

Multi-Level Perspectives on U.S.-Korea Strategic Integration in Naval Shipbuilding under the Ensuring Naval Readiness Act

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[Abstract]

This study analyzes the structural reconfiguration of the U.S. naval shipbuilding industrial base through the Multi-Level Perspective (MLP) and Strategic Inflection Point (SIP) frameworks. The U.S. naval shipbuilding industrial base faces a systemic transition crisis: chronic production delays of 24–36 months in Virginia-class and Columbia-class programs, a 26-fold cost disadvantage versus overseas commercial yards, and a workforce hollowed out from over 400 shipyards in the 1980s to merely 21 today. Under the Jones Act of 1920, a century of absolute protectionism created a deep ‘lock-in’ that insulated the regime from competitive innovation. At the landscape level, China’s shipbuilding capacity—estimated at over 200 times that of the U.S.—and its operation of 234 major warships versus the U.S. Navy’s 219 constitute an existential geopolitical pressure. This study identifies the Ensuring Naval Readiness Act as a Strategic Inflection Point that transitions the U.S. from autarkic protectionism to an alliance-integrated maritime security model. The key findings are as follows: First, integrating South Korea’s echo shipyard technologies and digital Maintenance, Repair, and Overhaul (MRO) capabilities can mitigate projected 12% dynamic productivity losses from geopolitical decoupling. Second, a comparative analysis of South Korea, Japan, and China reveals that East Asian state-led shipbuilding models—adapted into a ‘U.S.-type federated model’—offer the most viable pathway for regime reconfiguration, with South Korea providing the highest structural transferability. Third, four principal obstacles to Industry 4.0 adoption are identified—high initial capital expenditure (CAPEX), data interoperability barriers, cybersecurity vulnerabilities, and workforce transition friction—along with targeted mitigation strategies including a phased GX(Green Transformation), AX(AI Transformation) Technology Readiness Level (TRL) investment approach, open-standard API mandates, CMMC Level 3 compliance, and a Reskilling-First implementation protocol. The study concludes that the U.S. must shift from a closed domestic regime to a strategic node in a global security ecosystem in order to preserve its maritime dominance.

▶ **Key words:** Ensuring Naval Readiness Act (ENRA), Multi-Level Perspective (MLP), Strategic Inflection Point (SIP), Naval Shipbuilding Industrial Base, Geopolitical Decoupling

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[요 약]

본 연구는 다층적 관점(MLP: Multi-Level Perspective)과 전략적 변곡점(SIP: Strategic Inflection Point) 이론을 활용하여 미국 해군 조선 산업 기반의 구조적 재편 과정을 분석한다. 미국 해군 조선 산업 기반은 버지니아급·콜롬비아급 프로그램의 24~36개월 납기 지연, 해외 상업 조선소 대비 26배의 비용 열위, 1980년대 400개 이상에서 현재 21개로 축소된 조선소 수 등 심각한 구조적 전환 위기에 직면해 있다. 1920년 존스법(Jones Act) 하의 100년에 걸친 절대적 보호주의는 경쟁적 혁신으로부터 레짐을 고립시키는 깊은 '고착화(lock-in)' 효과를 초래하였다. 거시 환경(Landscape) 차원에서 미국의 약 200배에 달하는 중국의 조선 건조 능력과 중국 해군의 주요 함정 234척(미 해군 219척) 보유는 실존적 지정학적 압력으로 작용하고 있다. 본 연구는 2025년 발의된 '해군 준비태세 보장법'을 자급주의적 보호주의에서 동맹 통합형 해양 안보 체제로의 전환을 촉발하는 전략적 변곡점으로 규정한다. 주요 연구 결과는 다음과 같다. 첫째, 한국의 친환경·디지털 조선소 기술과 디지털 유지·보수·정비(MRO) 역량의 통합은 지정학적 디커플링에 따른 12%의 역동적 생산성 손실을 완화할 수 있다. 둘째, 한국·일본·중국의 비교 분석 결과, 동아시아의 국가 주도형 선박 건조 모델을 '미국형 연방 선박건조 모델(U.S.-type federated model)'로 변형 적용하는 방안이 레짐 재편의 가장 실현 가능한 경로이며, 한국이 가장 높은 구조적 이전 가능성을 보유한다. 셋째, Industry 4.0 도입의 네 가지 핵심 장애요인—높은 초기 자본 지출(CAPEX), 데이터 상호운용성 장벽, 사이버보안 취약점, 인력 전환 마찰—을 식별하고, GX & AX 연계기반의 기술준비수준(TRL) 단계별 투자 전략, 개방형 API 표준 의무화, CMMC Level 3 준수, 재교육 우선(Reskilling-First) 구현 프로토콜 등 구체적인 위험 관리 전략을 제시한다. 결론적으로, 미국은 해양 패권을 유지하기 위해 폐쇄적 국내 레짐에서 벗어나 글로벌 안보 생태계의 핵심 전략 노드로 전환해야 한다.

