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RWA on Public Chains: Govt Bonds to Real Estate Tech and Bottlenecks

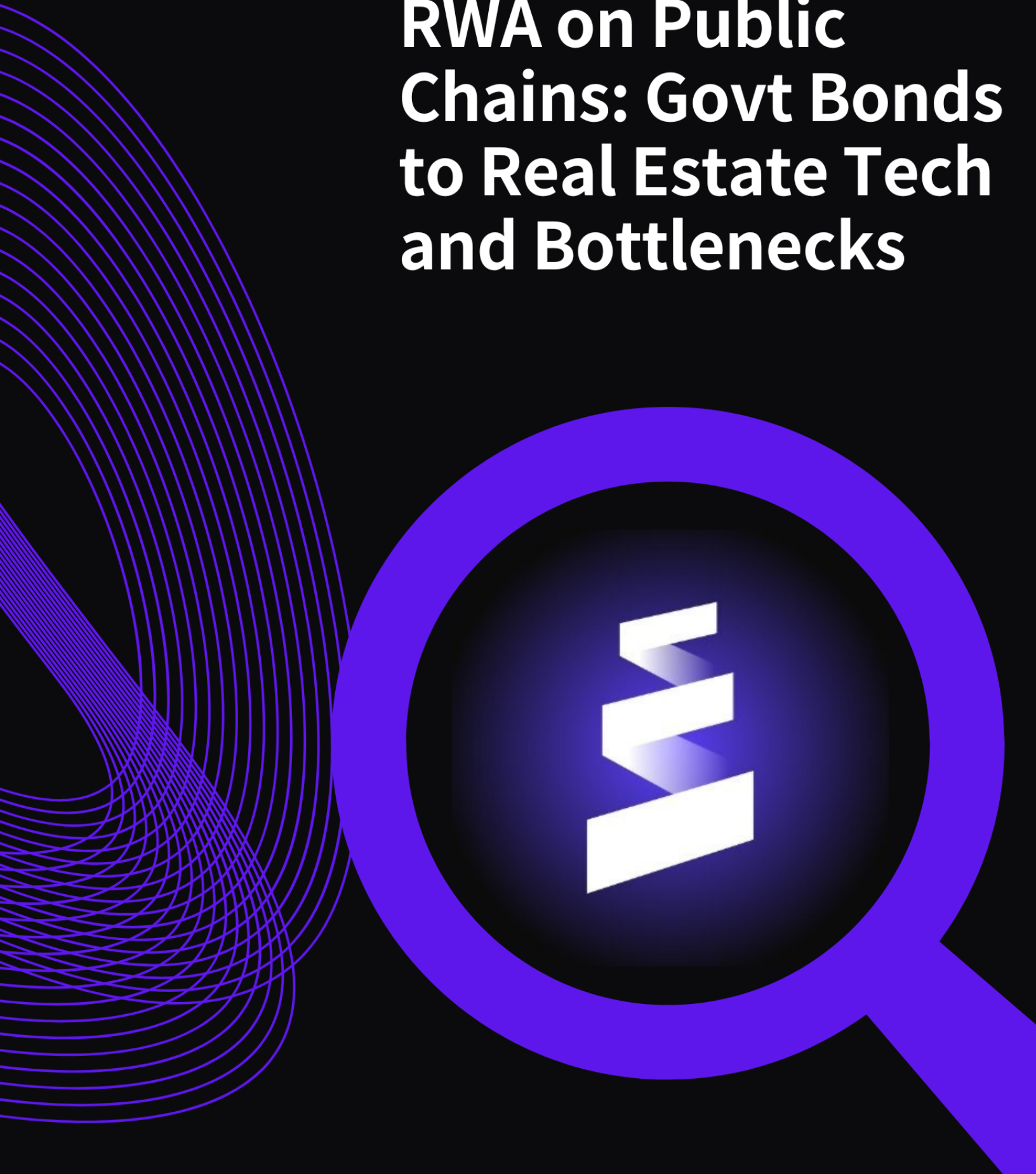

Table of Contents

Abstract

Real World Assets (RWA) are driving a structural restructuring of the global financial system. At its core is the digitization of traditional assets such as securities and real estate in the real economy through blockchain technology, enabling transparent, real-time, and auditable on-chain transactions of traditional assets on a global scale, thereby achieving liquidity restructuring and improved capital efficiency. Despite RWA's macro-logical potential as the "cornerstone of on-chain finance," its implementation faces three key challenges: the trusted boundaries of technical infrastructure, regulatory paradoxes at the institutional level, and liquidity dilemmas in the market.

This paper focuses on typical asset cases "from government bonds to real estate," systematically exploring the technical adaptation and implementation bottlenecks of RWA public chain practices. It emphasizes the importance of smart contracts, cross-chain interoperability, data credibility, and hybrid chain architectures, proposes a dual innovation path of technology and ecology, and provides systematic analysis and strategic reference for global RWA tokenization.

01 / Trade-off Framework for RWA On-Chain Tokenization

In the traditional financial system, asset rights confirmation, transactions, and settlement typically rely on paper contracts and centralized intermediary networks. This traditional transaction method is relatively inefficient and costly, also limiting the ability of assets to flow cross-border. With the development of blockchain technology, especially the maturity of public chain infrastructure centered on smart contracts and decentralized ledgers, RWA tokenization is providing a new operational paradigm for the global financial market. Assets can realize transparent and traceable transactions on-chain, and their cash flows, rights relationships, and transaction histories can all be recorded and executed through code and decentralized mechanisms, thereby significantly reducing information asymmetry and operational risks.

