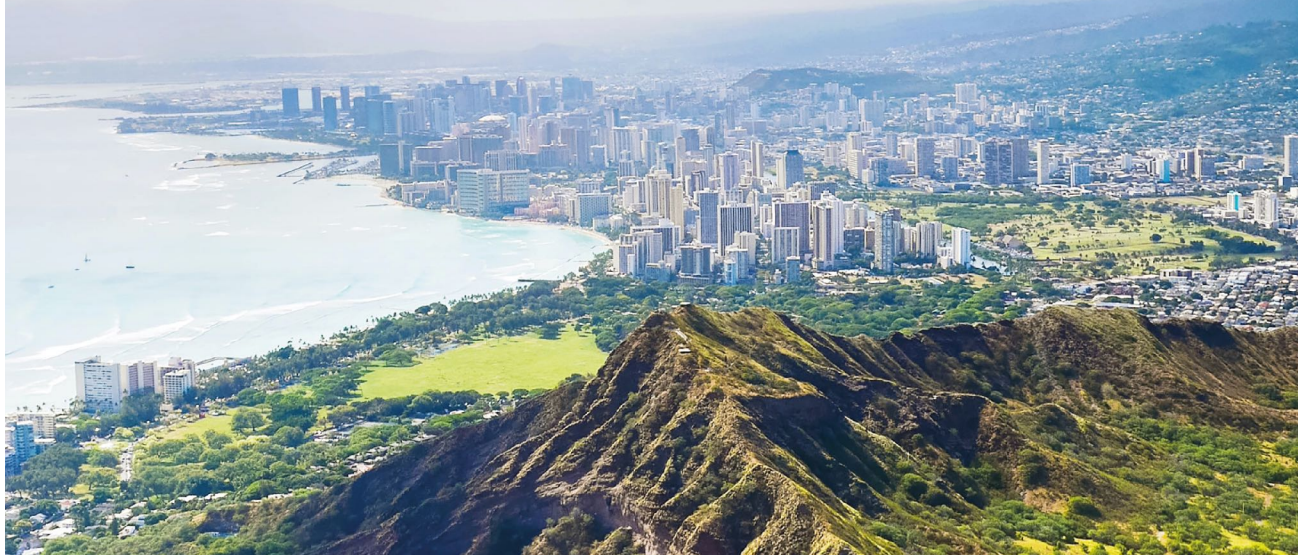
33rd Annual INCOSE international symposium

hybrid event

Honolulu, HI, USA
July 15 - 20, 2023



Jul 17, 2023: 10:45-11:25 AM (Track 2, Infrastructure & Rail, Session 1.3.2)

Lessons Learned and Recommendations for the Application of Systems Engineering as an Emerging Discipline in Transportation & Infrastructure Projects

Oliver Hoehne, ESEP, PMP, CSM
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WSP USA
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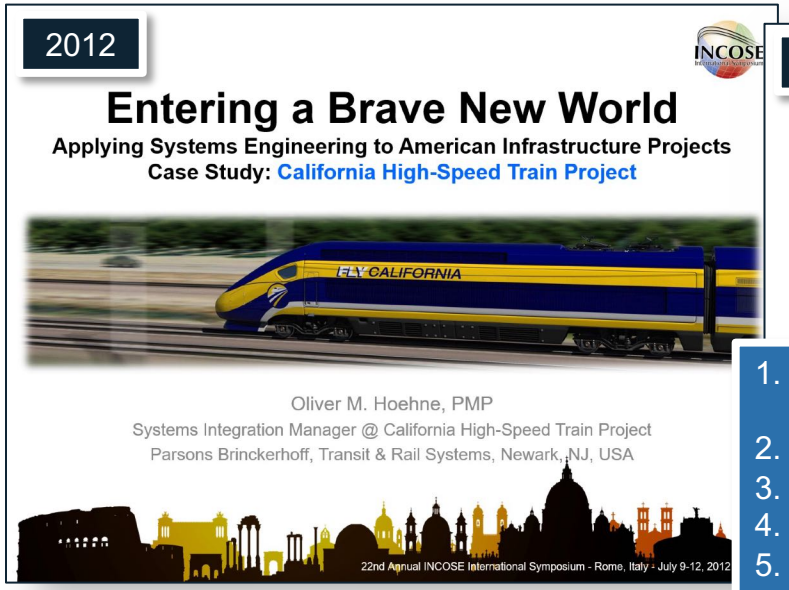
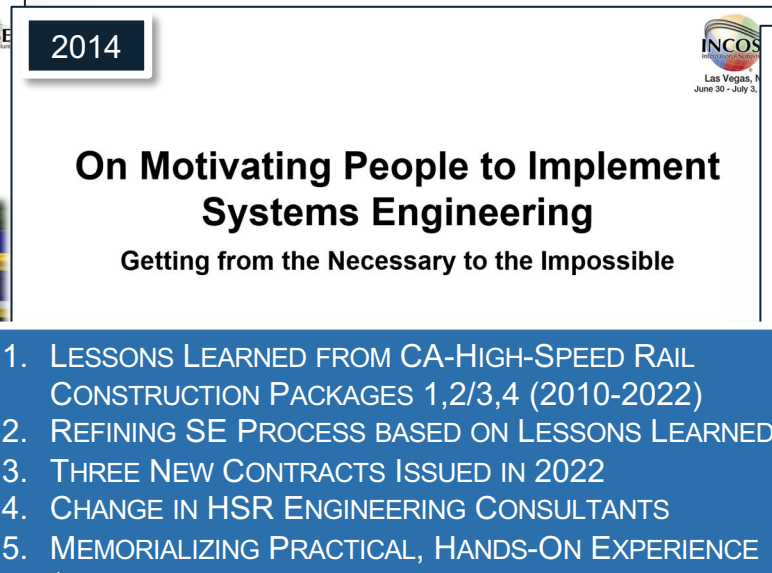
AGENDA

- **Background & Introduction**
  - Motivation
  - Infrastructure & Transportation Project
  - U.S. Infrastructure & Transportation Industry
  - Advice for Systems Engineers New to the Industry
  - Intended Audience
- **Lessons Learned**
  - Initial Systems Engineering Requirements & Results
  - Key Lessons Learned over 10+ Years
- **Recommendations**
  - Refining & Tailoring the Systems Engineering Requirements
  - Systems Development Life Cycle (SDLC) Model & Phases
  - Recommendations by Phase
- **Summary & Conclusion**

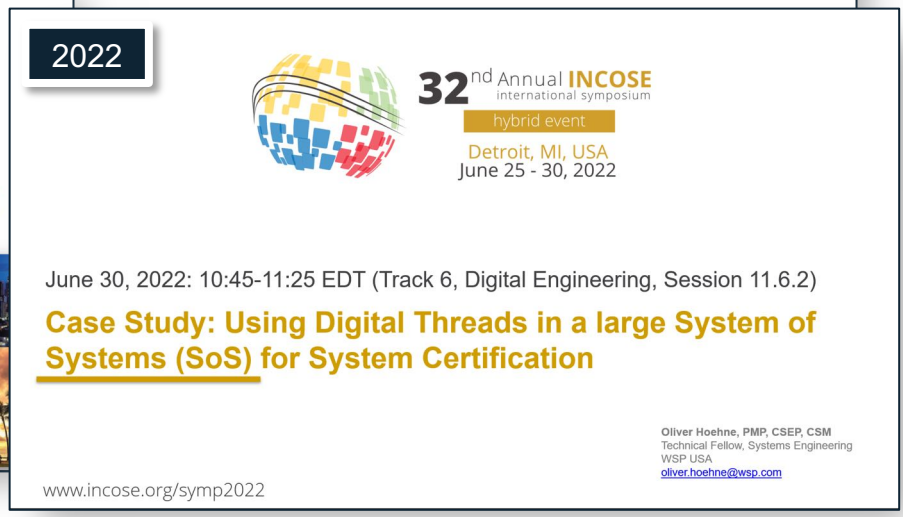
Background & Introduction

Motivation: Memorializing 10+ Years of Practical Experience





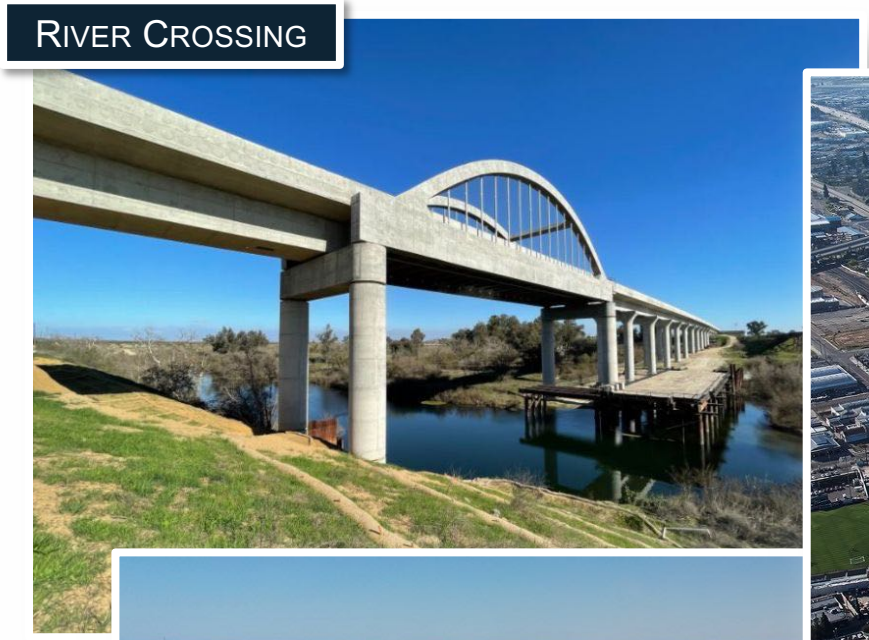
1. Lessons Learned from CA-High-Speed Rail Construction Packages 1,2/3,4 (2010-2022)
2. Refining SE Process based on Lessons Learned
3. Three New Contracts Issued in 2022
4. Change in HSR Engineering Consultants
5. Memorializing Practical, Hands-On Experience
6. $1 trillion U.S infrastructure bill



Background & Introduction

California High-Speed Rail System Program

River Crossing



Undercrossing

Trench

~300 Major Structures

Viaducts

BACKGROUND & INTRODUCTION

U.S. INFRASTRUCTURE & TRANSPORTATION INDUSTRY

THE POSSIBLE
SAFETY & SECURITY CERTIFICATION

MOVING AWAY FROM PAPER-CENTRIC

THE IMPOSSIBLE
SYSTEM ARCHITECURE & CONCEPT OF E. (CONT'D)

APPLYING HOLISTIC SYSTEMS APPROACH

2014

THE POSSIBLE
DESIGN SUBMITTAL REVIEW CHECKLISTS

APPLYING REQUIREMENTS BASED REVIEWS

- Systems Engineering Champion
- Communicate Clearly (WIIFY)
- Show Applicability
- Help Others Achieving Short-Term Result
- Early Adaptors

Building an RVTM

THE IMPOSSIBLE
MODEL BASED SYSTEMS ENGINEERING (PLANNED)