▶ **주제어:** 해군 준비태세 보장법(ENRA), 다층적 관점(MLP), 전략적 변곡점(SIP), 해군 조선 산업 기반, 지정학적 디커플링

I. Introduction

The U.S. Navy is currently facing an unprecedented 'readiness crisis' that threatens its historical maritime dominance and national security objectives [1]. As of January 2025, the U.S. fleet maintains approximately 296 battle force ships, a figure that falls significantly short of the 355 to 381 ships required by modern defense strategy architectures. This numerical shortfall is severely compounded by a chronic 'hollowing out' of the U.S. industrial base. In 1980, manufacturing accounted for roughly 20% of U.S. GDP; by 2024, it had plummeted to under 10%.

The crisis is highly visible in chronic production delays. A comprehensive 45-day Navy shipbuilding review conducted in early 2024 revealed that the Columbia-class ballistic missile submarine program

faces delays of 12 to 16 months, the Virginia-class attack submarines face 24 to 36 months of delay, and the Constellation-class frigate faces a 36-month setback. Concurrently, China has consolidated its position as the world's preeminent shipbuilder, commanding nearly 70% of global commercial orders [2]. China currently operates 234 major warships compared to the U.S. Navy's 219, with projections showing China reaching 425 battle force ships by 2030 while the U.S. struggles to maintain 294 [1, 2].

The purpose of this study is to apply the 'Socio-Technical System Transition' framework to diagnose the structural destabilization of the U.S. naval shipbuilding industrial base. By utilizing the Multi-Level Perspective (MLP) and Strategic

Inflection Point (SIP) theories, the paper explores how landscape-level pressures create 'windows of opportunity' for niche breakthroughs—specifically, the integration of allied shipbuilding capacities via the Ensuring Naval Readiness Act (ENRA). Critically, this study extends prior analyses by: (1) conducting a refined comparative analysis of East Asian shipbuilding models and their transferability to the U.S. context; and (2) systematically examining the barriers and risk management strategies associated with Industry 4.0 adoption in U.S. naval shipyards.

The paper is structured as follows: Section II reviews previous studies. Section III details the MLP research framework. Section IV presents empirical findings on regime destabilization, landscape pressures, strategic niches, a comparative global analysis, and Industry 4.0 barriers. Finally, Section V summarizes findings and discusses academic and practical significance.

II. Previous Studies

The transition crisis in U.S. naval shipbuilding industrial base requires a multidisciplinary approach combining socio-technical transition studies, international relations, macroeconomics, and risk management. The following table summarizes key findings from seminal literature and their implications for this study.

Table 1. Summary of Key Literature and Implications

Author (Year)	Key Theory / Concept	Core Findings & Implications for this Study
Geels (2002) [3]	Multi-Level Perspective (MLP)	Transitions occur through complex interplay of Landscape, Regime, and Niche levels. Explains 'lock-in' mechanisms and how external shocks create windows of opportunity. Forms the foundational framework for analyzing U.S. Navy systemic inertia.
Geels (2011) [4]	MLP – Process Theory	Defends MLP as a 'process theory' tracing event sequences across levels, explaining why highly locked-in regimes resist internal reform. Essential for justifying the descriptive methodology.

