + API.

- **Exchange field** `[56]hpt = AlignedQuoteTokenTracker`.
- **Per-token state:** `isAligned`, `firstAlignedTime`, `evmMintedSupply`, `dailyAmountOwed`, `predictedRate`.
- **Validator sidecar:** `aqa-publisher` (github.com/native-markets/aqa-publisher).
- **Rate source:** 30-day SOFR average from NY Fed, FRED, OFR (median of 3 sources).
- **Submission:** `validatorL1Stream` action with `riskFreeRate` field, daily at 22:00 UTC.
- **Protocol rate:** Stake-weighted median of all active validator votes.

- **Fee benefits:** 20% lower taker, 50% better maker rebate for aligned stablecoins.

This is also a begin-block surface: `update_aligned_quote_token` is the current effect-9 lane in the widened testnet note.

10. Outcomes and Settlement Surface

CONFIRMED for the baseline market model; HYPOTHESIS for the leading solvency-risk lane.

- **Risk mode:** 1x isolated-only, no leverage, no funding.
- **Settlement authority:** `oracleUpdater` posts final outcome via `SettleOutcome`.
- **Post-settlement behavior:** open orders auto-cancel via `outcomeSettledCanceled`; new orders reject via `outcomeSettledRejected`.
- **Question metadata:** `fallbackOutcome`, `namedOutcomes`, `settledNamedOutcomes`.
- **User token operations:** `SplitOutcome`, `MergeOutcome`, `MergeQuestion`, `NegateOutcome`.

Current open risk lane:

- `MergeQuestion` / fallback reconciliation is still the leading higher-order solvency hypothesis.
 - The repo should treat question-level accounting as riskier than the simpler YES/NO pair mechanics until the binary path is closed.
-

11. Gossip Protocol

CONFIRMED from binary RE.

- **Frame format:** `[u32BElen][u8kind][body]`. Traced data frames often use LZ4 with `kind=0x01`, while greetings use `kind=0x00`.
- **Port 4001 greeting:** `bincode-fork TcpGreeting` with chain-based variant index. Current live observations are testnet variant 3 (8 bytes total) and mainnet variant 2 (7 bytes total).
- **Broader chain enum:** the ABCI-stream chain mapping still tracks `Local=0`, `Sandbox=1`, `Testnet=2`, `Mainnet=3`; do not conflate that with the observed 4001 `TcpGreeting` variant index.
- **Port 4003 authenticated greeting:** `keccak256("HyperliquidConsensusPayload"+0x00+bincode(content))`; content is `bincode`, not `msgpack`.
- **Port 4003 signed content:** the greeting is variable-sized, not a tiny fixed blob. Captured content closes a 20-byte validator address, `varint` round, 1-byte variant flag, optional 32-byte ABCI extra, several additional counters plus a 32-byte hash, a sorted `heartbeat_statuses` map, and a trailing empty-mempool `varint`. A few middle counters still lack semantic labels.

- **Connection:** Server-side `connection_checks` — unknown peers rejected after 5s timeout.
 - **Loopback:** Dominated by `MsgConcise/OutMsgConcise` (tag 27/28).
-

12. Guard System

All rate-limited effects use `BucketGuard`:

```

    struct BucketGuard {
last_time: Option<u64>, // ms
interval_ms: u64,
}

```

Guard	Interval	Effect
<code>funding_distribute_guard</code>	8000ms	Funding settlement
<code>funding_update_guard</code>	8000ms	Premium sampling
<code>cancel_oi_cap_guard</code>	1000ms	OI cap order cancellation
<code>book_empty_user_states_pruning_guard</code>	60000ms	Book cleanup
<code>reset_recent_oi_guard</code>	1000ms	HIP-3 OI reset
<code>hip3_stale_mark_px_guard</code>	From snapshot	Stale mark refresh
<code>begin_block_logic_guard</code>	1000ms	Reentrancy protection
<code>funding_err_dur_guard</code>	60000ms	Funding error duration

13. Implementation Status

Component	Status	Tests
Action handlers (97)	All implemented	330+
Begin-block (9 + 5)	All implemented	Tested
Bootstrap (57 fields)	55/57 parsed	Bootstrap test
CoreWriter decoder	15 actions + RLP scanner	7 tests
ADL + BOLE liquidation	Execution implemented	ADL plan + candidates tests
Pipeline stages	6 stages with real logic	4 tests
RPC (30+ endpoints)	Consolidated in <code>hl-rpc</code>	Info tests
Integration tests	18 E2E devnet tests	All pass
Total	482 tests, 0 failures	Release: 11MB