In the practical implementation of RWA, public chains play a key role in connecting real-world assets with on-chain transactions. Through smart contracts, the ownership structure, profit distribution rules, and regulatory constraints of assets can be encoded and executed on-chain, replacing intermediary roles in traditional finance with programmed trust. This mechanism not only enhances transaction transparency but also provides a technical foundation for cross-border asset circulation. For example, through cross-chain protocols, underlying assets are registered on consortium chains or permissioned chains, while the circulation layer completes transactions on high-liquidity public chains, forming a balance between compliance and liquidity.

In this process, the on-chain tokenization of real-world assets is not a simple technical migration but involves multi-dimensional trade-offs between technical capabilities, regulatory requirements, and market practices. As the underlying infrastructure, public chains need to strike a balance between the ideal of decentralization and the reality of strong regulation, while meeting multiple needs such as asset rights confirmation, data credibility, transaction efficiency, and liquidity. For different types of assets, such as government bonds and real estate, their trade-off frameworks have obvious differences, which determine multiple considerations including the technical selection, architectural design, and ecological adaptation path of public chains.

1.1 Asset Rights Confirmation and Trust

The primary issue of on-chain tokenization is how to ensure asset rights confirmation and transaction credibility. RWA tokens usually do not directly represent the property rights of underlying assets but form claims or equity rights to assets through Special Purpose Vehicles (SPV). Public chains need to have the ability to map off-chain legal structures, enabling on-chain tokens to accurately correspond to the equity shares of SPVs. At the same time, legal and compliance arrangements should be made to provide investors with bankruptcy isolation and recourse guarantees. For standardized assets such as government bonds, this mapping is relatively direct: SPVs hold underlying government bonds, issue tokens through smart contracts, and on-chain transactions directly correspond to cash flows and profit distribution. However, for non-standard assets such as real estate, there are complex legal fault lines between on-chain tokens and underlying property rights. The on-chain tokenization of such non-standard assets requires public chain platforms to provide more flexible rule encoding technologies, supplemented by cross-jurisdictional legal recognition mechanisms, to ensure the realization of asset liquidity and recourse rights.

At the level of data credibility, public chains usually rely on decentralized oracles (such as Chainlink) to provide Net Asset Value (NAV), proof of reserves, and cross-chain interoperability services. Cash

flows of standardized assets can be directly verified through existing data sources, while dynamic valuation of non-standard assets requires the integration of AI and the Internet of Things (IoT). IoT sensors collect real-time asset operation data, such as rent flows, equipment status, and energy consumption data. AI models integrate market information and operation data to achieve dynamic valuation and risk pricing, providing a credible value anchor for on-chain tokens. This "digital twin" approach is not only a technical means but also an important support for legal compliance, laying the foundation for the tradability of non-standard assets.

1.2 Technical Performance and Stability

Public chains undertake high-liquidity transactions and cross-border circulation, finding a balance between compliance and market depth. Technical performance and stability are key to ensuring the security, efficiency, and traceability of institutional-grade assets. Traditional financial institutions have far higher requirements for public chains than ordinary crypto projects, and different types of assets and regulatory environments have significantly different architectural requirements. Institutional conservatives (such as the European Union) tend to adopt permissioned consortium chains, sacrificing partial decentralization and liquidity in exchange for compliance adaptability. Such chains can provide clear access control, audit trails, and data storage compliance, making them suitable for storing assets highly sensitive to legal constraints. Market-driven players (such as the United States and Hong Kong) prefer public chains such as Ethereum and Solana to meet the goals of low-latency high-frequency trading and T+0 settlement, balancing compliance and performance through hybrid architectures. For example, China Merchants International deployed a US dollar money market fund on Solana, valuing its theoretical TPS limit of 65,000 and block time of 0.39 seconds.

1.3 Liquidity and Ecological Integration

RWA itself has limited liquidity and needs to connect to the DeFi ecosystem to achieve asset recirculation. Liquidity depth and ecological integration capabilities determine the transaction convenience, composability, and capital recirculation capacity of RWA tokens, which are the core of asset appreciation.

- **Ecological Maturity and Liquidity Depth:** RWA needs to have the ability to access global liquidity. Although Ethereum has insufficient efficiency in transaction throughput and confirmation time, it has become the preferred choice for most TradFi institutions due to its security, high trustlessness, and large ecosystem. At the same time, it needs to rely on a mature DeFi ecosystem to expand scenarios. For example, Aave Horizon already supports typical government bond RWA tokens[1][2], allowing users to convert tokenized assets into interest-bearing financial modules through lending operations. This ecological integration not only enhances asset liquidity but also provides a collateral foundation for stablecoins, forming a closed loop of "issuing tokens = purchasing bonds."
- **The Cornerstone Role of Stablecoins:** Stablecoins are the core of RWA pricing, settlement, and liquidity support, and their compliance directly affects ecological trust. The U.S. GENIUS Act requires U.S. dollar stablecoins to be fully reserved 1:1 with U.S. dollar deposits and U.S. Treasury bonds, forming a closed loop of "issuing tokens = purchasing bonds" and deeply linking stablecoin credit with U.S. sovereign credit. Hong Kong's Stablecoin Ordinance (effective August 2025), as the world's first comprehensive regulatory framework for fiat-backed stablecoins, provides clear compliance expectations for the RWA ecosystem[3].
- **Cross-Chain Interoperability:** RWA needs to achieve global circulation under the hybrid architecture of "permissioned chain for rights confirmation + public chain for circulation."

Public chains need to build trusted channels through cross-chain protocols such as Chainlink CCIP. For example, Guotai Junan and Ant Group's "two-chain-one-bridge" architecture connects compliant assets on consortium chains with global liquidity on Ethereum through cross-chain bridges. However, the social trust dependency risk of cross-chain bridges remains difficult to eliminate. Such risks mainly stem from the trust foundation of bridge operators, verification nodes, and off-chain management institutions. Once bridge operators act opaquely or operational errors occur, it may lead to asset freezes, delayed settlement, or distorted transaction data. Social trust dependency risks not only increase investors' concerns about the security of cross-chain assets but also affect the accuracy of asset pricing and liquidity. Specifically, both parties to the transaction must additionally rely on intermediaries or third-party services to confirm the asset status. This trust cost complicates the transaction process, reduces on-chain transparency, and may form liquidity fragmentation. Assets between different chains cannot flow freely and efficiently, limiting the potential of RWA's global circulation.

