

Volume 1

CHAPTER 2

Standards, Regulations, and the US Framework

Communications-Based Train Control
A Comprehensive Guide for US Transit Professionals
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Chapter Overview

- Examine IEEE 1474 — the cornerstone US standard for CBTC procurement and system specification
- Explore IEC 62290 — the international functional framework defining ATP/ATO/ATS and Grades of Automation
- Understand safety assurance via IEC 61508 SIL framework and the CENELEC trilogy (EN 50126/50128/50129)
- Navigate FTA oversight: Safety Management Systems, State Safety Oversight, and Capital Investment Grants
- Analyze NTSB's role as the most influential advocate for CBTC adoption through accident investigations
- Compare US, European, and Chinese regulatory models — three philosophies, three outcomes

2.1

IEEE 1474 Standard Family

Standards Framework for CBTC

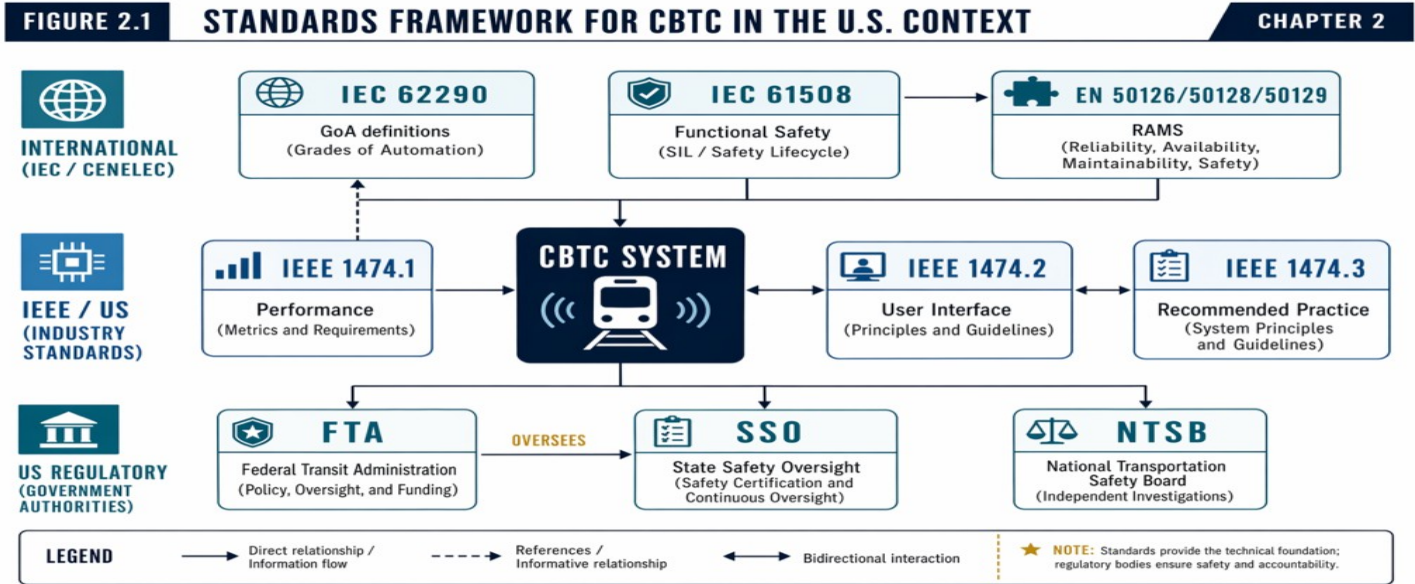


Figure 2.1 — Standards framework for CBTC in the U.S. context.