Joo & Lee (2013) [5]	SIP & Catch-up Innovation	Illustrates how technology followers use Strategic Inflection Points for 'Path-Creating' catch-up – applied to allied nations entering the U.S. defense supply chain.
Góes & Bekkers (2023) [6]	Geopolitical Decoupling	Multi-sector GE model shows East/West decoupling produces dynamic productivity losses up to 12%. Highlights strategic necessity for South Korea to remain within the Western innovation hub.
Hötte (2020) [7]	Transition Economics	ABM demonstrates how policy interventions stabilize transition pathways – relevant for understanding U.S. regime reconfiguration through allied integration.

While previous studies utilizing MLP have predominantly focused on commercial, historical, or sustainability transitions [3, 4], this research applies the framework specifically to a 'Military-Maritime Security Regime.' This study also defines ENRA not merely as a minor legislative adjustment, but as a formal catalyst for regime reconfiguration, bridging international relations theory with innovation studies.

III. Research Framework

This study employs the Multi-Level Perspective (MLP) as its core methodological approach. MLP is a middle-range theory that conceptualizes systemic transitions as non-linear, co-evolutionary processes resulting from the interplay of developments across three analytical levels [4]. The three levels are defined in the context of this study as follows:

Landscape (Macro) is slow-moving, exogenous external factors. In this study: bipolar geopolitical decoupling, global supply chain fragility, and the global push toward decarbonization.

Regime (Meso): The 'deep structure' of rules, engineering practices, actors, and infrastructures. This encompasses the U.S. Navy's procurement habits, the century-old protectionist Jones Act, and the physical limitations of existing U.S. shipyards.

Niche (Micro): Protected experimental spaces where radical innovations are nurtured. This

includes advanced robotic welding, AI-driven Condition-Based Maintenance (CBM+), and foreign direct investment in allied shipyards.

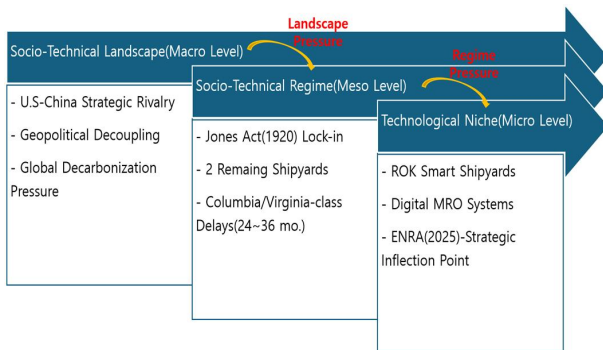


Fig. 1. Three Key Layers of MLP analysis

The MLP methodology is uniquely suited for this research because it directly addresses 'Inertia' and 'Lock-in.' As [9] and [4] argue, rigorous mathematical models often fail to capture multi-dimensional co-evolutionary dynamics of large-scale industry transitions. Furthermore, integrating Failure Mode, Effects, and Criticality Analysis (FMECA) provides a rigorous micro-level tool to assess technical, economic, and regulatory risks associated with integrating niche technologies into the existing U.S. military framework [8].

IV. Research Findings and Discussion

4.1 Regime Destabilization: Internal Structural Failures

The U.S. naval shipbuilding industrial base is experiencing a profound 'Transition Crisis' driven by internal structural failures. Decades of absolute protectionism under the Jones Act of 1920 and the Burns-Tollefson Amendment of 1968 fostered a closed-loop system isolated from global competitive pressures. This deep structural 'lock-in' has resulted in an extreme cost disparity: U.S.-produced ships are now estimated to be 26 times more expensive than comparable vessels built in overseas commercial markets [10]. A recent Congressional Budget Office (CBO) report estimates

that executing the Navy's FY2025 30-year shipbuilding plan would cost an average of \$35.8 billion per year for new-ship construction alone—46 percent higher than the average appropriations over the past five years [1]. Total annual costs including nuclear refueling and outfitting balloon to \$40.1 billion.

Beyond financial costs, the regime is failing operationally. The 45-day review ordered by the Secretary of the Navy in early 2024 revealed: the Columbia-class SSBN delayed 12-16 months; Virginia-class Block IV/V SSNs delayed 24-36 months; CVN-80 carrier delayed 18-26 months; and the Constellation-class frigate delayed 36 months. These delays are fundamentally tied to severe workforce shortages — the industry has shrunk from over 400 shipyards in the 1980s to merely 21 today.