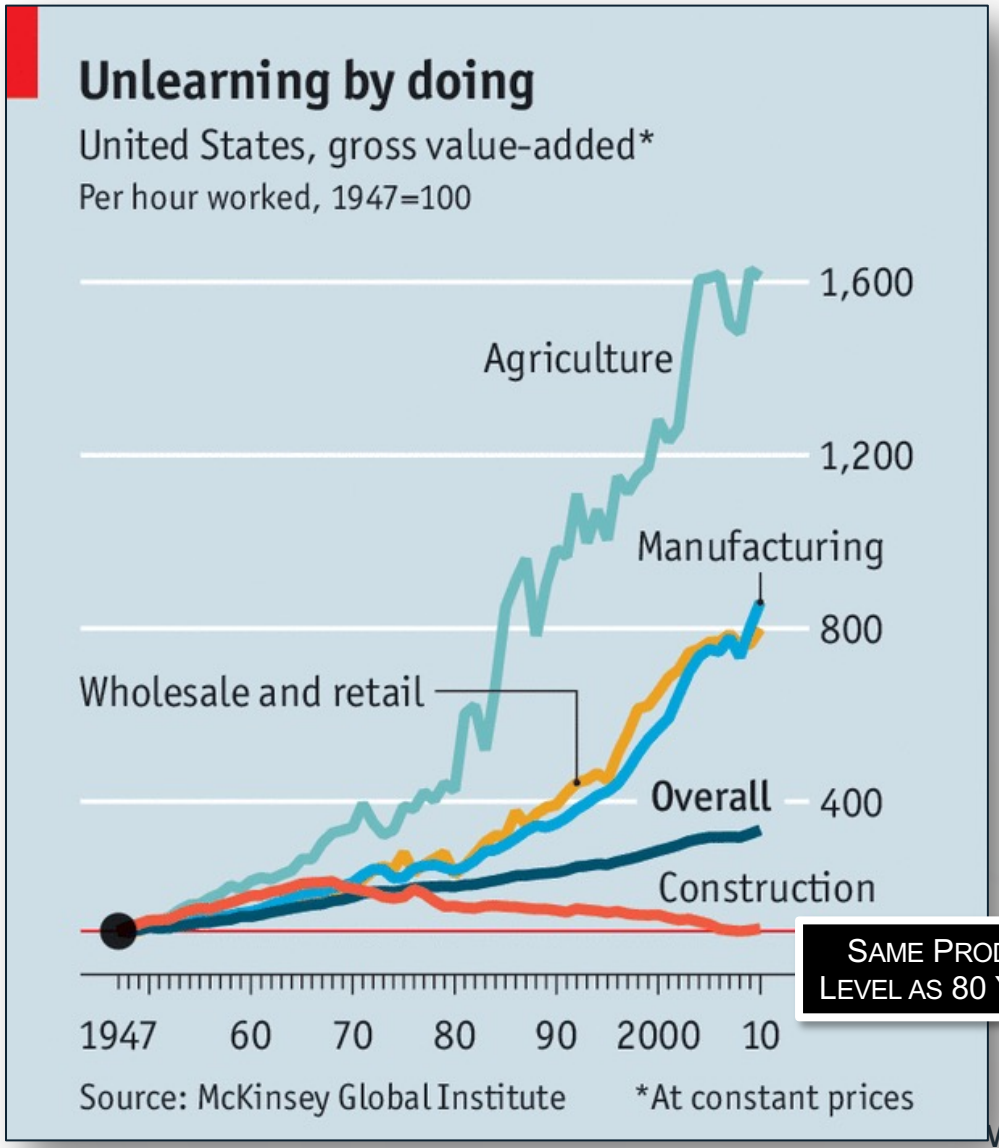
TOWARDS MODEL BASED SYSTEMS ENGINEERING

- Systems Engineering Champion
- Communicate Clearly (WIIFY)
- Show Applicability
- Help Others Achieving Short-Term Results
- Just do it, Ask Forgiveness Later
- Early Adaptors

SE VISION VS. STATE OF THE INDUSTRY

BACKGROUND & INTRODUCTION

U.S. INFRASTRUCTURE & TRANSP. INDUSTRY EFFICIENCY & PRODUCTIVITY



SAME PRODUCTIVITY LEVEL AS 80 YEARS AGO

Source: https://www.economist.com/business/2017/08/17/efficiency-eludes-the-construction-industry

Least-improved

Efficiency eludes the construction industry

The Economist

American builders' productivity has plunged by half since the late 1960s

Background & Introduction

Advice for Systems Engineers New to the Industry

Disincentives for Systems Engineering: Any design & construction firm proposing additional, unsolicited work (i.e., SE as an upfront investment) in a firm-fixed price and low-bid environment will be at a **competitive disadvantage** due to increased bid costs and may consequently lose the bid.

Topic	Advice, Common Infrastructure & Transportation Observations
Nomenclature & Terminology	Learn the language to communicate effectively
Systems Engineering	Considered not applicable (misunderstood as the engineering of systems)
Systems Engineer Position/Role	Does not exist. Expect highly functional / stovepiped organizations
Stakeholders	Other/third parties requiring coordination with (e.g., regulators, utilities)
Operations & Maintenance	Happens after design and construction, taken care of "by others"
Requirements	Are expected "to be known" or "to be familiar with" ("I know what I am doing")
Architecture	The art or practice of designing and constructing buildings
Integration	Happens after design and construction, taken care of by an integrator
Verification & Validation (V&V)	Confusing to industry, use of quality mgmt. instead, avoidance of transparency
Firm Fixed-Price, Low Bid Contracts	Expect delivery of fixed scope and low bid quality, every change → big $$$
Progress, Progress, Progress	WISCY syndrome ("Why isn't Sammy constructing yet")

Background & Introduction

Intended Audience: Owner & Owner's Representative(s)

There are five key players in the U.S. infrastructure industry: (1) The owner, (2) owner's representatives (program/project management consultants), (3) design consultants, (4) construction managers, and (5) the construction firms. Owners can be private or public entities, such freight railroads, utility owners, state departments of transportation, public transportation agencies, port authorities, etc.

As the infrastructure bill calls primarily for investments into roads, bridges, rail, ports, airports, power, water, broadband, and other major public projects (the "infrastructure"), this paper is written from a **public owners'** (and **owner representatives'**) perspective.

Owners have great leverage in determining the scope of work and required proposer qualifications for their projects, and have therefore **the power to introduce systems engineering requirements** into their procurement contracts.

Owners have the opportunity and authority to level the playing field, by **making Systems Engineering a mandatory contract requirement** for all proposers to comply with.

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  - Initial Systems Engineering Requirements & Results
  - Key Lessons Learned
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  - Systems Development Life Cycle (SDLC) Model & Phases
  - Recommendations by Phase
- **Summary & Conclusion**

LESSONS LEARNED

INITIAL SYSTEMS ENGINEERING REQS. ("VERIFICATION & VALIDATION")

CP1

California High-Speed Train Project

Agreement No.: HSR 13-06
Book 3, Part B, Subpart 1

Verification, Validation and Self-Certification

1. (SE) MANAGEMENT PLAN
2. REQUIREMENTS MANAGEMENT, INCLUDING TRACEABILITY
3. DESIGN MANAGEMENT
4. INTERFACE MANAGEMENT
5. INSPECTION & TESTING
6. VERIFICATION & VALIDATION
7. CHANGE MANAGEMENT

Revision No.	Date	Description
0	01 Mar 12	Initial Release, R0
1	04 Jun 12	Interoperability Items List updated, R1
2	23 Aug 12	Third Parties and Self-Certification addressed, R2
3	13 Dec 12	Minor Clarifications, Updated Interoperability Items, R3
4	31 Jul 13	EXECUTION VERSION

CP1

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CP4

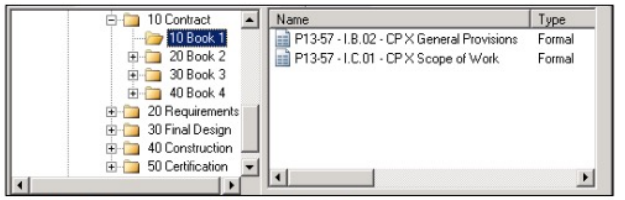


Figure 4: RM Tool – Sample Folder and File Structure

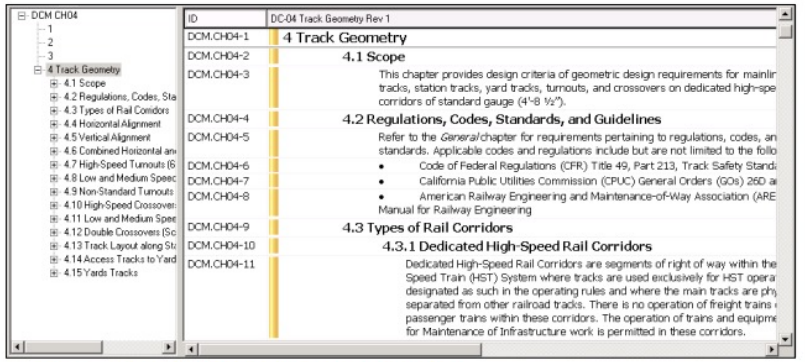


Figure 5: RM Tool – Sample Contract Document

Do not change or edit the original Contract documents.

2.2.3 Trace Technical Contract Requirements

Provide full traceability as depicted in Figure 3 and specified below using the RM tool:

- Supporting Documents (see Section 2.2.4 for definition) to Typical RVTMs and CILs (general clarifications or changes)
- Supporting Documents (see Section 2.2.4 for definition) to Submittal Specific RVTMs and CILs (site specific clarifications or changes)
- Typical RVTMs and CILs to Submittal Specific RVTMs and CILs
- Submittal Specific RVTMs and CILs to Final Design submittals
- Submittal Specific RVTMs and CILs to Construction submittals, including inspection and test submittals
- Submittal Specific RVTMs and CILs to Certification submittals

LESSONS LEARNED

INITIAL SYSTEMS ENGINEERING REQUIREMENTS (TRACEABILITY MATRIX)

CP1

Table 1: RVTM Template

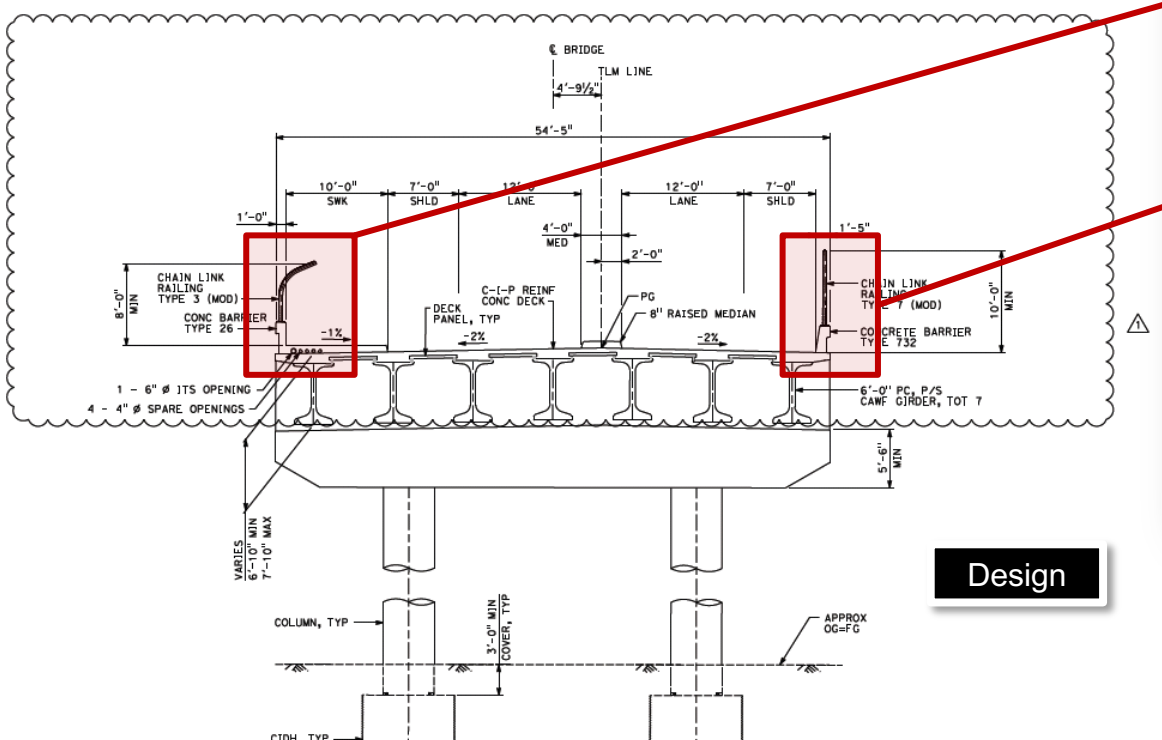
Technical Contract Requirement				Final Design					Construction		Testing/Acceptance	
				Requirements		Design						
Req. ID	Doc. ID	Document Section	Requirements Text	Derived Requirements	Apportioned Requirements	Allocation	Doc. ID/Name	Section	Doc. ID/Name	Section	Doc. ID/Name	Section
1	Design Criteria	4.4.5.3 Unbalanced Superelevation	The maximum unbalanced superelevation (Eu) shall be limited to 3 inches	N/A	N/A	Track Geometry	Drawing Set (e.g., Plan & Profile)	Drawing #	…	…	…	…
2	Design Criteria	5.8.2 Subballast or Asphalt Underlayment	The thickness shall be determined by analysis of the support required.	The thickness shall be xxx inches.	N/A	Track	Report …	Section #	…	…	…	…
							Cross Section (Typical)	Drawing #	N/A	N/A	…	…
							Cross Section (Site Specific)	Drawing #	Drawing Set (Released for Construction)	Drawing #	…	…
									Inspection (Plan, Procedure, Report)	Section #	…	…
									Drawing Set (As Constructed)	Drawing #	…	…
									…		Test/Acceptance (Plan, Procedure, Report)	Section #
3	Design Criteria	1.9 Climatic Conditions	Climatic conditions necessary for design, including those that are site-specific, shall be researched and considered by the designer	The design wind speed shall …	Wind loads on structures shall consider the design wind speed (velocity) as defined …	Structures	Report …	Section #	…	…	…	…
4	PHA	1.1.1.4 Derailment due to Washout	Perform hydraulics analysis and incorporate results into sub-grade design, slope protection, and setting of profile.	Hydraulics analysis shall …	N/A	Geotech	…	…	…	…	…	…
					Sub-grade shall …	Track	…	…	…	…	…	…
					Slope protection shall …	Civil		…	…	…	…	…
					Setting of profile shall …	Track Geometry		…	…	…	…	…
			Install appropriate drainage.	Drainage system shall …	…	Drainage	…	…	…	…	…	…
			Inspection and maintenance of drainage systems.	…	…	O&M	…	…	…	…	…	…