IEEE 1474.1: Performance & Functional Requirements

- Cornerstone US standard — cited in virtually every transit agency CBTC RFP
- Performance-based, not prescriptive: specifies WHAT a system must accomplish, not HOW
- Key metrics: headway (60–120 sec), safety (SIL 3/4), availability (98.5–99.5%), position accuracy (± 0.5 –1 m)
- Functional requirements: continuous MA communication, onboard autonomy, emergency braking, interoperability
- Does NOT mandate specific communication, localization, or hardware technology — suppliers choose

IEEE 1474 Family: Companion Standards

- IEEE 1474.1: Performance and functional requirements — the baseline for all US CBTC procurement
 - IEEE 1474.2: User interface (DMI) requirements — display layout, terminology, usability testing
 - IEEE 1474.3: Safety assurance — hazard analysis, V&V planning, SIL assignment, documentation
- Procurement practice: agencies cite IEEE 1474.1 as the common baseline specification
 - Risk allocation: compliance is vendor responsibility, verified through third-party V&V
 - Limitations: does not cover cybersecurity in depth, system integration, asset management, or training

2.2

IEC 62290: International CBTC Framework

IEC 62290 Grades of Automation (GoA 0-4)

GoA	Name	Driver Role	Example Systems
GoA 0	On-sight	Manual driving; ATP guidance	Older ATC systems
GoA 1	Non-automated ATP	Manual driving; ATP enforcement	Legacy CBTC retrofits
GoA 2	Semi-automatic (STO)	Auto accel/decel; manual stops	Paris Line 14; Copenhagen
GoA 3	Driverless (DTO)	Fully automated; operator monitors	Dubai Metro; Vancouver SkyTrain
GoA 4	Unattended (UTO)	Fully autonomous; no operator	Copenhagen Cityringen; Lyon D

IEEE 1474 vs. IEC 62290 Comparison

Aspect	IEEE 1474	IEC 62290
Origin	North America (APTA/transit agencies)	International (IEC working groups)
Scope	Performance, availability, headway	Functional architecture, GoA levels
GoA	Minimal discussion	Central — defines GoA 0-4
Safety	Implies SIL 4	Explicit SIL 4 for ATP
US Use	Cited in procurement RFPs	Increasingly cited for GoA