02 / Adaptability Analysis of Public Chain Practices

2.1 Public Chain Practices for Standardized Assets

As standardized, high-liquidity financial assets, government bonds have become the preferred target for RWA on-chain tokenization due to their stable returns, transparent cash flows, and widely recognized market mechanisms. Public chains mainly assume three types of functions in government bond tokenization: compliance embedding, transaction efficiency support, and data credibility verification.

2.1.1 Asset Attributes and Compliance Adaptation

Government bond tokenization (especially U.S. Treasury bond tokenization) is the most mature and largest segment in the RWA track. The reason why government bonds have taken the lead in achieving large-scale breakthroughs in the RWA market lies in their standardized, low-risk asset attributes, which perfectly align with the underlying requirements of public chains for "data verifiability" and "structural replicability," serving as a safe entry point for institutional capital into the RWA[4] field.

As a global benchmark for low-risk assets, the yield, maturity date, default probability, and repayment path of government bonds can all be accurately quantified and audited, meeting the strict risk control and compliance requirements of institutional investors. The stable risk-free yield they provide exactly matches the allocation needs of institutions and high-net-worth investors for "coupon substitute" assets, becoming the cash flow base in RWA evolution. As of the third quarter of 2025, the total scale of tokenized U.S. Treasury bonds has reached 7 billion to 8 billion U.S. dollars, occupying an absolute dominant position in the on-chain RWA market, confirming the market's widespread recognition of its safety and liquidity advantages.

In terms of tokenization paths, government bonds have formed a highly standardized operational process that is easy to replicate and expand on public chains: usually, SPVs or funds hold underlying short-term Treasury bills (T-Bills)/MMFs and entrust regulated custodians to hold the assets; platforms issue redeemable token shares on public chains through smart contracts; dividends and NAV are recorded and updated on-chain throughout the process, realizing full transparency of issuance, custody, and circulation, and significantly reducing the cost of redundant technical and compliance construction.

2.1.2 Technical Adaptation and Performance Optimization

Government bond tokenization has extremely high requirements for on-chain transaction efficiency and settlement. Public chains need to meet high TPS, low latency, align with the clearing cycle (T+1) of traditional financial markets, and meet data credibility commitments.

The technical adaptation of standardized assets in RWA public chain practices mainly relies on compliant token standards (ERC-1400/3643), KYC/AML whitelist embedding in smart contracts, and oracles to bridge off-chain data. Chainlink oracles provide dividend and NAV data, proof of reserves, and cross-chain interoperability services, ensuring that token values are synchronized with underlying government bond assets. This mechanism ensures the transparency of on-chain data and provides an auditable transaction bridge for institutional investors. Moreover, to meet strict compliance requirements, many RWA projects adopt permissioned whitelist contracts, ensuring that only addresses of qualified investors who have passed off-chain KYC/AML reviews by institutions (such as licensed financial institutions) can hold tokens or participate in transactions.

Performance optimization can alleviate the performance bottlenecks of Layer 1 public chains by strategically selecting high-performance public chains (such as Solana) or Layer 2 scaling solutions, with the ultimate goal of achieving instant, secure atomic settlement. Layer 2 solutions (such as Polygon, Arbitrum, Optimism) significantly improve transaction processing speed and reduce Gas fees by moving transaction processing off-chain while maintaining the security of the Ethereum mainnet. However, improving performance usually requires a trade-off between performance and decentralization—pursuing high efficiency (such as Solana) often means making certain compromises on decentralization and security. For institutions, finding a balance between performance and compliance is the key to the success of RWA[5] projects.

2.2 Public Chain Transformation of Non-Standard Assets

As a typical non-standard asset, real estate tokenization is a core area with both potential and challenges in RWA on-chain practices. Its difficulty lies in how to use public chain technology to break the inherent bottlenecks of complex legal rights confirmation and insufficient valuation transparency of off-chain real estate. This technical transformation is not a simple "asset on-chain" operation but a multi-dimensional systematic project involving ownership structure adjustment, data credibility verification, and smart contract automated management, requiring in-depth coordination between technological innovation and legal frameworks.

2.2.1 Ownership Segmentation and Liquidity Release

Real estate tokenization achieves asset fragmentation by dividing real estate equity into tradable tokens. This fragmentation transforms real estate equity into standardized tradable tokens, theoretically significantly lowering investment thresholds and allowing global retail investors to participate in asset allocation such as commercial real estate and private equity that were previously only accessible to large institutions. Pilot projects for fractionalized tokenization of commercial real estate ownership have emerged in Dubai, verifying the feasibility of the path.

However, ownership segmentation on public chains essentially relies on the support of off-chain legal structures. Currently, most institutional-grade projects do not directly realize the tokenization of property rights of underlying real estate but anchor tokens as claims or equity rights to SPVs by establishing SPVs in "legal enclaves" such as the Dubai International Financial Centre (DIFC). This requires public chain technology to adapt to complex legal rights mapping—for example, through security token standards such as ERC-3643 or ERC-1400, built-in compliance control functions ensure a one-to-one correspondence between on-chain tokens and off-chain SPV equity, meeting regulatory requirements for clarity of asset ownership.

2.2.2 Data Credibility and Integration of AI+IoT

As non-standard assets, real estate lacks a unified standardized valuation system, and their value is dynamically affected by multiple dimensions such as operational status and market environment. Public chain technology needs to support the authenticity and transparency of on-chain token values by introducing external trusted data, which relies on the in-depth integration of artificial intelligence (AI) and the Internet of Things (IoT).