LESSONS LEARNED

RESULTS: SAFETY REQUIREMENTS (MITIGATIONS FROM HAZARD ANALYSIS)

ID	Hazards & Mitigations	CI
1	**1 Infrastructure**	No
2	**1.1 R-O-W Generally**	No
12	**1.1.2 Collision**	No
26	**1.1.2.7 Object thrown from overpass**	No
176	**1.1.2.7.1 Mitigation #1**	Yes
	[1] INF: Install intrusion prevention fencing at overpasses.	

Risk of Thrown Objects



Design

Construction

LESSONS LEARNED

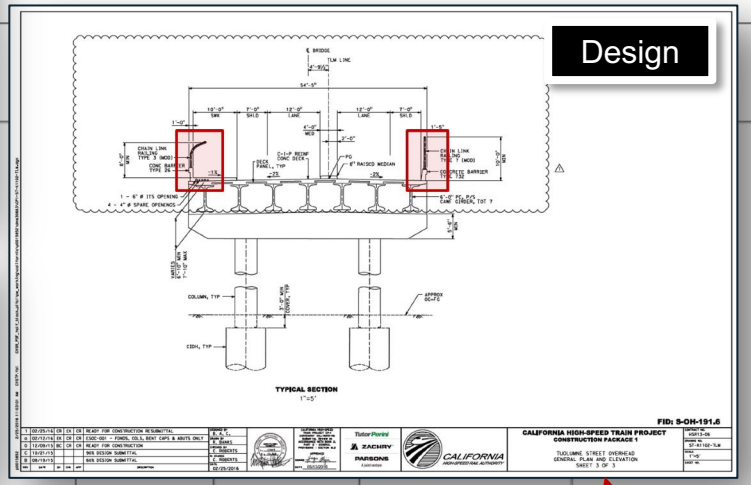
RESULTS: SAFETY REQUIREMENTS (USING CERTIFIABLE ITEMS LIST [CIL])

Certifiable Items List (CIL) as input into Safety & Security Certification Report (SSCR)

Table 1 - CIL

ID	Hazards & Mitigations	CI
1	1 Infrastructure	No
2	1.1 R-O-W Generally	No
12	1.1.2 Collision	No
26	1.1.2.7 Object thrown from overpass	No
176	1.1.2.7.1 Mitigation #1 [1] INF: Install intrusion prevention fencing at overpasses.	Yes

		(CEHL167)	1.1.2.2.1 Mitigation #1							
			roadway 1.1.2.5.1 Mitigation #1							
2	CEHL	CIL65 (CEHL176)	1.1.2.7 Object thrown from overpass 1.1.2.7.1 Mitigation #1	Mitigation #1 [1] INF: Install intrusion prevention fencing at overpasses.	N/A	N/A	Civil Guideway Structures	Yes, CEHL 176 is satisfied by chain link Type 3 (Mod) and Type 7 (Mod) fencing as shown on sheet ST-K1102-TLM	ST-K1102-TLM	Type 3 (Mod) & Type 7 (Mod): 2017Jun28_TLM_LookingNorth.jpg	Fencing is installed atop barriers
3	CEHL	CIL100 (CEHL203) CIL106 (CEHL208) CIL191 (CEHL262) CIL273 (CEHL317)	1.1.3.1 Fire and/or smoke on at-gr 1.1.3.1.2 1.1.3.2 \ and/or smoke adjacent to an at-grade alignment 1.1.3.2.2 Mitigation #2 1.2.1.7 Fire on elevated structures 1.2.1.7.1 Mitigation # 1	Use of non-flammable materials on	RFI-00196: The Authority concurs with the following definition: Flammable solids are solids that are readily combustible, or may cause or contribute to fire through friction. Readily combustible solids are powdered, granular, or pasty substances which are dangerous if they can be easily ignited by brief	N/A	Guideway Structures	Yes	S	gSouth2.jpg	Photo shows concrete structure



Safety Requirement

Reference & Traces to Objective Evidence

LESSONS LEARNED

INITIAL SYSTEMS ENGINEERING REQS. (INTEROPERABILITY, INTEGRATION)

RFP No. HSR 11-16

CP1

RFP No. HSR 11-16 California High-Speed Tr

ID	Interface	Document Reference(s)
		WITH THREE HIGH-VOLTAGE TRANSFORMERS Drawing DD-TP-D201, CONCEPTUAL LAYOUT SWITCHING STATION Drawing DD-TP-D301, CONCEPTUAL LAYOUT PARALLELING STATION Maintenance of Infrastructure, 2, CHST Infrastructure System And Maintainability Maintenance of Infrastructure, 2.5, Structures Maintenance of Infrastructure, 2.6, Electric Traction Maintenance of Infrastructure, 9.4, Right of Way Access Maintenance of Infrastructure, 9.6, Electric Power Transmission System (TP
	3.1.2 Interfaces with Guideway (excl. Trackwork)	
	3.1.2.1 Track Alignment	
IF 80	**3.1.2.1.1 Interface between SYS TP Maximum Grade @ Phase Break Requirements and GWY Infrastructure**	
	Purpose/Scope: Ensures that the SYS TP system maximum grade @ phase break requirements have been addressed by the INF team.	DCM, 20.7.2, Spacing of Traction Power Facilities DCM, 4.5.1, Maximum Grades
	3.1.2.2 Traction Power Facilities & Wayside Power Cubicles (Sites)	
IF 5597	**3.1.2.2.1 Interface between SYS TP Facility & WPC Site Location Requirements and GWY Infrastructure**	
	Purpose/Scope: Ensures that the SYS TP facility & WPC site location (where to install, not size) requirements have been addressed by the INF team.	DCM, 13.16.14, Overhead Contact System Motorized Disconnect Switch DCM, 13.16.4.1, Traction Power DCM, 13.3.10, Equipment Requirements and Tunnel Niches DCM, 20.12.1, Wayside Power Control Cubicles DCM, 20.7.2, Spacing of Traction Power Facilities DCM, 20.7.3, Additional Location Requirements Drawing DD-TC-004, STATION INTERLOCKING LAYOUT-TYPICAL Drawing DD-TC-005, UNIVERSAL INTERLOCKING LAYOUT-TYPICAL Drawing DD-TC-025, TYPICAL INTERLOCKING AT STATIONS

DCM 20: TRACTION POWER REQUIREMENTS

DCM 04: TRACK GEOMETRY REQUIREMENTS

LESSONS LEARNED

RESULTS: INTEROPERABILITY (INTERFACE CONTROL DOCUMENTS)

CALIFORNIA RAIL BUILDERS

INTERFACE CONTROL DOCUMENT (ICD)
IF 80 – Interface between SYS TP Maximum Grade at Phase Break Requirements and GWY Infrastructure

California High-Speed Rail Construction Package 4
Agreement No. HSR 14-32

Revision	00
Date	Date: .....
Doc. No.	CP4-6.27.37-0001
Prepared By	Cindy McLeod

Previous Revisions	
Number	Date

CP4

1. Signature Page

California High-Speed Rail Construction Package 4

CALIFORNIA RAIL BUILDERS	INTERFACE CONTROL DOCUMENT (ICD) IF 80 – Interface between SYS TP Maximum Grade at Phase Break Requirements and GWY Infrastructure	Revision:	00
	Doc No.: CP4-6.27.37-0001	Date:	Date: .....

2. EXECUTIVE SUMMARY

This report contains the Certifiable Items List (CIL) specific to all design packages (CP4) that IF 80 is applicable to and provides documentation on how this interface requirement was met. The allocation of this interface is for Guideway (Civil) only.

The CRB Interface Lead worked with the V&V team and the Des
assess all contract documents inclusive of manuals, reports, d
to demonstrate submittal compliance to the Technical Contract

The Interface Control Document Certification Report includes th

I) Certifiable items List (CIL) table for Interface Req
IV, Part E.1- Verification Validation and Self -Certi
II) Drawings and/or other relevant documentations
requirements have been met.

With the completed certifiable items list(CIL) and associated
Document Certification Report, CRB is using this report as a C
Submittal.

By signing below, the following CRB staffs certify that ICD for I
and the Design Lead. The signature provided by the Design Lea
for each critical item contained in the CIL matrix fully satisfies t

Design Lead: ----------

Interface Lead: ----------

2. CIL with Traces to Objective Evidence

California High-Speed Rail Construction Package 4

CALIFORNIA RAIL BUILDERS	INTERFACE CONTROL DOCUMENT (ICD) IF 80 – Interface between SYS TP Maximum Grade at Phase Break Requirements and GWY Infrastructure	Version:	00
	Doc No.: CP4-6.27.37-0001	Date:	Date: .....

3. CERTIFIABLE ITEMS LIST (CIL)

Table 1: CIL

Req.ID	Document ID	CIL ID	Document Section	Requirements Text	Derived Requirements	Apportioned Requirements	Allocation	Design Section	Design Document	In Compliance with Contract Document
1008	30 CP4 IF-REG	IF 80	DCM 20.7.2	Purpose/Scope: Ensure that the SYS TP Maximum Grade @ Phase Break Requirements have been addressed by CRB team.	0.79% grade on the HSR profile at TPSS location (sta. 15555+00) and 1.03% grade at 2500 feet to the north as per DWR No: 013 Rev.00 (Title: Maximum Grade through System Sites Areas) N/A	0.79% grade on the HSR profile at TPSS location (sta. 15555+00) and 1.03% grade at 2500 feet to the north N/A	Guideway/Middle Civil Guideway/North Civil	Middle Track Guideway Plan and Profile North Civil Segment A1 Track Alignment Plan and Profile	TT-D1047 to TT-D1065 TT-D1006	Yes Yes

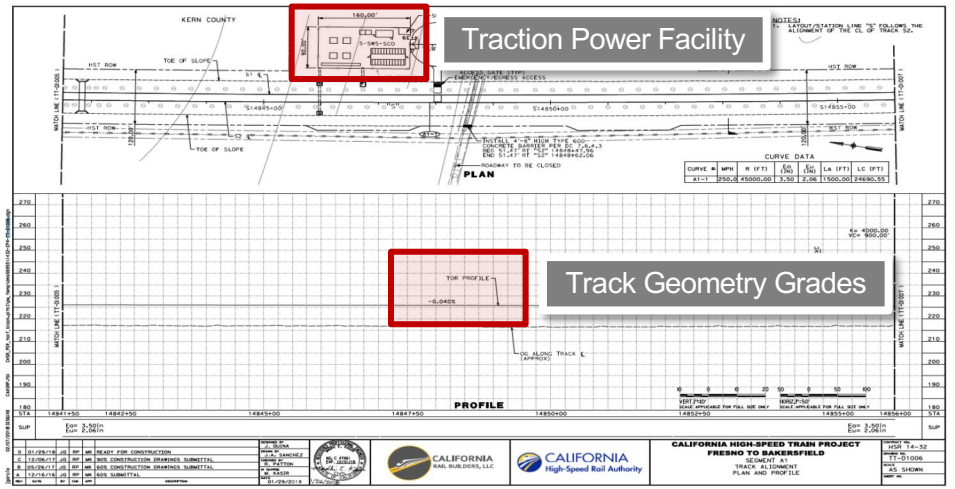
Note: IF 80 is not applicable to South(Civil) of CP4.