2.3

Safety Standards: IEC 61508 & CENELEC Trilogy

SIL Levels and CBTC Function Mapping

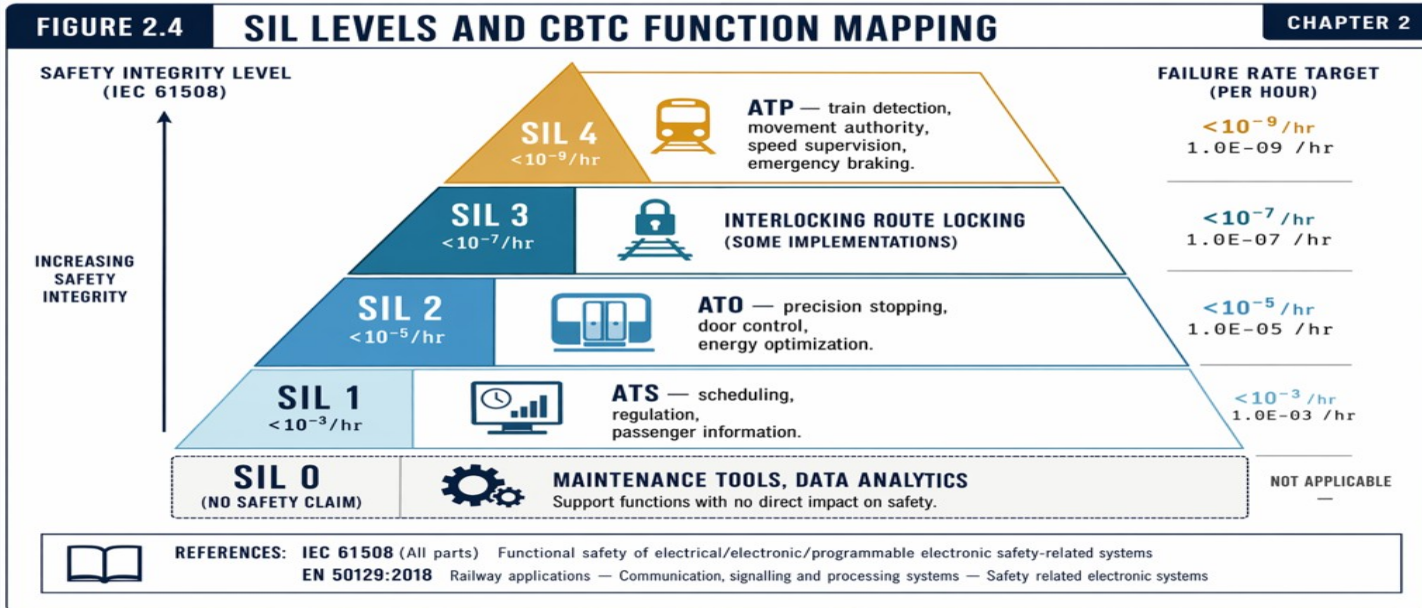


Figure 2.2 — Safety Integrity Levels (SIL 1-4) mapped to CBTC functions.

SIL 4: The Safety Gold Standard

10^{-9}

per hour

Max dangerous failure rate for
ATP (SIL 4)

2.25×

effort

SIL 4 engineering vs. SIL 2 (3,600
vs. 1,600 hrs)

\$2-4M

Typical SIL 4 ATP certification cost

V-Model Lifecycle for Safety-Critical Systems

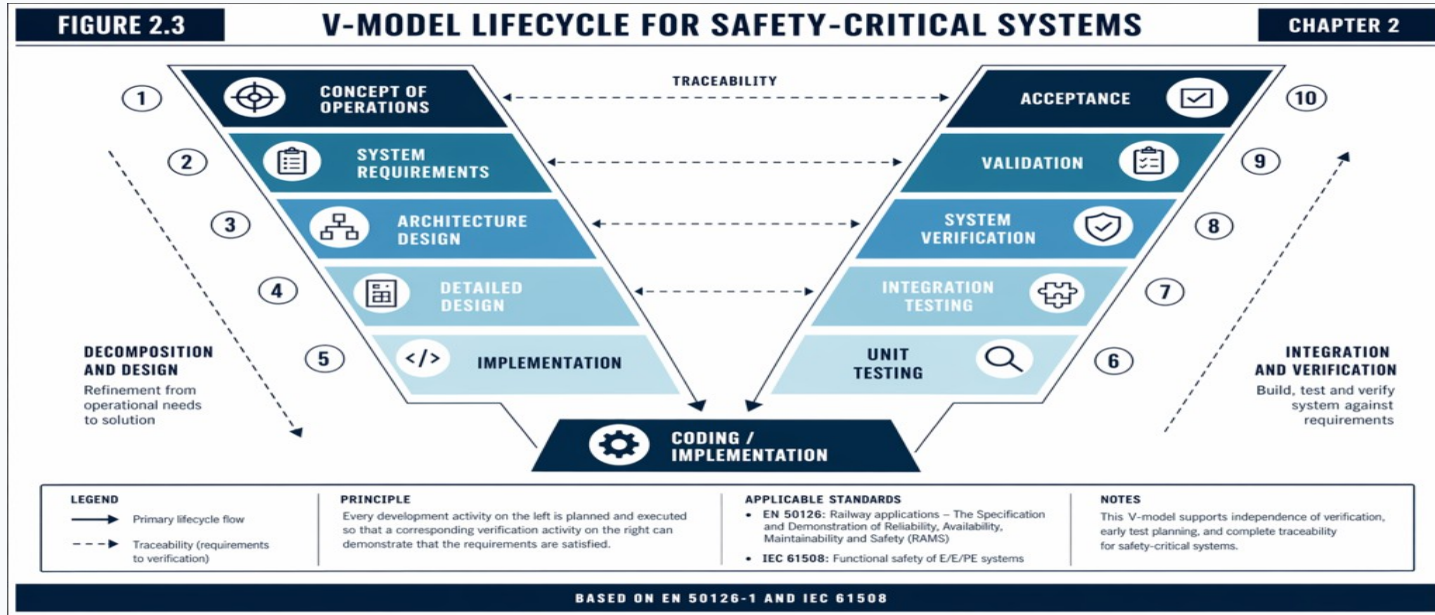


Figure 2.3 — EN 50126 V-Model: each development phase paired with a verification phase.