4.2 Landscape Pressure: China's Naval Expansion and Geopolitical Decoupling

China has successfully executed a 'civil-military fusion' strategy, commanding 69.2% of global shipbuilding orders [2]. Leaked U.S. Navy intelligence slides in 2023 warned that China's shipbuilding capacity is over 200 times greater than that of the United States [1, 2]. China currently operates 234 major warships compared to the U.S. Navy's 219, with projections showing China reaching 425 battle force ships by 2030 while the U.S. struggles to maintain 294 [1, 2]. [6] demonstrate through a multi-sector general equilibrium model that geopolitical 'decoupling' into Western and Eastern blocs would result in dynamic productivity losses up to 12%. This landscape pressure underscores that the U.S. cannot restore its maritime dominance in isolation.

4.3 Strategic Inflection Point: ENRA and Regime Reconfiguration

The re-introduction of the Ensuring Naval Readiness Act (ENRA, S.406) in 2025 represents a classic Strategic Inflection Point (SIP) [5]. ENRA

explicitly acknowledges the failure of absolute autarky by amending 10 U.S. Code §8679 to allow U.S. naval vessels to be constructed and maintained in shipyards located in NATO or Indo-Pacific allied nations, provided it is more economical and free from Chinese ownership. Complementary legislation – the SHIPS for America Act and the Maritime Security Trust Fund – further institutionalizes this transition by providing stable financial incentives for allied integration and shipyard modernization [2].

4.4 Comparative Global Analysis: East Asian State-Led Models and the U.S.-Type Federated Adaptation

A critical weakness in prior assessments of allied integration has been the superficial enumeration of competitor nation models without examining their structural transferability to the U.S. political-economic context. This section conducts a refined three-country comparative analysis – South Korea, Japan, and China – and proposes a concrete 'U.S.-type federated model' derived from these comparisons.

South Korea presents the highest transferability for three structural reasons. First, its chaebol-led shipbuilding ecosystem – anchored by HD Hyundai, Samsung Heavy Industries, and Hanwha Ocean – provides the vertical integration capacity necessary to rapidly absorb and execute large-scale naval contracts. Second, South Korea's demonstrated willingness to localize operations within U.S. regulatory frameworks is evidenced by Hanwha's acquisition of Philly Shipyard and subsequent qualification under U.S. Navy MRO procurement. Third, South Korea's advanced digital infrastructure – including AI-driven condition-based maintenance (CBM+), digital twin platforms, and robotic laser welding systems – directly addresses the three primary failure modes identified in U.S. shipyard productivity: labor shortages, throughput inefficiency, and quality inconsistency.

Japan represents a medium-transferability partner. Its keiretsu model and the Acquisition, Technology & Logistics Agency (ATLA) governance structure create institutional compatibility with U.S. defense procurement frameworks. Japan's strength lies in precision manufacturing culture and modular construction methodologies that could complement South Korea's scale advantages. However, Japan's shipbuilding industrial base is predominantly oriented toward domestic defense requirements, limiting the surplus capacity available for U.S. program integration. A viable pathway involves Japan specializing in high-precision subsystems – propulsion, sensors, and stealth coatings – within a multilateral division of labor.

China's model, while representing the most efficient state-directed shipbuilding structure globally, is categorically excluded from U.S. partnership considerations due to its adversarial geopolitical alignment and the ENRA's explicit restriction against Chinese-owned facilities. Ironically, China's model provides the clearest articulation of what the U.S. seeks to replicate: a seamless civil-military industrial fusion where commercial shipbuilding capacity directly supports naval expansion. This observation underscores the structural imperative for the U.S. to cultivate equivalent capacity within its allied network.

The proposed 'U.S.-Type Federated Model' adapts East Asian state-led efficiency within the constraints of the U.S. free-market system, strong labor organizations, and ITAR/FMS regulatory requirements. In this model, South Korean and Japanese yards serve as Tier-1 module fabricators for hull sections, propulsion systems, and digital infrastructure, while U.S. shipyards – supported by the Maritime Security Trust Fund – focus on final assembly, weapons systems integration, and classified subsystems. This division preserves U.S. sovereign control over sensitive technologies while leveraging allied efficiency for non-classified construction phases. The federated architecture

also creates a competitive incentive structure that historically has been absent from the single-vendor monopoly dynamics of current U.S. naval procurement.