At the level of data authenticity verification, IoT technology is the core support. By deploying smart sensors to collect real-time asset operation data (such as rent receipt records, commercial real estate foot traffic, equipment operation status, energy consumption data, etc.) and uploading these data to the chain through encryption protocols, the transparency and traceability of asset returns are ensured. For example, Ant Group's "Blockchain + IoT" AntChain Inside architecture applied in the new energy field has realized real-time on-chain of new energy equipment operation data, solving the consistency problem between on-chain data and physical asset status—this model can be

extended to commercial real estate, alleviating investors' concerns about information asymmetry regarding the actual value of assets by real-time monitoring cash flows and operational conditions.

At the level of dynamic valuation and risk pricing, AI technology becomes a key supplement. Addressing the pain point of the lack of a unified standard for non-standard asset valuation, AI models can integrate operational data collected by IoT with external market data (such as regional land price indices, rent fluctuation trends, macroeconomic indicators) to achieve automated valuation and risk pricing, providing a dynamic and fair value anchor for on-chain tokens. This requires public chain platforms to have strong computing and data processing capabilities, capable of integrating and analyzing multi-source heterogeneous data, and providing a valuation foundation for asset liquidity. A JLL report points out that Automated Valuation Models (AVM) have been widely used in commercial real estate valuation, combining AI technology to process multi-dimensional data including net operating income, leasing conditions, and market changes, thereby significantly improving valuation efficiency and transparency[10]. C3.ai's "Commercial Property Appraisal"[11] system integrates structured and unstructured data to support multiple valuation methods (income approach, comparative approach, cost approach) to enhance valuation accuracy. Although currently mainly applied in the traditional real estate field, introducing AI models into the valuation and risk pricing of RWA tokenization is not purely conceptual but has operational paths. However, it should also be noted that current practices mainly focus on tangible real estate or existing assets, and migrating this capability to on-chain RWA (especially involving cross-border underlying assets, jurisdictional differences, and tokenized structures) is still in its early stages. The simultaneous advancement of technology, data, and compliance is particularly critical.

2.2.3 Automation and Built-in Compliance of Programmable Trust

Smart contracts are the core technology that endows real estate tokenization with "programmable trust" on public chains, undertaking the dual functions of automated asset management and built-in compliance logic, and serving as a key link connecting technical architectures and regulatory requirements.

In terms of revenue management and fund supervision, smart contracts can solidify rules such as rent income distribution and asset dividends into code, realizing automatic calculation and distribution of returns, and significantly reducing friction costs and delays caused by the participation of traditional intermediaries. In trust-sensitive scenarios such as real estate pre-sales and prepaid rents, smart contracts can set up fund supervision accounts, ensuring that fund usage complies with agreements through code logic of "earmarked funds" and "payment according to agreements," providing performance guarantees in the absence of traditional trust intermediaries.

At the level of compliance control, smart contracts need to have built-in KYC/AML whitelist mechanisms and restricted transfer clauses. For example, contracts based on security token standards can use permission control functions to allow only compliant investors who have passed qualification reviews to hold or trade tokens, while automatically blocking illegal transfer behaviors, meeting regulatory requirements for investor suitability management, and providing a compliance foundation for traditional financial institutions to participate in real estate tokenization.

2.3 Common Technical Support and Competitive Pattern of Public Chains

From the perspective of market competition, public chains present three characteristics in RWA implementation[6]:

Highly decentralized public chains (such as Ethereum): Mature ecosystem and strong liquidity but limited performance.

High-performance public chains (such as Solana, Sei): Suitable for high-frequency trading and settlement but low decentralization.

Permissioned/consortium chains (such as AntChain, Euroclear DLT): Compliance-friendly and legally controllable but limited liquidity.

In addition, Pharos Network, which focuses on RWA and stablecoin scenarios, serves as an emerging differentiated option with both high-performance support and compliance adaptability, further enriching the scope of technical selection. Different assets and investors have different choices for chains, forming a hybrid architecture as the mainstream practice path:

资产类型	Project Name	Underlying Chain	Core Technology (Key Highlights)
Government Bonds	BlackRock BUIDL Fund	Ethereum (Mainnet)	ERC-20 Tokenization, SPV Risk Isolation
Government Bonds	Ondo Finance OUSG	Ethereum (Mainnet)	ERC-3643 Compliance Token, Dynamic Oracle
Real Estate	Causeway Bay Office Building (Hong Kong)	Ethereum + Polygon	ERC-3525 (SFT), Digital Twin
Real Estate	Dubai Apartment Tokenization	Solana (Token-2022)	ZK-KYC, Real-time Rent Distribution Contract
New Energy	GCL New Energy PV Power Plant	AntChain (Hybrid Architecture)	AI Power Generation Forecasting, Dynamic Revenue Distribution
New Energy	Longshine Group Charging Piles	AntChain	Delivery vs Payment (DvP), Data On-Chaining
Agriculture/Data	Malu Grape RWA	HashKey Chain	Agricultural Data NFTizati
Source: BUIDL Fund Official Website, Ondo Finance Official Documentation, Longshine Technology Official Announcements, and Project Whitepapers			

03 / Multiple Barriers to RWA Implementation

Although the tokenization of real-world assets (RWA) has formed initial practices in fields such as government bonds and real estate, there are still significant barriers to large-scale commercial implementation. These bottlenecks not only stem from technical and performance limitations but also reflect structural mismatches between legal systems, regulatory logic, and decentralized financial mechanisms at a deeper level.

3.1 Structural Bottlenecks in Law and Regulation

The adaptability of law and regulation is the primary barrier to the large-scale implementation of RWA. The core contradiction lies in the difficulty of bridging the gap between on-chain token transfer records and off-chain legal rights, leading to fundamental judicial uncertainty in asset rights confirmation and circulation.