Safety Governance Workflow

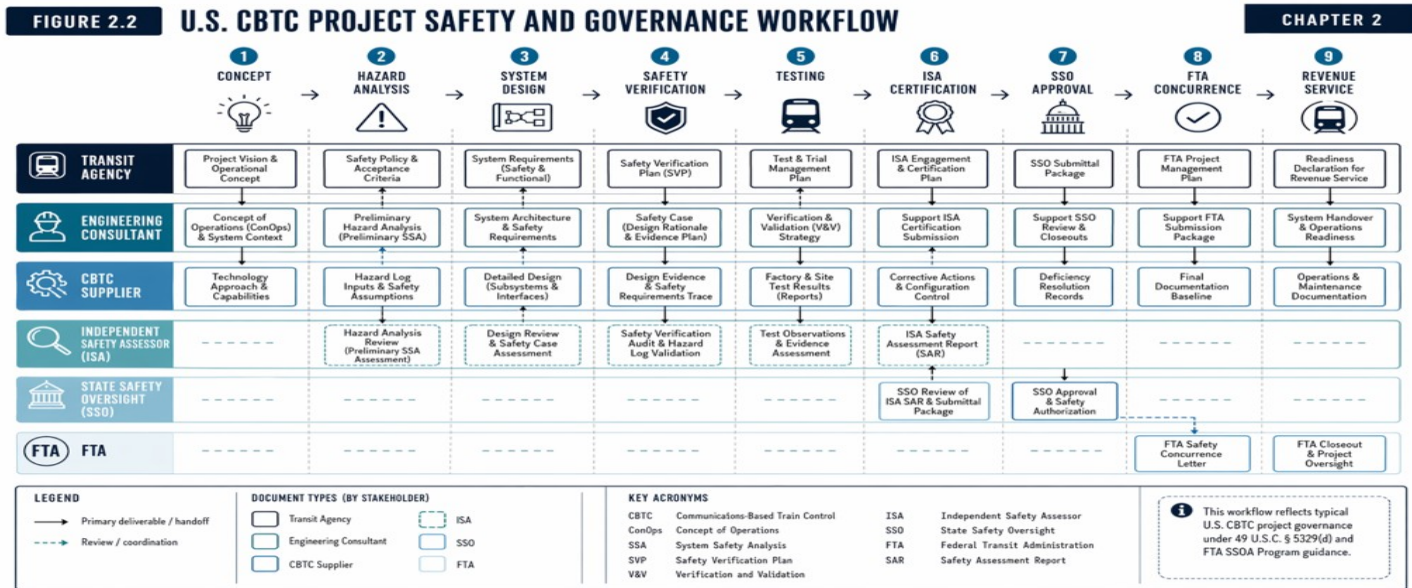


Figure 2.4 — U.S. CBTC project safety and governance workflow.

2.4

FTA Requirements and Federal Oversight

FTA Safety Management Systems (SMS)

- Codified in 49 CFR Part 673 — performance-based safety approach for all FTA-funded transit
- Safety Risk Assessment (SRA) required before CBTC deployment — must address legacy/CBTC transition
- Safety Performance Targets (SPTs): quantified goals for collisions, derailments, fires, injuries
- State Safety Oversight (SSO) programs review and approve CBTC projects at the state level
- SSO approval timelines: 12–24 months — must be budgeted early in project planning