4.5 Industry 4.0 Adoption Barriers and Risk Management in U.S. Naval Shipyards

The integration of Industry 4.0 technologies – defined in this study as the convergence of digital twin platforms, artificial intelligence-driven maintenance systems (CBM+), three-dimensional laser scanning (3DLS), additive manufacturing (AM), and robotic process automation – into U.S. naval shipyards offers substantial productivity gains. However, the pathway to adoption is obstructed by four principal categories of barriers that must be systematically addressed through evidence-based risk management strategies.

① High Initial Capital Expenditure (CAPEX): The most immediate barrier to Industry 4.0 adoption is the prohibitive upfront investment required. Retrofitting a single major U.S. naval shipyard with full digital twin infrastructure, automated welding systems, and AI-driven task management platforms is estimated to require capital investments in the range of \$500 million to \$2 billion, depending on facility scale and existing infrastructure maturity. For the 21 remaining U.S. naval shipyards, the aggregate investment requirement poses a systemic financing challenge that cannot be resolved through existing appropriations cycles. The recommended mitigation strategy is a phased 'Technology Readiness Level (TRL) escalation' approach driven by GX(Green Transformation), AX(AI Transformation): initial investments should prioritize high-ROI, low-disruption technologies such as AI-driven scheduling software and GX quality control systems (TRL 7-9 range), before committing to capital-intensive physical infrastructure such as full robotic welding lines for liquid hydrogen and ammonia engine assembly and containment system (CCS) fabrication technologies. The Maritime Security Trust Fund, authorized

under the SHIPS for America Act, should establish a dedicated Industrial Modernization Grant program providing matching funds of up to 50% for qualifying shipyard technology investments, contingent on demonstrated productivity benchmarks.

② Data Interoperability and System Integration Barriers: U.S. naval shipyards currently operate a fragmented ecosystem of legacy Enterprise Resource Planning (ERP) systems, Computer-Aided Design (CAD) platforms, and proprietary vendor software that lack standardized Application Programming Interfaces (APIs). This fragmentation prevents the seamless data flow required for effective digital twin operation, in which real-time sensor data from physical assets must continuously update virtual models to enable predictive maintenance. The mitigation framework requires the adoption of open-standard data exchange protocols – specifically, the Ship Structure Committee's vessel data interchange standards and DoD's Digital Engineering Strategy mandates – as preconditions for any new shipyard modernization grants. Allied technology partners, particularly South Korean firms operating under joint development agreements, must comply with these interoperability standards as contractual requirements, ensuring that technology transfer enhances rather than deepens systemic fragmentation.

③ Cybersecurity Vulnerabilities in Networked Shipyard Environments: The increased network connectivity inherent in Industry 4.0 architectures fundamentally expands the cybersecurity attack surface of naval industrial facilities. The integration of Operational Technology (OT) networks – controlling physical processes such as automated welding and crane operations – with Information Technology (IT) networks creates hybrid vulnerabilities that traditional cybersecurity frameworks are ill-equipped to address. State-sponsored cyber actors, particularly those affiliated with China's People's Liberation Army

Strategic Support Force (PLASSF), have demonstrated persistent interest in penetrating U.S. defense industrial base networks. The recommended mitigation approach requires mandatory compliance with NIST SP 800-82 (Industrial Control Systems Security) and CMMC (Cybersecurity Maturity Model Certification) Level 3 requirements for all shipyard systems handling Controlled Unclassified Information (CUI). For allied shipyard partners operating under ENRA frameworks, a tiered cybersecurity assessment protocol – modeled on the existing AUKUS Pillar II information assurance framework – should be established before any classified design data is shared through federated production networks.