Most RWA tokens (such as tokenized government bonds and private credit) do not directly represent the property rights of underlying assets but are claims or equity rights to SPVs[7]. The substantive legal problem brought by this structure is whether token holders can "pierce the SPV" and exercise recourse rights against underlying assets in judicial practice when the custodian bank becomes insolvent or the issuer defaults. This issue lacks clear precedents in common law jurisdictions such as the United States and the United Kingdom, resulting in high uncertainty in judicial outcomes. Legal opinions can only explain rights relationships within the existing framework and cannot create property rights not explicitly granted by law, further exacerbating the fragility of rights protection.

The conflict between the global circulation of RWA and the territoriality of underlying assets and sovereign regulation has become increasingly prominent, forming multiple legal fault lines. In dual-jurisdiction regions such as Dubai, underlying real estate follows civil law property rights rules, while the contractual rights represented by tokens may be established in common law financial centers (such as DIFC). Such differences in legal systems may lead to conflicting rulings by courts in different jurisdictions, triggering the risk of a "judicial civil war." In the United States, there is an ongoing game between regulatory authorities regarding the definition of token nature. The SEC adheres to the principle of "substance over form" and classifies most income-generating RWA tokens as securities through the Howey Test, forcing them to comply with strict Securities Act registration processes, imposing extremely high compliance costs and uncertainty on project parties. Compliance teams need to strike a difficult balance between continuous information disclosure transparency and ICT information security confidentiality, further increasing the friction cost of regulatory adaptation.

For RWA projects involving assets in Mainland China, data sovereignty and cross-border transfer restrictions constitute unavoidable compliance bottlenecks[8]. China’s Data Security Law clearly states that "important data shall not be transferred overseas in principle," forcing projects to adopt prudent data localization and cross-border flow strategies. Enterprises need to pass the cross-border security assessment of the Cyberspace Administration of China, with an approval cycle of 45 to 60 working days, which has become a key factor affecting project progress. Such restrictions may prevent global investors from accessing original and complete underlying asset data, reducing asset transparency and ultimately affecting pricing and liquidity.

Region/Jurisdiction	Main Regulatory Contradictions	Core Risk Points	Typical Manifestations
United States (Common Law)	SEC defines token nature based on "substance over form"; most income-generating RWA are classified as securities	Triggers Securities Act registration obligations with extremely high compliance costs; conflict between information disclosure requirements and ICT security	Securities classification based on the Howey Test; project parties face high legal consultation and registration processes
Common Law Jurisdictions (UK, etc.)	Lack of clear precedents for SPV piercing; tokens represent SPV claims/equity rather than underlying property rights	When the custodian bank becomes insolvent or the issuer defaults, token holders cannot confirm their right to recourse against underlying assets	Courts lack stable property rights recognition for token rights; legal opinions cannot make up for rights gaps
Dubai (Dual Jurisdiction: Civil Law + DIFC Common Law)	Inconsistent legal systems for underlying assets and tokens (civil law real estate vs. DIFC common law contractual rights)	Courts in different jurisdictions may issue conflicting rulings, triggering a "judicial civil war"	Real estate registration is subject to civil law, while token contract disputes may fall under DIFC jurisdiction
Mainland China (Civil Law) [13]	Strict data sovereignty and cross-border transfer restrictions; difficulty in transferring underlying asset data overseas	Projects need to pass the Cyberspace Administration of China's cross-border security assessment (45–60 working days), affecting issuance progress; insufficient transparency affects pricing	Data Security Law restricts cross-border transfer of original asset data; requires localized data architecture
Global Level (Cross-Regional Issues)	Difficulty in bridging the gap between on-chain token records and off-chain legal rights	Unclear rights confirmation, restricted cross-border circulation	Global investors struggle to access consistent legal protection; judicial and regulatory fragmentation.

Source: Dubai VARA and DFSA Regulatory Documents, "RWA Tracking Series: Multi-Path RWA Policy Research Framework" [12], "RWA Cross-Border Assessment and Legal Connection" [13] Research Reports, etc.

3.2 Bottlenecks in Financial and Institutional Costs

High initial investment, long implementation cycles, and strict capital controls limit RWA innovation to a small number of large institutions, forming significant industry entry barriers.

Institutional-level compliance costs constitute the core threshold for RWA projects, making them more like "luxury goods" customized for industry giants at the current stage. The complete implementation process of RWA usually takes 18 to 24 months. The long cycle, coupled with dynamic changes in regulatory policies, excludes a large number of small and medium-sized innovative projects. For example, the average approval time for a German crypto license is 18 months, and policy adjustments during this period may render previous investments obsolete, increasing project uncertainty risks.

The complexity of cross-border fund repatriation is a key vulnerability in the RWA closed loop. Overseas funds need to be repatriated to domestic entity accounts through official channels such as Qualified Foreign Limited Partners (QFLP) and Overseas Direct Investment (ODI), with complex processes and high policy uncertainty. When a single dividend exceeds 5 million US dollars, it needs to be filed in the State Administration of Foreign Exchange system. Any attempt to conceal virtual asset investment through superficial trade settlement may fail in penetrating reviews, restricting the flexibility of fund flow.

3.3 Challenges in Technical and Security Vulnerabilities

RWA has strict requirements for technical adaptability, but the core technical components connecting off-chain and on-chain are often the weakest links in the system. Moreover, performance improvement often comes at the cost of sacrificing decentralization, forming an inherent tension between technical security and efficiency.

As a key hub connecting the permissioned chain/consortium chain rights confirmation layer and the public chain circulation layer, cross-chain bridges are widely recognized as the weakest and most controversial link in the ecosystem. Their security mostly relies on the "trust assumptions" of a few participants rather than cryptographic trustless guarantees, making cross-chain bridges a major target for hacker attacks. In most hybrid architectures, cross-chain bridges, oracles, or underlying Layer 2 still have centralized control points. For example, high-performance Layer 2 often sacrifices decentralization, allowing users to enjoy high throughput while having to entrust part of their trust to operators, deviating from the core trust logic of blockchain technology.