FTA Capital Investment Grant Programs

Program	Cost Threshold	Federal Share	Key Criteria
New Starts	\$250M+	Up to 80%	Cost-effectiveness; ridership
Small Starts	\$75M-\$250M	Up to 80%	Local funding commitment
Core Capacity	No threshold	Up to 80%	Congestion relief
Section 5307	Variable	80%	State DOT approval

2.5

NTSB Safety Recommendations

FTA Approval Pathway for CBTC Projects

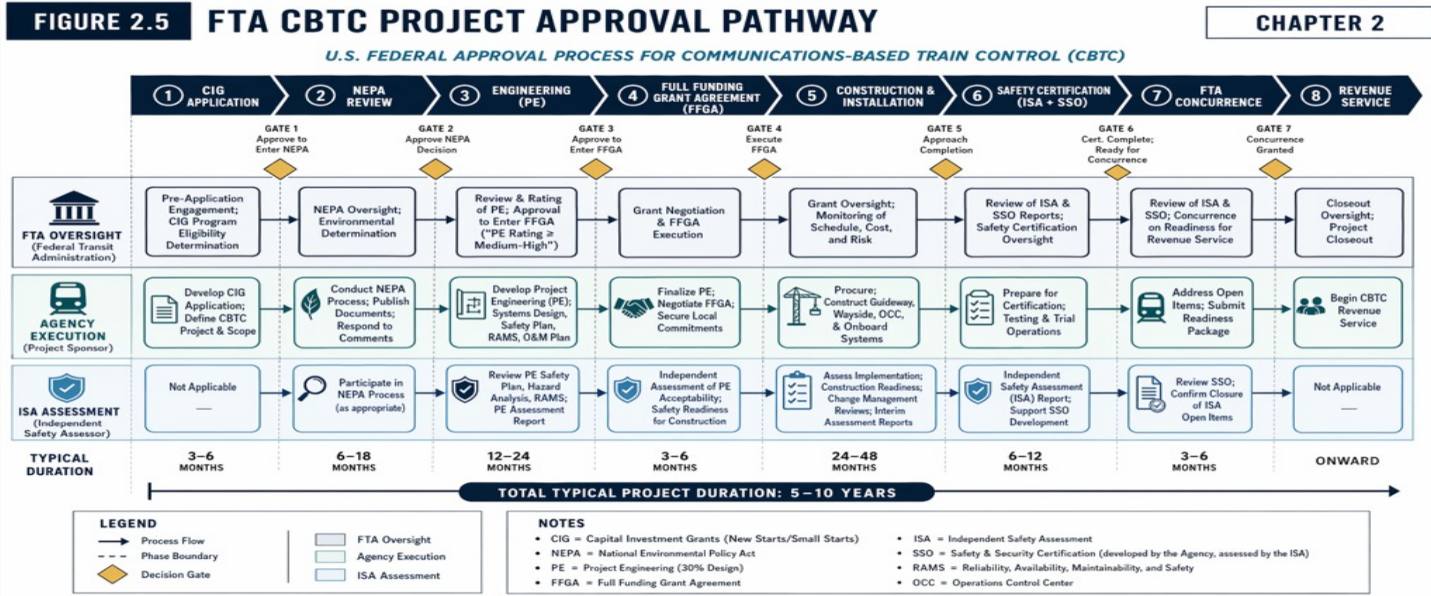


Figure 2.5 — FTA approval pathway from concept through revenue service.

NTSB: The Catalyst for CBTC Adoption

- Independent federal agency — investigates accidents, issues recommendations (no enforcement power)
- "Most Wanted List" highlights top safety priorities — transit train control has been a persistent item
- 2014 CTA O'Hare Blue Line: NTSB explicitly recommended CBTC for all US transit systems (H-15-007)
- 2009 WMATA Fort Totten collision: 9 fatalities — catalyzed Washington Metro modernization
- NTSB findings used by agencies to justify FTA funding, build stakeholder confidence, and manage liability