Reason: There is no phase break at South(Civil) design

California High-Speed Rail Construction Package 4

CALIFORNIA RAIL BUILDERS	INTERFACE CONTROL DOCUMENT (ICD) IF 80 – Interface between SYS TP Maximum Grade at Phase Break Requirements and GWY Infrastructure	Version:	00
	Doc No.: CP4-6.27.37-0001	Date:	Date: .....

North Civil Segment A1 Track Alignment Plan and Profile(TT-D1006)



3. Excerpted Objective Evidence

www.incose.org/symp2

LESSONS LEARNED

KEY LESSONS

SDLC: SYSTEMS DEVELOPMENT LIFE-CYCLE REQUIREMENTS (UPDATED V&V REQUIREMENTS BASED ON LESSONS LEARNED)

Topic	Challenge(s)	Lesson Learned, SDLC Updates
Ability and willingness to implement SE	– Incomplete, incorrect, inconsistent, and/or delayed SE implementation	– Additional training requirements – Additional process detail – More detailed technical guidance – SDLC milestones tied to payment milestones (Enforcement)
"Leave it to the contractor" mentality	– Each CP developed differently, inconsistent SE implementations	– SDLC as CHSRS standard – RM tool handbook and model (CHSRS, 2022)
Governing requirements	– Continuous discussions of applicable requirements – Moving targets – Uncontrolled changes	– SDLC phases & associated requirements baselines – Strengthened configuration management
Breakdown structures, allocated requirements	– Incomplete and changing breakdown structures – Late discovery of system elements – Requirement allocation	– SDLC phases & associated deliverables – System breakdown structure – Site breakdown structure – Submittal breakdown structure
RAM	– See first bullet (SE)	– See first bullet (SE) – SDLC phases & associated engineering analyses (including RAM)

LESSONS LEARNED

KEY LESSONS (CONT'D)

Topic	Challenge(s)	Lesson Learned, SDLC Updates
V&V during Construction	– Lack of appropriate inspection & test planning – Lack of detailed traceability to specific objective evidence	– SDLC phase with associated (early) verification & validation and inspection & testing deliverables – Strengthened V&V requirements
Independent V&V	– Specificity of ICE/ISE scope subject to independent V&V	– CHSRS bulletin with further detailed ICE/ISE scope – SDLC invoking bulletin
Frequent changes	– Number of RFIs, DVRs, DLs, DCNs, FCNs – Continuous changes to requirements, design, and construction baselines	– Strengthened requirements & configuration management
Certification, acceptance & handover	– Lack of certification planning – Moving targets – ICE/ISE certifications	– SDLC phases & associated certification deliverables – Added certification management – CHSRS bulletin (ICE/ISE scope)

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RECOMMENDATIONS: REFINING & TAILORING

REFINING THE SYSTEMS ENGINEERING REQUIREMENTS

INITIAL SE

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REFINED SE

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MANAGEMENT PLAN & SUPPORTING REQS.

REQUIREMENTS BY SDLC PHASE

TRADITIONAL VVSC PROCESS REQUIREMENTS

DELIVERABLES BY SDLC PHASE

ncose.

RECOMMENDATIONS: REFINING & TAILORING

TAILORING USING THE INCOSE SE HANDBOOK (4TH EDITION)

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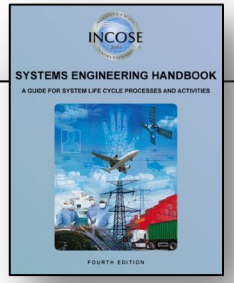
Use Industry-Specific Language



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www.incose.org/symp2023

RECOMMENDATIONS: REFINING & TAILORING

TAILORING BY CONTRACT TYPE (CONSIDERING COMPLEXITY & MATURITY)

CIVIL WORKS

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TRACK & SYSTEMS

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RECOMMENDATIONS: REFINING & TAILORING

PROVIDING STANDARDS: IMPLEMENTING THE SDLC (HANDBOOK & MODEL)

3.3.1 Level 1 Requirements

3.3.1.1 Contract Requirements Baseline

The contract requirements baseline (CBL) is defined as the executed Contract documents captured in the RM tool including their attributes and allocated attribute values, as presented in Figure 3 and described below.

Create the CBL including the following:

- Confirm the correct and complete set of executed Contract documents and revisions.
- Identify the executed Contract documents subject to management in the RM tool. Unless otherwise agreed to in writing by the Authority, this includes all executed Contract documents with the exception of reference documents.

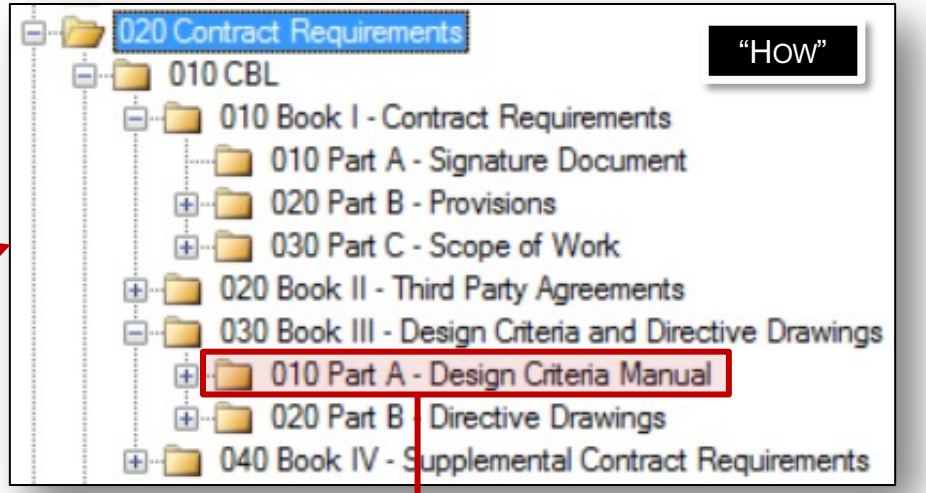
"WHAT"

- Capture the executed Contract documents in the RM tool.
- Additionally capture files that may be electronically embedded in the executed Contract documents, including the (1) Preliminary hazard analyses (PHA), (2) Threat and vulnerability assessments (TVA), (3) Interfaces, and (4) environmental requirements.
- The executed Contract documents are configuration items. As the executed Contract forms the basis and starting point for requirements management, the executed Contract documents must not be changed in the RM tool. For change management throughout the project life cycle (e.g., directive letters, design variances, etc.) refer to the CfM section 4.3.
- Perform technical contract requirements (TCR) and critical items (CI) analysis and allocation. For definition of TCRs and CIs refer section 4.1. In general, all TCRs and CIs are to be labelled as such. Only when a TCR or CI invokes an engineering analysis, label the TCR or CI as an EA.
- Perform regulations, codes, standards, and guidelines (RCSG) analysis and allocation, to be further analyzed as part of the design and code analysis report (DCAR, section 3.3.1.2). Allocate each individual RCSG requirement to the DCAR, including the ones listed in RCSG summary sections as well as individually referenced RCSG requirements throughout the body of text. All identified RCSGs are considered TCRs or CIs.

SDLC

For flow down and tracing of the allocated CBL requirements refer to the DCAR (section 3.3.1.2) and TCR and CI masterlists forming the system requirements baseline (section 3.3.2.1).

"HOW"



ID	08/02/2021 Rev. 4.5 - BOD	_TCR/CI
DCM02.18	**2 Basis of Design**	Heading
DCM02.20	**2.2 Design Criteria Elements**	Heading
DCM02.23	**2.2.3 Train Operation**	Heading
DCM02.29	**2.2.3.6 Operating and Design Speed**	Heading
DCM02.30	The System design speed shall be 250 mph.	TCR

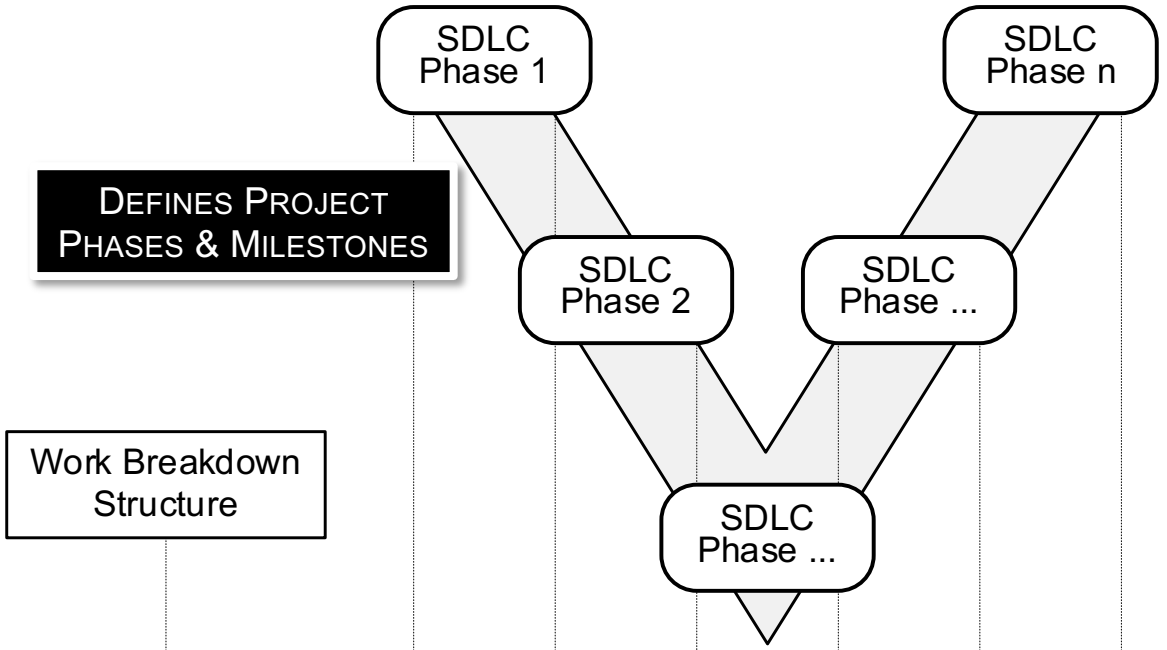
STANDARD / MODEL

PROGRESS

- **Background & Introduction**
  - Motivation
  - Infrastructure & Transportation Project
  - U.S. Infrastructure & Transportation Industry
  - Advice for Systems Engineers New to the Industry
  - Intended Audience
- **Lessons Learned**
  - Initial Systems Engineering Requirements & Results
  - Key Lessons Learned
- **Recommendations**
  - Refining & Tailoring the Systems Engineering Requirements
  - **Systems Development Life Cycle (SDLC) Model**
  - Recommendations by SDLC Phase
- **Summary & Conclusion**