The external risks of underlying public chains constitute significant technical and geopolitical exposures. Relying on key financial infrastructure on overseas public chains such as Ethereum means that sovereign parties cannot exert direct influence. Once external networks encounter regulatory restrictions, protocol upgrades, or community governance changes, they may unilaterally change RWA transaction rules or cut off circulation channels. Such risks cannot be completely avoided through the project's own technical optimization.

The inherent tension between technology and law further exacerbates system vulnerability. The "code is law" characteristic of smart contracts faces friction in the real judicial system. When code conflicts with the legal intent of the whitepaper due to vulnerabilities, courts usually prioritize safeguarding tangible legal implications over flawed code execution. The RWA system is highly dependent on oracles to transmit off-chain asset information. If oracles are insufficiently decentralized or have single points of failure in data sources, attackers can undermine the asset value foundation by manipulating data, forming systemic security risks.

3.4 Systemic and Market Acceptance Risks

Liquidity mismatch is the most critical systemic risk of RWA, essentially a temporal mismatch between the immediacy of on-chain transactions and the long-term nature of underlying asset cash flows. On-chain transactions can be realized in real-time, but the cash flow recovery cycle of underlying assets (such as 180-day accounts receivable, long-term bonds, real estate) is long. Once a market panic occurs, large-scale real-time redemption demands may exceed the project's cash reserves, triggering liquidation mechanisms and causing a sharp drop in token prices. For example, an accounts receivable RWA project once experienced a surge in redemption applications of 300 million US dollars in a single day due to mismatches between asset maturity and redemption commitments, ultimately initiating liquidation, highlighting the real harm of this risk.

The valuation challenge of non-standard assets restricts the standardization process of RWA. Non-standard assets such as real estate, intellectual property, and art lack a unified valuation system, and their value is affected by multiple factors such as market environment and asset status. It requires the in-depth integration of traditional auditing with technologies such as AI and IoT to build dynamic and credible digital twins to alleviate the problem of valuation fairness. However, the current level of technological integration is still insufficient to completely eliminate valuation disputes.

The "identity crisis" of market acceptance further hinders the popularization of RWA. For traditional financial institutions (TradFi), RWA needs absolute regulatory certainty and security. For crypto-native investors, RWA products led by licensed institutions with strict KYC on permissioned chains are regarded as a departure from the spirit of decentralization. This split in identity recognition may lead to the drift of pricing power. If the main liquidity of RWA comes from the overseas crypto market, its price will be affected by speculative sentiment and macro liquidity shocks in that market, interfering with the independence and stability of the local asset valuation system.

04 / Trust Breakthrough in RWA Public Chain Practices

The core challenge of RWA on-chain tokenization lies in finding a sustainable balance between the traditional financial demand for stability and control and the decentralized technical logic of public chains. In other words, the path to breaking through RWA is essentially a fusion breakthrough of institutional trust and algorithmic trust. It is not a single-dimensional technical assault but a systematic solution covering regulatory adaptation, architectural innovation, and asset strategies. Such a solution must not only ensure clear ownership and regulatory access in the legal sense but also maximize the liquidity and efficiency advantages brought by public chains.

The essence of RWA is the "digital mapping of real-world assets," and its value foundation still lies in off-chain legal rights and regulatory frameworks. Therefore, if any RWA project cannot effectively connect the regulatory system with on-chain mechanisms, its on-chain tokens, even with perfect technical implementation, will only be "rootless symbols."

Therefore, the first breakthrough point for RWA public chain development lies in how to embed compliance in decentralized systems and build a verifiable, traceable, and regulable on-chain trust bridge.

4.1 Embedded Compliance

Trust in traditional finance comes from regulatory authorities, custodian banks, and legal contracts, while the goal of RWA is to "codify" this trust. In practice, mainstream RWA projects generally adopt whitelist mechanisms—setting identity access conditions at the smart contract level, so that only qualified investors who have passed off-chain KYC/AML (Know Your Customer/Anti-Money Laundering) reviews can be granted on-chain permissions to hold and trade tokens. For example, security tokens issued by Securitize are developed based on the ERC-1400 standard, which allows embedding transfer restrictions at the contract level to ensure that tokens can only flow between wallet addresses that meet regulatory requirements. This mechanism realizes the automated migration of the traditional financial "qualified investor system" to the chain.

At the same time, the establishment of legal bridges is key to ensuring RWA compliance. Usually, project parties map the ownership or income rights of underlying assets (such as bonds, real estate, or fund shares) to on-chain tokens through SPVs or trust structures. Token holders have economic rights in SPVs rather than direct property rights to underlying assets. This structure effectively separates the legal risks of assets from on-chain transaction risks, enabling tokenized assets to meet legal requirements while having on-chain liquidity.

Compliance innovation does not mean strict tightening but the intelligent evolution of the regulatory model itself. The "regulatory sandbox" mechanism has become the core strategy for global financial regulators to promote RWA implementation. The Monetary Authority of Singapore's (MAS) "Project Guardian" and the Hong Kong Monetary Authority's "Ensemble" program both allow institutions to issue and test tokenized financial instruments in a controlled environment. This mechanism enables innovators to explore new models without violating existing laws, while providing regulators with real-time observation and intervention interfaces.

Accompanying this is the rise of the "functional regulation" concept. Regulators are gradually shifting from "assessing risk based on form" to "assessing risk based on function"—that is, no longer using token form as the sole standard but focusing on whether its economic function constitutes a security, fund, or derivative. The U.S. Securities and Exchange Commission (SEC)'s principle of "substance

over form" proposed in the Howey Test reflects this thinking. This shift allows RWA to find an adaptive space within the existing legal framework, avoiding falling into regulatory vacuums due to formal differences.