④ Workforce Transition and Human Capital Friction: Perhaps the most structurally persistent barrier is the human dimension of Industry 4.0 adoption. The existing U.S. naval shipyard workforce – characterized by aging demographics, high attrition rates, and skill sets oriented toward manual fabrication rather than digital system operation – faces significant displacement risk from automation-driven productivity improvements. The United Steelworkers (USW) and International Brotherhood of Boilermakers have historically resisted technological changes that reduce direct labor requirements, creating a political economy of inertia that reinforces the existing regime's lock-in. The proposed mitigation strategy involves a 'Reskilling-First' implementation protocol: no automation investment should proceed without a concurrent workforce development commitment, funded at a minimum 15% ratio of the automation CAPEX. Community College-based 'Maritime Technology Institutes,' modeled on Germany's Berufsakademie dual-track vocational system, should be established in proximity to major shipyard clusters (Newport News, Bath, Pascagoula) to provide stackable credentials in digital manufacturing, robotic system operation, and CBM+ data analytics. This approach transforms automation from a workforce displacement threat

into a workforce upgrade opportunity, reducing union resistance and building the human capital base required for sustained Industry 4.0 operations.

4.6 Internal Regime Resistance: Political Barriers and Strategic Mitigation

Beyond the technology adoption barriers detailed above, regime reconfiguration will face three principal sources of institutional resistance. First, labor union opposition from organizations such as the United Steelworkers requires a phased co-production transition – allied yards initially performing only MRO and module fabrication in the U.S., while workforce development programs transfer technology training to domestic workers, mirroring the successful F-35 co-production model. Second, technology leakage risk requires a tiered information-sharing protocol aligned with AUKUS Pillar II standards and FMS security requirements, ensuring classified design data remains with U.S. prime contractors while commercial manufacturing processes are shared with allied yards. Third, the risk of bypassing U.S. small and medium-sized suppliers (SMEs) is addressed through a federated 'Nation as a Shipyard' model – U.S. SMEs supply specialized components while allied yards manage hull and module production – supported by Maritime Security Trust Fund grants contingent on Industry 4.0 compatibility certification. Collectively, GX and AX transformation trajectories constitute more than incremental technological improvements; they represent the socio-technical transition pathways through which the federated shipbuilding model can institutionally embed allied industrial capacity within the U.S. maritime security regime, thereby enabling sustainable niche-to-regime level reconfiguration consistent with the Multi-Level Perspective framework advanced in this study.

V. Conclusions

This study comprehensively analyzed the profound transition crisis facing the U.S. naval shipbuilding industrial base through MLP and SIP frameworks. The research confirms that the U.S. Navy's current trajectory is unsustainable, with costs running 46% above historical appropriations and production delays threatening national security. The Ensuring Naval Readiness Act (ENRA) serves as a vital legislative mechanism for Regime Reconfiguration — transitioning from isolated autarky to an Alliance-Driven Ecosystem.

The expanded comparative analysis confirms that South Korea offers the highest structural transferability for allied integration, with Japan providing a complementary role in precision subsystems. The proposed 'U.S.-Type Federated Model' — adapting East Asian state-led efficiency within U.S. free-market and ITAR constraints — represents the most viable pathway for regime reconfiguration. Critically, the success of this transition is contingent on systematically resolving the four principal Industry 4.0 adoption barriers: CAPEX financing gaps (mitigated through the Maritime Security Trust Fund's Industrial Modernization Grant program), data interoperability fragmentation (addressed through open-standard API mandates), cybersecurity vulnerabilities (resolved through CMMC Level 3 and AUKUS-aligned protocols), and workforce transition friction (addressed through Reskilling-First implementation and Maritime Technology Institutes).

Academic Significance: This research applies the MLP framework to a highly rigid, security-critical military-industrial sector, demonstrating that established defense regimes — despite immense 'lock-in' mechanisms — are subject to socio-technical transition dynamics when landscape pressures are severe enough. The integration of FMECA risk analysis with MLP transition theory provides a novel methodological

bridge between innovation studies and defense industrial policy research.

Practical Significance: For U.S. policymakers, this study provides actionable insights: simply injecting more capital into a broken system will not resolve the readiness crisis. Policymakers must aggressively pursue niche innovations through federated shipbuilding models, allied MRO clusters, and world-standard digital shipyard practices — while proactively managing the political economy of labor transition and cybersecurity risk. For South Korean and Japanese shipbuilding industries, this research highlights a critical strategic pivot: transitioning from commercial merchant shipbuilders to 'Indispensable Security Nodes' deeply integrated into the Western maritime defense bloc, thereby securing long-term high-value growth and mitigating the risks of global economic fragmentation.

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