RECOMMENDATIONS: SDLC MODEL

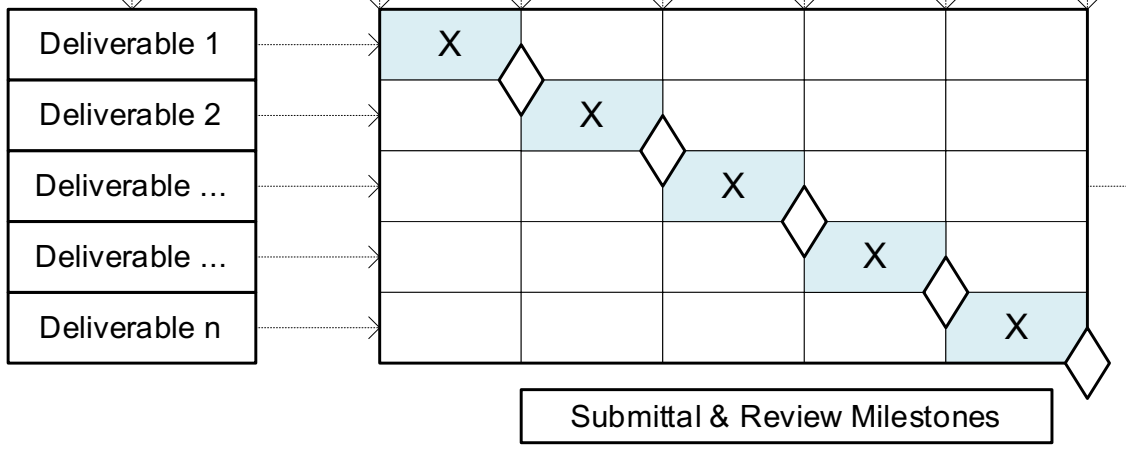
SYSTEMS DEVELOPMENT LIFE CYCLE (SDLC) MODEL



DEFINES PROJECT PHASES & MILESTONES

Work Breakdown Structure

SERVES AS FRAMEWORK TO ALLOCATE PROJECT DELIVERABLES TO PROJECT PHASES

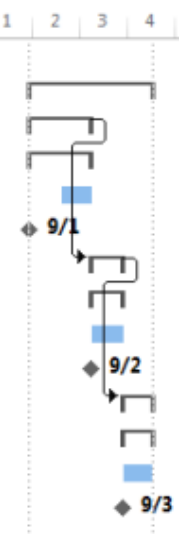


Submittal & Review Milestones

Schedule

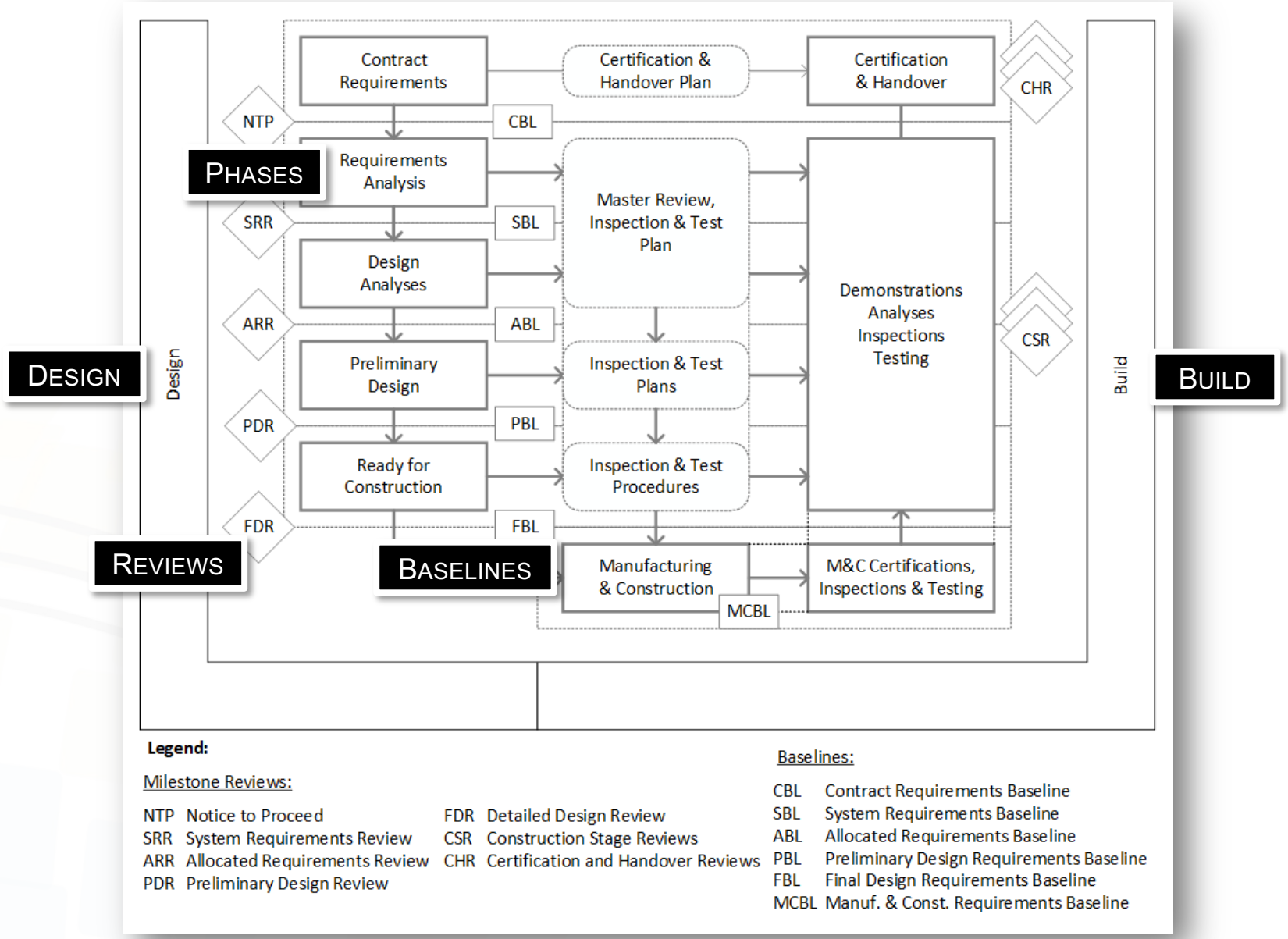
INPUT INTO PROJECT SCHEDULES, MILESTONES

	Task Name	Duration
1		
2	TECHNICAL SCHEDULE	3 days
3	SDLC Phase 1	1 day
4	[D] Deliverable 1	1 day
5	[A] Activities ...	1 day
6	[M] Milestone 1	0 days
7	SDLC Phase 2	1 day
8	[D] Deliverable 2	1 day
9	[A] Activities ...	1 day
10	[M] Milestone 2	0 days
11	SDLC Phase n	1 day
12	[D] Deliverable n	1 day
13	[A] Activities ...	1 day
14	[M] Milestone n	0 days



RECOMMENDATIONS: SDLC MODEL

SYSTEMS DEVELOPMENT LIFE CYCLE MODEL (CONT'D)



RECOMMENDATIONS: SDLC MODEL

SDLC MODEL: DOCUMENT STRUCTURE, PHASE, DELIVERABLES

Table of Contents

3.2 Mobilization Phase

3.2.1 Project Plans

Provide the Contractor SEMP as defined in section 2.1. Provide oth
as specified in the Contract. Refer to section 6.1 for other mobiliza

3.3 Requirements Analysis Phase

The requirements analysis (RA) phase represents the combi
requirements phases of a typical systems development life cycle (

The RA phase **applies** to both design bid build (DBB) and desig
during preliminary engineering (PE), environmental clearance (E
design (FD) stages in conformance with the Authority stage
procedure.

The **key purpose** of the RA phase is to (1) Capture the executed
contract requirements baseline, (2) Perform applicable engineeri
and code analysis, (3) Create the system requirements baseline, (4)
(5) Develop certification and handover plan, as figuratively prese
refer to section 1.5.

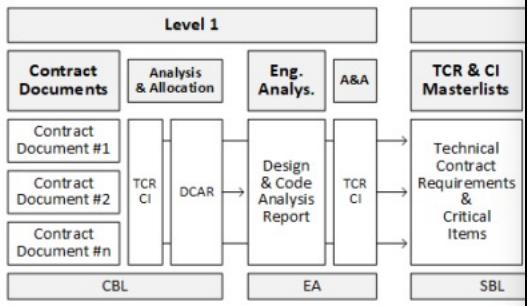


Figure 3: Requirements Analysis Phase

The **key deliverables** for the RA phase are listed in section 6.2
Contract requirements baseline, (2) Engineering analyses, (3) Sy
Master test plan, and the (5) Certification and Handover Plan.

The **review milestone** for the RA phase is the **system requiremen**
is completed when all RA phase deliverables defined in the Cont
Authority (i.e., approved or a Statement of No Objection).

The RA phase deliverables listed below are **configuration iter**
executed Contract documents, the RM tool version of each deliv
copy. Manage any change following the configuration manageme

6 Review Milestone Deliverables

This section summarizes the key SDLC deliverables described in this do
not all deliverables are listed. It is the Contractors responsibility to deve
and consistent submittal list of all Contract deliverables.

6.1 Mobilization Phase

Provide the following SDLC deliverables for the mobilization phase revi

Table 3: Milestone Submittals – Mobilization P

Milestone Submittals / Deliverables	Section	Subject
TECHNICAL MANAGEMENT		
• Systems Engineering Management Plan	2.1	Revie
• Technical Work Breakdown Structure	2.2	Revie
• Technical Schedule	2.3	Revie
• Organizational Breakdown Structure	2.4	Revie
• Technical Risk Mitigations	2.5	Revie
CROSS-CUTTING SE METHODS		
• RM Tool License	4.1.1	Revie
• RM Tool Installed	4.1.1	Revie
• RM Tool Implementation Plan (CRIMP)	4.1.2	Revie
• Configuration Item and Baseline (CIBL) Log	4.3.1.1	Revie
• CIBL Naming Convention	4.3.1.2	Revie
• CIBL Revision Numbers	4.3.1.3	Revie
• Configuration Release Control Strategy	4.3.5.1	Revie
SPECIALTY ENGINEERING INTEGRATION		
• As required by specialty engineering process	5	Revie

6.2 Requirements Analysis Phase

Provide the following SDLC deliverables for the system requirements re

Table 4: Milestone Submittals – System Requireme

Milestone Submittals / Deliverables	Section	Subject
SYSTEMS DEVELOPMENT LIFE CYCLE		
• Contract Requirements Baseline	3.3.1.1	Revie
• Engineering Analyses – DCAR	3.3.1.2	Revie
• System Requirements Baseline (Informal)	3.3.2.1	Revie
• System Requirements Baseline (Formal)	3.3.2.1	Revie
• Master Review, Inspection and Test Plan	3.3.2.2	Revie
• Certification and Handover Plan	3.3.2.3	Revie

Additionally, RA phase deliverables are considered **technical contract submi**
the deliverables as a TCS following the Verification & Validation (V&V) proce

3.3.1 Level 1 Requirements

3.3.1.1 Contract Requirements Baseline

The contract requirements baseline (CBL) is defined as the executed Co
captured in the RM tool including their attributes and allocated attribute valu
Figure 3 and described below. The executed Contract in the SDLC context ref
and signed version of the Contract that was agreed to by both the Authority a

Create the CBL including the following:

- Confirm the correct and complete set of executed Contract documents
- Identify the executed Contract documents subject to management in th
  otherwise agreed to in writing by the Authority, this includes all
  documents with the exception of reference documents.
- Capture the executed Contract documents in the RM tool.
- Additionally capture files that may be electronically embedded in the
  documents, including the (1) Preliminary hazard analyses (PHA
  vulnerability assessments (TVA), (3) Interfaces, and (4) environmental
- The executed Contract documents are configuration items. As the
  forms the basis and starting point for requirements management, the
  documents must not be changed in the RM tool. For change manageme
  project life cycle (e.g., directive letters, design variances, etc.) refer to th
- Perform technical contract requirements (TCR) and critical items
  allocation. For definition of TCRs and CIs refer section 4.1. In general
  are to be labelled as such. Only when a TCR or CI invokes an enginee
  the TCR or CI as an EA.
- Perform regulations, codes, standards, and guidelines (RCSG) analysis
  be further analyzed as part of the design and code analysis report (DCA
  Allocate each individual RCSG requirement to the DCAR, including
  RCSG summary sections as well as individually referenced RC
  throughout the body of text. All allocated RCSGs are considered TCRs
- For flow down and tracing of the allocated CBL requirements refer to
  3.3.1.2) and TCR and CI masterlists forming the system requirement
  3.3.2.1).