4.2 Multi-Layered System and Cross-Chain Interconnection

The second breakthrough direction of RWA comes from the evolution of technical architecture. The tokenization of real-world assets not only needs to meet the performance requirements of high throughput and low latency but also address the complex circulation issues across jurisdictions and systems. Therefore, public chains need to transform from a single ledger to a multi-layered, cross-chain structural system.

The development of Layer 2 provides a technical foundation for this transformation. For assets that require high-frequency settlement and regular income distribution, such as government bonds, bills, and funds, Layer 2 solutions can undertake a large number of high-frequency tasks, while Layer 1 is responsible for final rights confirmation and auditing. Taking StarkNet as an example, its Rollup architecture based on zero-knowledge proofs can maintain high performance while achieving result verifiability on Layer 1. This means that RWA assets can operate in a division of labor between different layers: income calculation and transaction matching are completed on Layer 2, while regulatory auditing and asset registration are conducted on Layer 1, ensuring both security and flow efficiency.

Cross-chain interoperability is another key condition for the global circulation of RWA. Differences in virtual machines, consensus mechanisms, and data formats between different public chains make it difficult for assets to flow between chains. The emergence of protocols such as Chainlink's CCIP, Cosmos's IBC, and LayerZero provides underlying communication capabilities for the free transfer of assets between multiple chains. For example, a tokenized U.S. Treasury bond can be registered on Ethereum, settled on Avalanche, and participate in liquidity pools on Solana. All states are kept consistent through cross-chain protocols. This "multi-chain mutual recognition" architecture enables on-chain finance to truly achieve the possibility of global distributed settlement.

Currently, mainstream projects are gradually adopting high-performance public chains or Layer 2 scaling solutions to achieve efficient transaction operations. L2 solutions such as Polygon and Arbitrum significantly improve throughput and reduce Gas costs by moving most transaction calculations to off-chain batch processing before uploading results to the chain. For example, some RWA protocols on Arbitrum have achieved transaction efficiency close to that of traditional securities trading systems, while transaction settlement still remains within the security framework of the Ethereum mainnet.

In terms of high-performance chains, Solana has become the preferred platform for some institutional RWA projects due to its ultra-high TPS (approximately 65,000 transactions per second) and extremely low fees. China Merchants International and some fund management institutions in Hong Kong have deployed money market funds (MMFs) on Solana, realizing high-frequency settlement of on-chain fund products.

However, there is still a fundamental trade-off between performance and decentralization. High-performance chains often rely on fewer validation nodes, meaning sacrifices in security and censorship resistance. This needs to be balanced through institutionalized auditing and technical hybrid architectures.

For markets with strict regulatory requirements and sensitive asset ownership (especially Mainland China), the realistic path of RWA tends to be a "hybrid chain" model—placing asset rights confirmation and compliance management on consortium chains, then connecting to the public chain

ecosystem through cross-chain bridges. This "dual-chain architecture" can not only ensure the controllability of local regulation but also release global capital liquidity.

Taking the exploration of Ant Group and Guotai Junan International as an example, they adopt a "two-chain-one-bridge" architecture. Asset rights confirmation, registration, and compliance processes are completed on AntChain, while interaction with international investors and liquidity acquisition are achieved through bridging to the Ethereum ecosystem. This model balances three goals: data sovereignty, regulatory access rights, and global liquidity, making it a realistic compromise for institutional-grade RWA.

In Europe, a similar concept is reflected in permissioned distributed ledger systems such as Euroclear DLT and SG-Forge. These systems are operated by regulated financial institutions, allowing real-time regulatory access to transaction data, while connecting to open public chains through cross-chain interfaces, forming a two-layer trust system of "regulatory visibility—flow accessibility."

4.3 Liquidity Flywheel

Technology and regulation are only the support systems of RWA. What truly determines market scale and sustainability is the asset and liquidity selection strategy. To form a stable ecosystem, RWA must start with the most standardized, easiest-to-value, and most regulatory-recognized asset classes, and gradually build an institutional-grade liquidity flywheel.

4.3.1 Standardized, Low-Risk Assets as the Ecological Starting Point

The initial development of RWA prioritizes asset classes with high standardization, controllable risks, and clear valuation. Such assets have transparent cash flow structures, high credit ratings, and strong regulatory recognition, enabling the establishment of market trust and valuation consensus in the early stage.

Current mainstream practices mainly focus on government bonds, money market funds (MMFs), and high-quality credit assets. Government bond RWA tokens, such as BlackRock's BUIDL Fund and Ondo Finance's OUSG product, rely on U.S. Treasury bond returns, not only providing a "risk-free rate benchmark" for the DeFi ecosystem but also becoming the core underlying assets for stablecoin reserves and DAO treasuries. The on-chain tokenization of such assets not only brings transparent profit distribution and programmable financial contract structures but also promotes the institutionalization of the on-chain fixed-income market.

At the same time, private credit has gradually become a high-yield growth pole in the RWA ecosystem. Protocols such as Centrifuge and Maple directly match SME loans with institutional investors through on-chain matching mechanisms, realizing the tokenized circulation of assets with a yield range of 8%–18%. This model effectively broadens the capital supply channel, re-integrating the previously illiquid SME financing market into the on-chain financial system. More importantly, on-chain credit protocols achieve real-time auditing, risk measurement, and automated profit distribution through smart contracts, fundamentally improving transparency and capital utilization efficiency, and laying the foundation for the formation of an "on-chain credit market."

This bottom-up asset evolution path allows RWA to gradually transition from "low-risk anchoring" to "high-yield innovation," establishing a multi-layered market structure between liquidity and profitability.