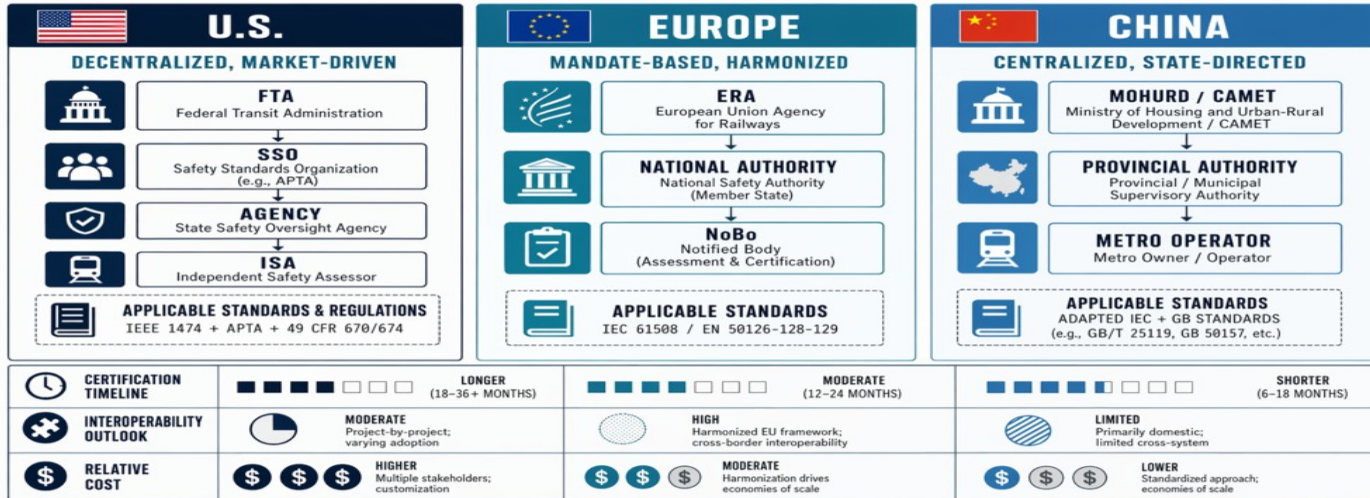
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US vs. Europe vs. China Regulatory Comparison

Regulatory Model Comparison

FIGURE 2.6 U.S. VS. EUROPE VS. CHINA REGULATORY MODEL COMPARISON

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NOTE: Regulatory models influence safety assurance process, certification effort, interoperability potential, and total cost of ownership for CBTC systems.

Figure 2.6 — U.S. (decentralized) vs. Europe (mandate-driven) vs. China (state-directed).

Three Models, Three Philosophies

- US: Decentralized, market-driven — no federal CBTC mandate; IEEE 1474 voluntary; FTA oversight
- Strength: flexibility, innovation, local autonomy
- Weakness: fragmentation, slow adoption (~25% of metros), limited interoperability

- Europe: Top-down mandate — ERA/ETCS for mainline; CENELEC certification required; 24–36 month timelines
- China: State-directed — MOHURD/CAMET standards; rapid deployment (18–24 mo); \$12–20M per 30-km line
- Lesson: US should consider corridor-level standardization and interoperability incentives

Key Takeaways

1. IEEE 1474 is the cornerstone US CBTC standard — performance-based requirements enabling vendor innovation while ensuring safety and interoperability
1. IEC 62290 provides the international lingua franca for functional architecture and GoA classification — increasingly cited alongside IEEE 1474 in US procurement
1. SIL 4 ATP is the global safety baseline, achieved through formal methods, redundancy, and Independent Safety Assessment per CENELEC standards
1. The FTA regulates through SMS and SSO, not technology mandates — funding via Capital Investment Grants creates both opportunity and compliance burden
1. NTSB investigations (CTA O'Hare, WMATA Fort Totten) have been the single most influential catalyst for CBTC adoption in the United States

End of Chapter 2

Next: **Chapter 3: CBTC System Architecture Overview**

Questions & Discussion