3.3.1.2 Engineering Analyses – Design and Code Analysis Report

The design and code analysis report (DCAR) analyses the current design, indus
design and construction codes for applicability to the design and constructio
Prepare the DCAR as required in the Contract.

RECOMMENDATIONS: SDLC MODEL

SDLC MODEL: APPLIED & TAILORED TO INFRASTRUCTURE

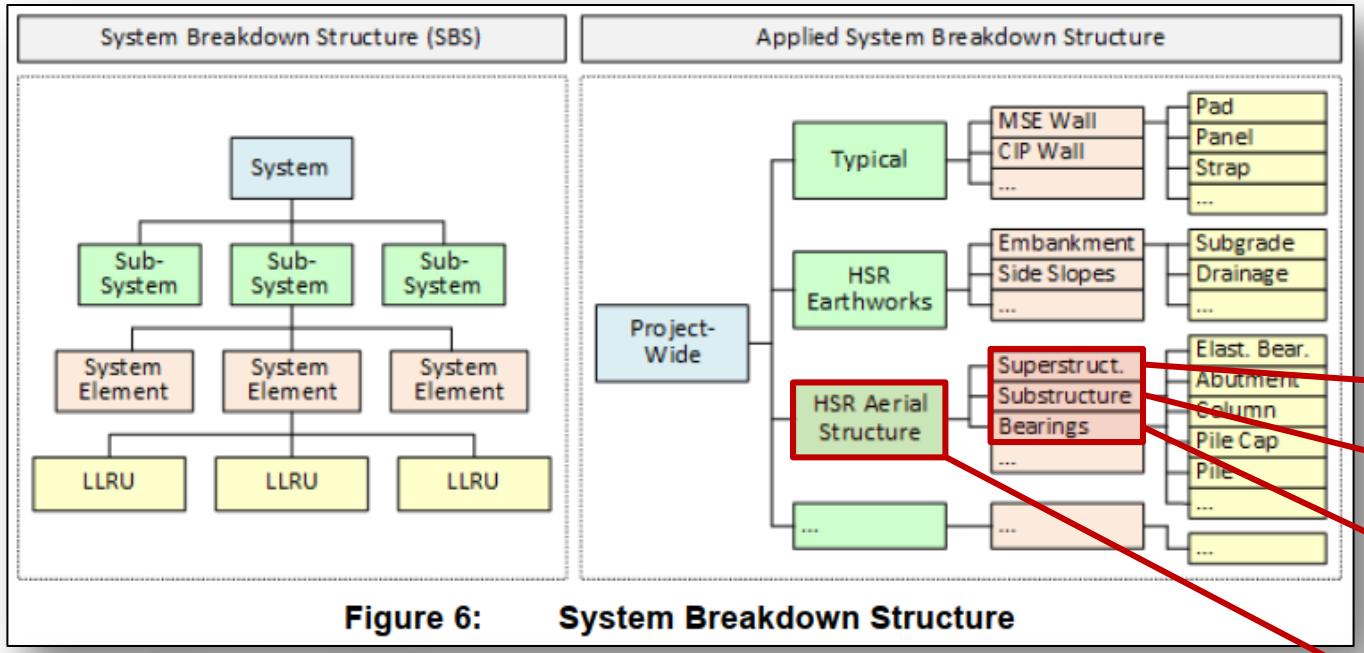
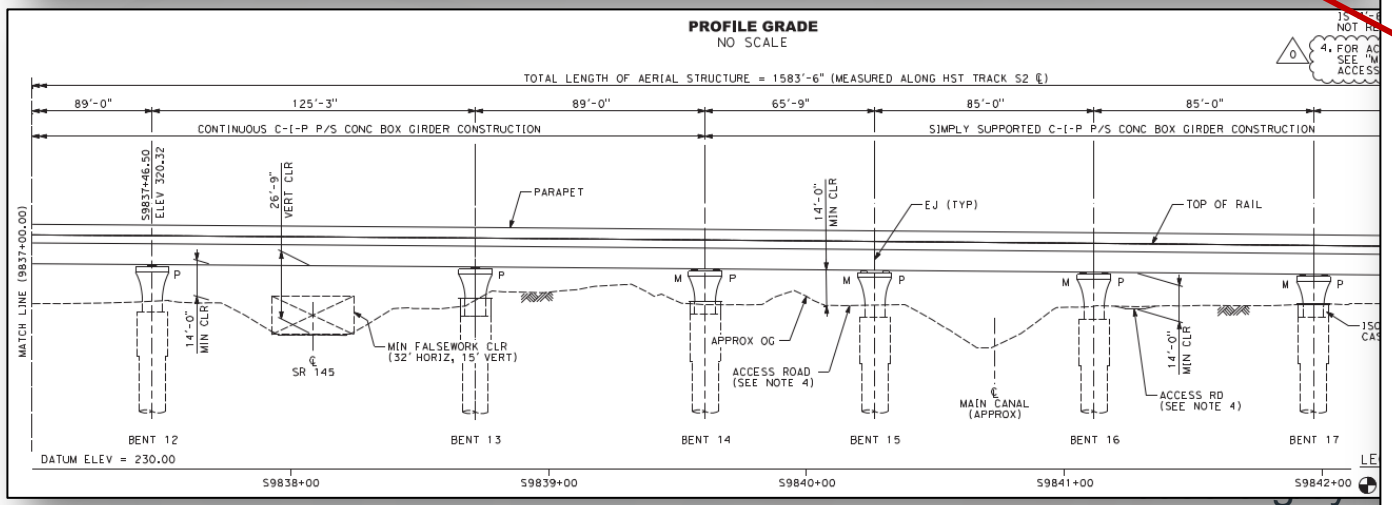
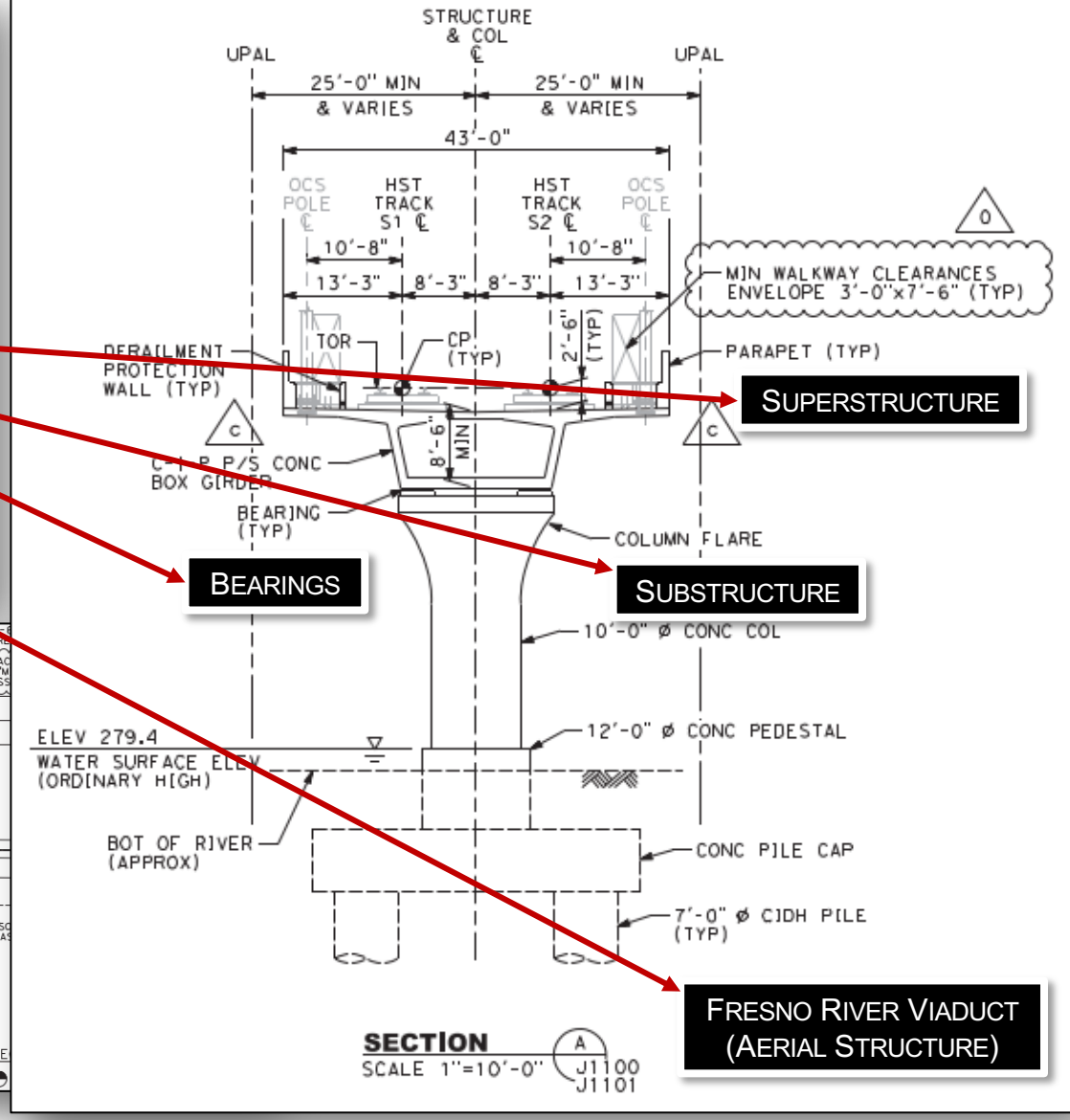


Figure 6: System Breakdown Structure





PROGRESS

- **Background & Introduction**
  - Motivation
  - California High-Speed Rail System Program
  - U.S. Infrastructure & Transportation Industry
  - Advice for Systems Engineers New to the Industry
  - Intended Audience
- **Lessons Learned**
  - Initial Systems Engineering Requirements & Results
  - Key Lessons Learned
- **Recommendations**
  - Refining & Tailoring the Systems Engineering Requirements
  - Systems Development Life Cycle (SDLC) Model & Phases
  - **Recommendations by Phase**
- **Summary & Conclusion**

Recommendations: By SDLC Phase

Mobilization Phase

- **Key Purpose:**
  - Mobilize the project team & establish project resources (e.g., office space, equipment, etc.)
  - Occurs immediately after project award ("Notice to Proceed" [NTP])
- **Key (SE) Deliverables:**
  - Systems Engineering Management Plan (SEMP)
  - Other planning documents associated with the mobilization phase & review milestone
- **Review Milestone:**
  - Mobilization Phase Review (MPR)
- **Key Recommendation:**
  - **Do** take advantage of the early goodwill ("honeymoon") project phase
  - **Do** request detailed management plans, describing how the Contractor plans to execute the project (i.e., planned deliverables, activities, timelines, processes, templates, etc.)
  - **Do** get all Contractor commitments in writing (e.g., the Contractor SEMP)
  - Management plans indicate Contract understanding, document commitments, and serve as the basis for future audits
  - **Do not** allow the Contractor to shortcut or skip the planning efforts (*"failing to plan is planning to fail"*)

Recommendations: By SDLC Phase

Requirements Analysis (RA) Phase

General Provisions
234 Pages, 1,334 *Shall* Statements

Scope of Work
97 Pages, 447 *Shall* Statements

Design Criteria Manual
1,279 Pages, 7,951 *Shall* Statements

Third Party Agreements
551 Pages, 1,819 *Shall* Statements

Standard Specifications
434 Pages, 2,274 *Shall* Statements

CONSTRUCTION PACKAGE 1 (HSR 13-06)