4.3.2 Institution-Led and Capital Flywheel

The large-scale growth of the RWA ecosystem is inseparable from the in-depth participation of traditional financial institutions. The entry of global leading institutions such as BlackRock, Franklin

Templeton, and J.P. Morgan marks that RWA has officially transformed from an edge experiment in the crypto world to an infrastructure innovation in the financial system. Institutional participation not only brings credit endorsement and brand trust but also promotes the unification and upgrading of infrastructure standards such as compliance, custody, clearing, and valuation.

With the injection of institutional capital, RWA tokens have gradually become important underlying collateral assets for DeFi protocols, participating in lending, derivative pricing, and stablecoin issuance. This structure forms a self-reinforcing capital efficiency cycle:

Tokenized assets → Collateralized lending → Capital reuse → Enhanced liquidity → Attraction of more institutional assets

In this process, on-chain assets have gradually evolved from simple passive holding tools to "composable assets" in financial networks—capable of acting as income generators and circulating and reusing between different protocols, forming a systematic capital multiplier effect.

This mechanism not only improves the efficiency of asset use but also reshapes the risk pricing and return structure of the financial market.

The continuous entry of institutional capital has enabled the RWA ecosystem to form a closed-loop system driven by both institutional trust (compliance regulation, custody security) and algorithmic trust (smart contracts, verifiable transparency).

05 / The Financial Future of "Dual-Track Trust"

From government bonds to real estate, the on-chain tokenization process of RWA is becoming the core engine of the global financial digital transformation. In the foreseeable future, the evolution of RWA will shift from the superficial action of "asset on-chain" to the in-depth transformation of "value restructuring." The on-chain tokenization process transforms assets from static ownership certificates into dynamic value units, which not only have the function of rights confirmation but also can realize profit distribution, collateralized refinancing, and even cross-border circulation through smart contracts. This capability makes RWA the core carrier for the reconstruction of financial production relations.

The future financial market will no longer be a binary opposition between "on-chain" and "off-chain," but a hybrid structure of multi-layered nesting and dynamic collaboration. Assets are generated and confirmed on permissioned chains, distributed and circulated on public chains, and achieve atomic settlement of value transfer through cross-chain bridges. Cross-border capital flow will no longer be solely constrained by geopolitical financial power but may achieve mutual trust within a broader, technology-neutral rule system. This restructuring is not limited to the financial level but will also profoundly affect the operation of the real economy. Areas that traditionally struggle to access the capital market, such as small and medium-sized enterprises, green energy projects, creative industries, and scientific research innovation, will have the opportunity to achieve financing and risk diversification through tokenization. The future capital market will no longer be an exclusive arena for a few large financial institutions but an open, networked, algorithm-driven financial ecosystem. The logic of value creation will also change accordingly—capital will no longer passively pursue returns but actively participate in the value capture of productive activities.

In the long run, the development of RWA will ultimately drive finance from "value transfer" to "value creation." Assets will no longer be just symbols of stock wealth but part of a network of productive factors. Financial activities will no longer be just the flow of capital but an extension of the value creation process. The safe returns of government bonds, stable rents of real estate, derivative values of data, and tradability of carbon assets will all be re-priced and organized under the same logic.

When government bonds, real estate, and other assets can be expressed and exchanged in the same digital grammar, the meaning of finance will no longer be just the flow of funds but a reconstruction of social production relations. This is the most profound significance of RWA—it is not a technological revolution but an institutional innovation at the civilizational level.

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Contributors

Authors: Huijie Tang (𝕏 @web3sensen)

Reviewers: Colin Su, Grace Gui, NingNing, Owen Chen

Design: Alita Li

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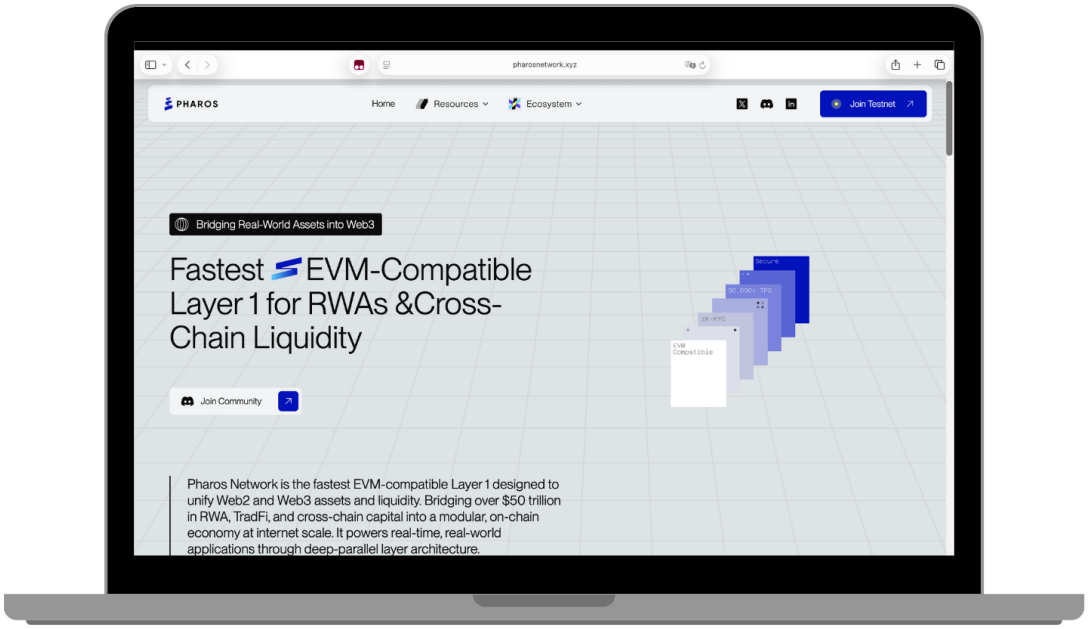

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From RWA to On-Chain Finance.
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