D AGREEMENT: HSR 13-06

- Pt A - Subpart 1 – Signature Document
- B2 - Pt A - Subpart 2 – Special Provisions
- B2 - Pt B – General Provisions
- B2 - Pt C - Subpart 1 – Scope of Work
- B2 - Pt D - Subpart 1 – Community Benefits Agreement
- 3 - Pt A - Subpart 1 – Basis of Design
- 3 - Pt A - Subpart 2 – Organizational Conflict of Interest Policy
- 3 - Pt A - Subpart 3 – Revised Small and Disadvantaged Business Enterprise Program
- B3 - Pt B - Subpart 1 – Verification, Validation and Self-Certification
- B3 - Pt B - Subpart 2 – Reliability, Availability and Maintainability
- Pt B - Subpart 5 – Design Variance Request Process
- t B - Subpart 6 – Safety and Security Management Plan
- t B - Subpart 7 – Aesthetic Guidelines for Non-Station Structures
- t B - Subpart 8 – Cost and Scheduling Controls Program
- B3 - Pt B - Subpart 9 – Payment Milestone Data Pack Specifications
- B3 - Pt C - Subpart 1 – Design Criteria
- B3 - Pt C - Subpart 2 – CADD Manual
- B3 - Pt C - Subpart 3 – Plan Preparation Manual
- B3 - Pt D - Subpart 1 – Third Party Entities Master and Cooperative Agreement Updates
- Pt D - Subpart 2 – Approach for Obtaining ICS Environmental Approvals/Permits
- Pt D - Subpart 4 – Mitigation, Monitoring and Reporting Program
- Pt D - Subpart 5 – Design Variance Report
- Pt D - Subpart 6 – CP01 Transportation Mitigation
- Pt D - Subpart 7 – Draft Engineering and Construction UPRR Agreement
- B3 - Pt D - Subpart 7 – Caltrans and Railroad Agreements Caltrans SR99
- B3 - Pt D - Subpart 8 – City Fresno Design Guidelines Clarifications
- Pt E - Subpart 1 – Directive Drawings
- Pt E - Subpart 2 – Preliminary Ground Motion Data
- Pt E - Subpart 3 – Record of Survey and Control Monument Data
- Pt E - Subpart 4 – Right-of-Way Acquisition Plan
- B3 - Pt E - Subpart 5 – Geotechnical Baseline Report We American Avenue
- B3 - Pt E - Subpart 5 – Geotechnical Baseline Report Av

Environmental Documents

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DIVISION 02 – TECHNICAL GENERAL REQUIREMENTS AND EXISTING CONDITIONS
02 01 00 STANDARD SPECIFICATIONS GENERAL STATEMENTS
02 01 56.39 TEMPORARY TREE AND PLANT PROTECTION
02 21 13 SITE SURVEYS
02 21 23 FIELD ENGINEERING
02 21 33 PHOTOGRAPHIC DOCUMENTATION
02 22 00 EXISTING CONDITIONS ASSESSMENT
02 41 00 DEMOLITION

DIVISION 03 – CONCRETE
03 05 15 PORTLAND CEMENT CONCRETE
03 05 18 PRESTRESSED CONCRETE
03 11 00 CONCRETE FORMING
03 11 14 FALSEWORK
03 15 00 CONCRETE ACCESSORIES
03 15 13 WATERSTOPS
03 15 15 ELASTOMERIC BEARING PADS
03 15 23 CONCRETE ANCHORS
03 20 00 CONCRETE REINFORCING
03 30 00 CAST-IN-PLACE CONCRETE
03 35 00 CONCRETE FINISHING
03 37 13 SHOTCRETE
03 40 00 PRECAST CONCRETE
03 43 00 PRECAST CONCRETE SEGMENTAL CONSTRUCTI
03 62 00 NON-SHRINK GROUTING
03 70 00 MASS CONCRETE

DIVISION 05 – METAL
05 05 22 METAL WELDING
05 12 00 STRUCTURAL STEEL FRAMING
05 50 00 METAL FABRICATIONS
05 51 00 METAL STAIRS

DIVISION 07 – THERMAL AND MOISTURE PROTECTION
07 95 63 BRIDGE BEARINGS
07 95 66 BRIDGE EXPANSION JOINT ASSEMBLIES
07 95 73

DIVISION 09 – FINISHES
09 96 00 HIGH-PERFORMANCE COATINGS

DIVISION 31 – EARTHWORK
31 05 00 COMMON WORK RESULTS FOR EARTHWORK
31 09 13 GEOTECHNICAL INSTRUMENTATION AND MONITORING
31 11 00 CLEARING AND GRUBBING
31 23 19 DEWATERING
31 23 26 AGGREGATE DRAINAGE LAYER
31 35 00 SLOPE PROTECTION
31 35 33 TURF AND HYDROSEED SLOPE PROTECTION
31 38 13 REINFORCED SLOPES AND EARTH STRUCTURES
31 39 13 GROUND ANCHORS
31 50 13 TEMPORARY EXCAVATION SUPPORT AND PROTECTION
31 62 00 DRIVEN PILES
31 63 29 DRILLED CONCRETE PIERS AND SHAFTS

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32 11 23 AGGREGATE BASE COURSES
32 31 13 CHAIN LINK FENCES AND GATES
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DIVISION 33 – UTILITIES
33 05 16 UTILITY STRUCTURES
33 05 25 SUPPORT AND PROTECTION OF UTILITIES
33 05 28 TRENCHING AND BACKFILLING FOR UTILITIES
33 05 33 RELOCATION OF EXISTING UTILITIES
33 11 00 WATER UTILITY DISTRIBUTION PIPING
33 40 00 STORM DRAINAGE UTILITIES

Which of the 10,000+ of Requirements apply to the Project?

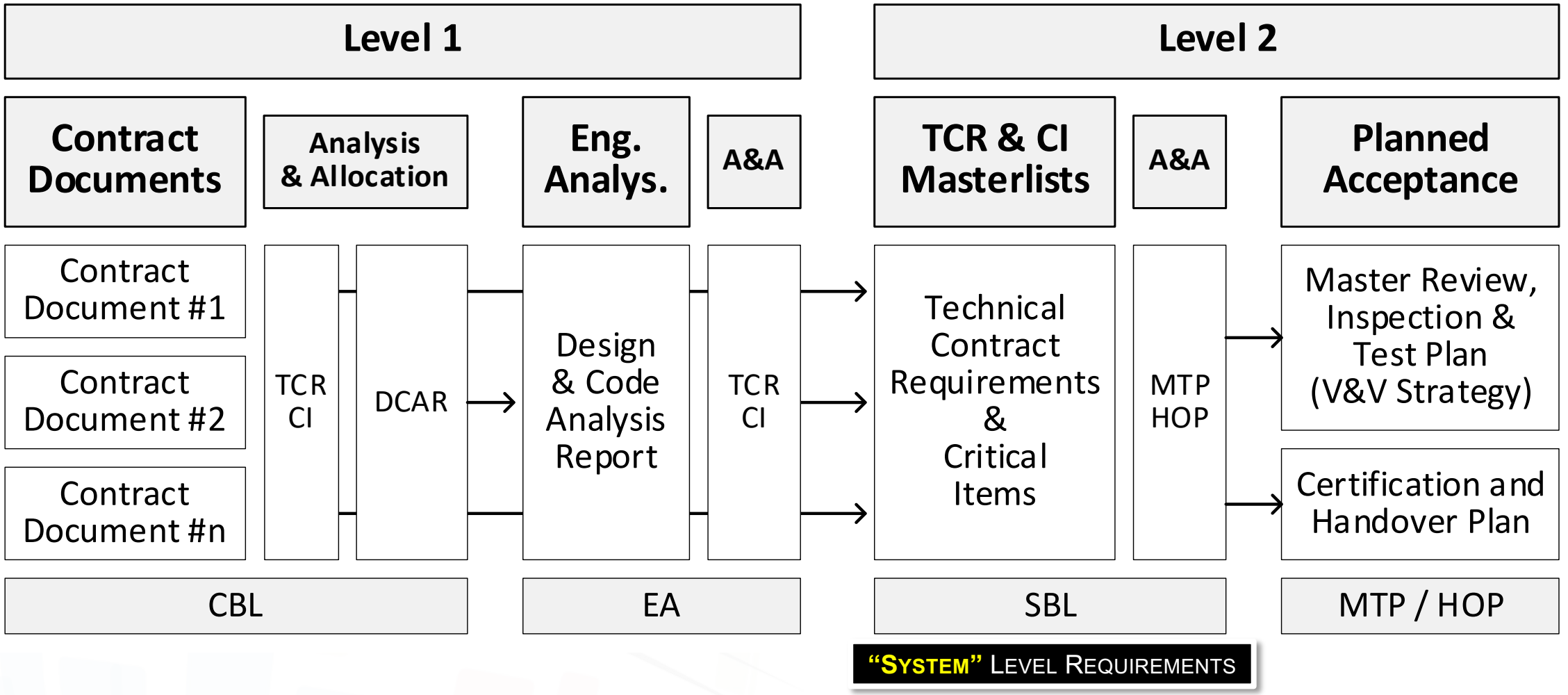
Recommendations: By SDLC Phase

RA Phase: Overview

- **Key Purpose & Activities:**
  1. Determine the governing (executed) contract documents (“baseline”)
  2. Perform initial engineering analyses such as the design and code analysis
  3. Establish a system requirements baseline (i.e., masterlist of all formally managed TCR and CI requirements, using the requirements management process & tools)
  4. Plan for design reviews, inspections, and testing
  5. Plan for the infrastructure certification and handover (e.g., to the next Contractor)
- **Key (SE) Deliverables:**
  1. Contract Requirements Baseline (CBL)
  2. Design and Code Analysis Report (DCAR)
  3. System Requirements Baseline
  4. Initial Master Review, Inspection, and Test Plan (MTP)
  5. Initial Certification and Handover Plan (HOP)
- **Review Milestone:**
  - System Requirements Review (SRR)

RECOMMENDATIONS: BY SDLC PHASE

RA PHASE: OVERVIEW (CONT'D)



Recommendations: By SDLC Phase

RA Phase: Summary

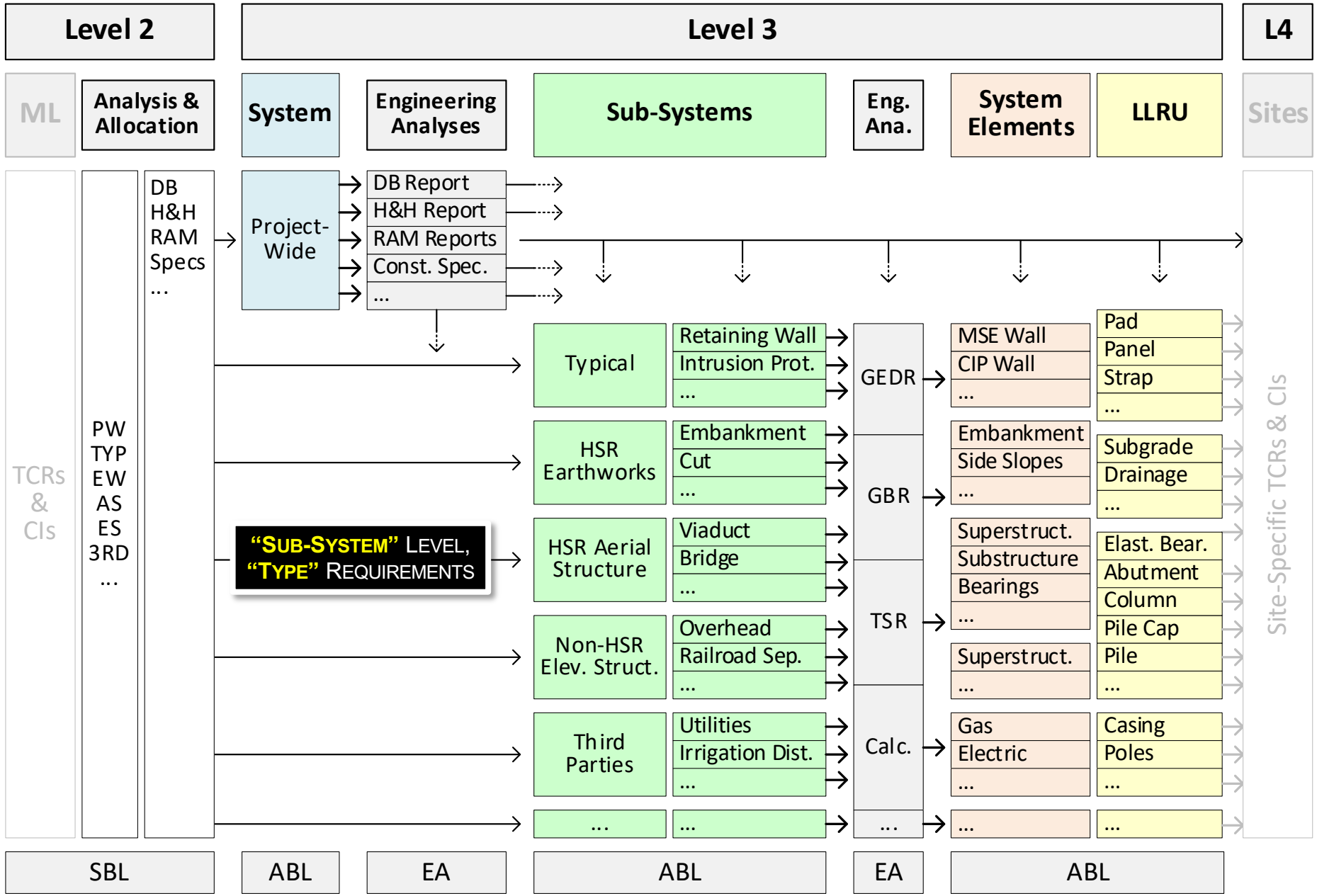
- **Key Recommendations:**
  - **Do** insist on formal requirements management
  - **Do not** let anybody convince you that they “know” or are “familiar with” with thousands of contract requirements, including all (100s to 1,000s of) contract changes over time
  - **Do** ensure the use of the correct contract document versions
  - **Do** use a risk-based approach selecting the contractual requirements subject to formal requirements management
  - **Do** clarify all referenced regulations, codes, standards, and guidelines
  - **Do** lock down the requirements (baselines) subject to requirements management
  - **Do** enforce strict configuration management
  - **Do not** allow uncontrolled requirements baseline changes
  - **Do** define for each requirement an initial verification and validation (V&V) method for both the design and construction phase (i.e., inspection, testing, demonstration, analysis)
  - **Do** require the contractor to think ahead of how the completed structures will eventually be transitioned and handed over to the owner, or to the next contractor
  - **Do not** accept any design submittals before the requirements analysis has been completed

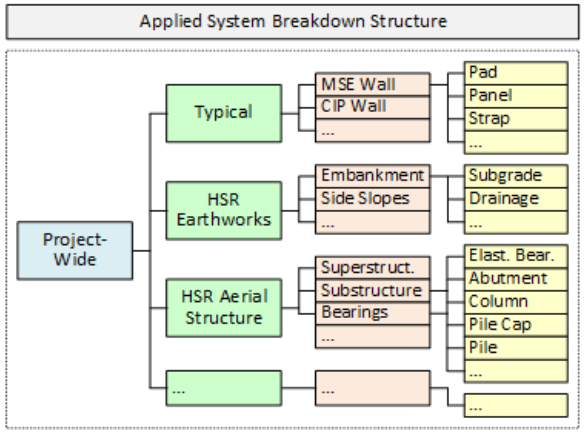
RECOMMENDATIONS: BY SDLC PHASE

DESIGN ANALYSIS (DA) PHASE: OVERVIEW

- **Key Purpose & Activities:**
  1. Decompose the system level (SBL) requirements into smaller, typical requirements subsets, incl.:
  2. Develop a system breakdown structure
  3. Analyze and allocate the system level requirements to the system breakdown structure elements
  4. Create requirements subsets using the allocated requirements
  5. Develop a site and submittal breakdown structure
  6. Perform infrastructure typical engineering analyses and incorporate the resulting requirements
- **Key (SE) Deliverables:**
  1. System Breakdown Structure (SBS)
  2. Site and Submittal Breakdown Structure (SSBS)
  3. Engineering Analyses (EA)
  4. Allocated Requirements Baseline (ABL)
  5. Updated SBL (requirements allocations) and MTP (planned objective evidence)
- **Review Milestone:**
  - Allocated Requirements Review (ARR)

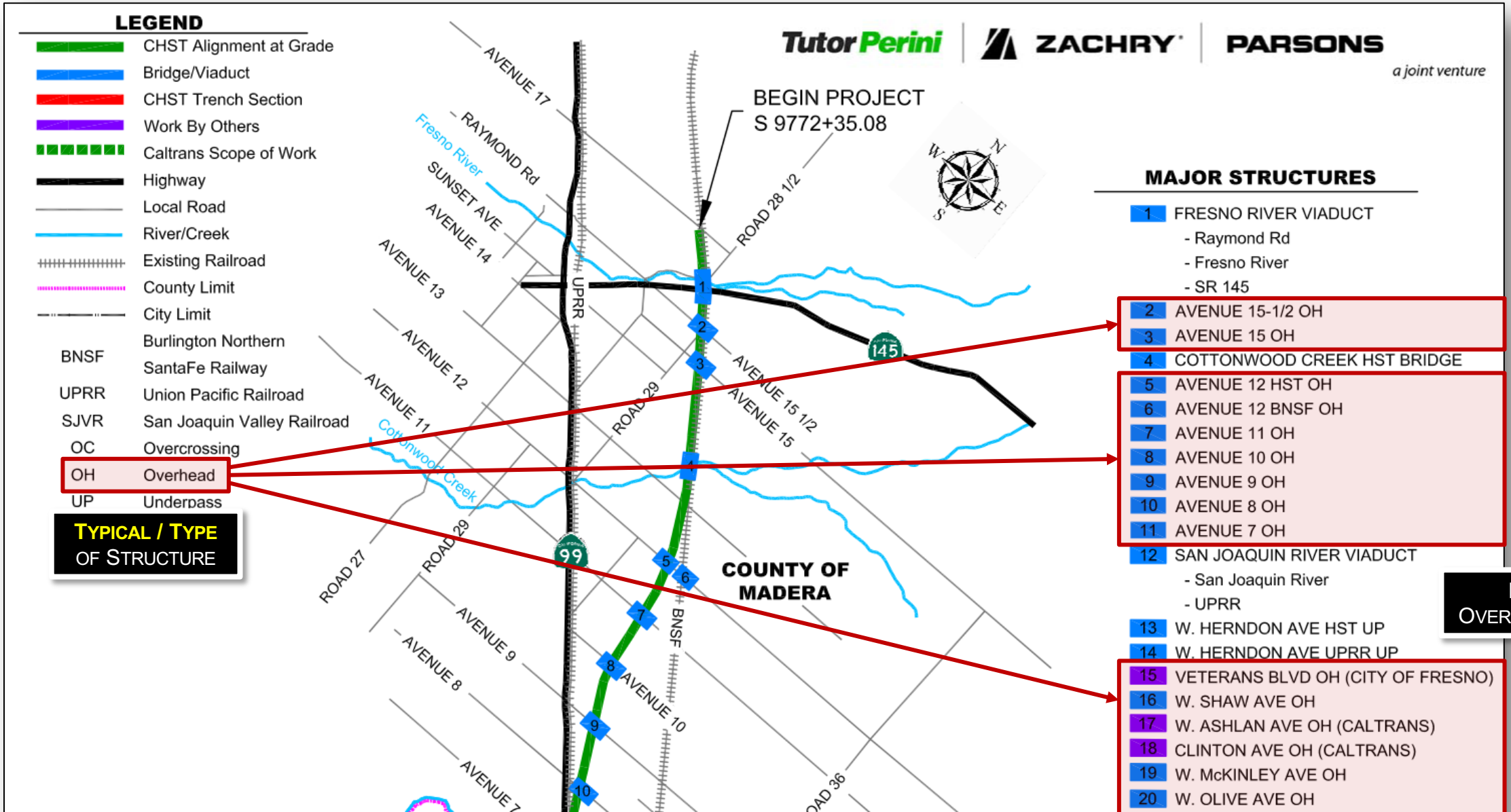
RECOMMENDATIONS: DA PHASE – OVERVIEW (CONT'D)





RECOMMENDATIONS: BY SDLC PHASE

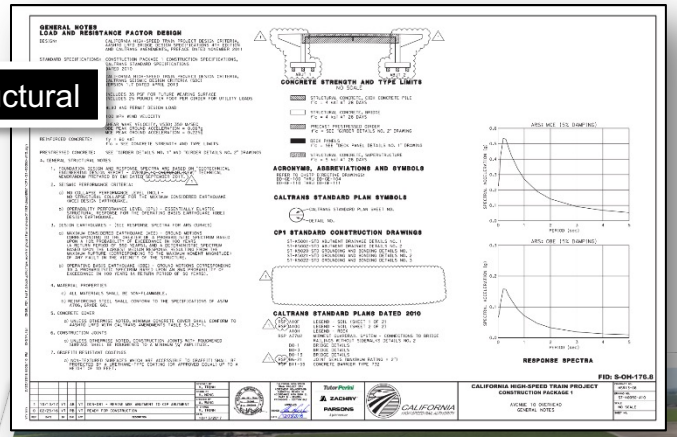
DA PHASE: TYPICAL STRUCTURES AND PLANNED SITES



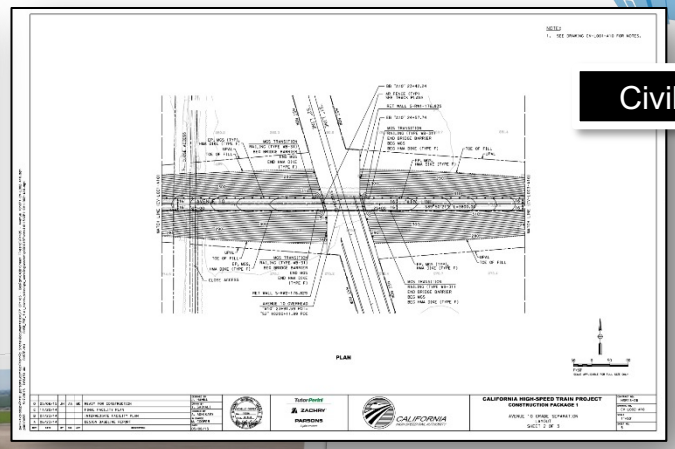
RECOMMENDATIONS: BY SDLC PHASE

DA PHASE: SITES & PLANNED DESIGN SUBMITTALS

Structural



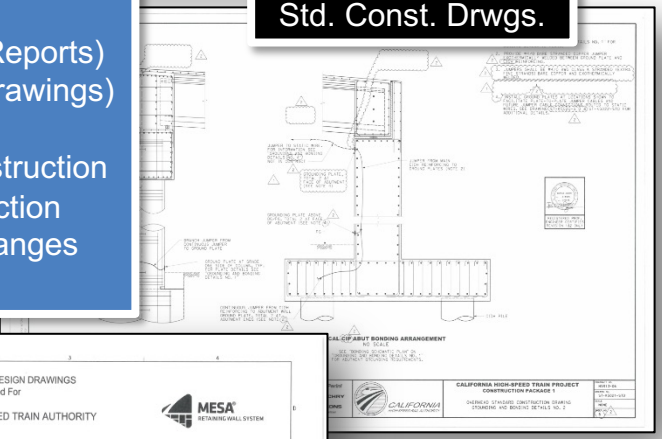
Civil



Submittals:

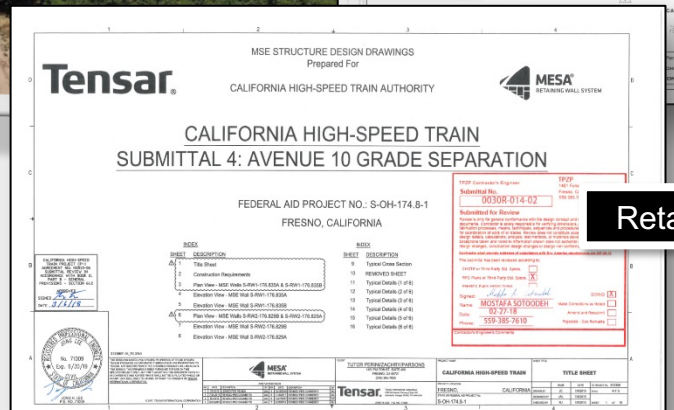
- Draft, Final (e.g., Reports)
- 60%, 90% (e.g., Drawings)
- Calculations
- Early Start of Construction
- Ready for Construction
- Design & Field Changes
- As-Builts

Std. Const. Drwgs.



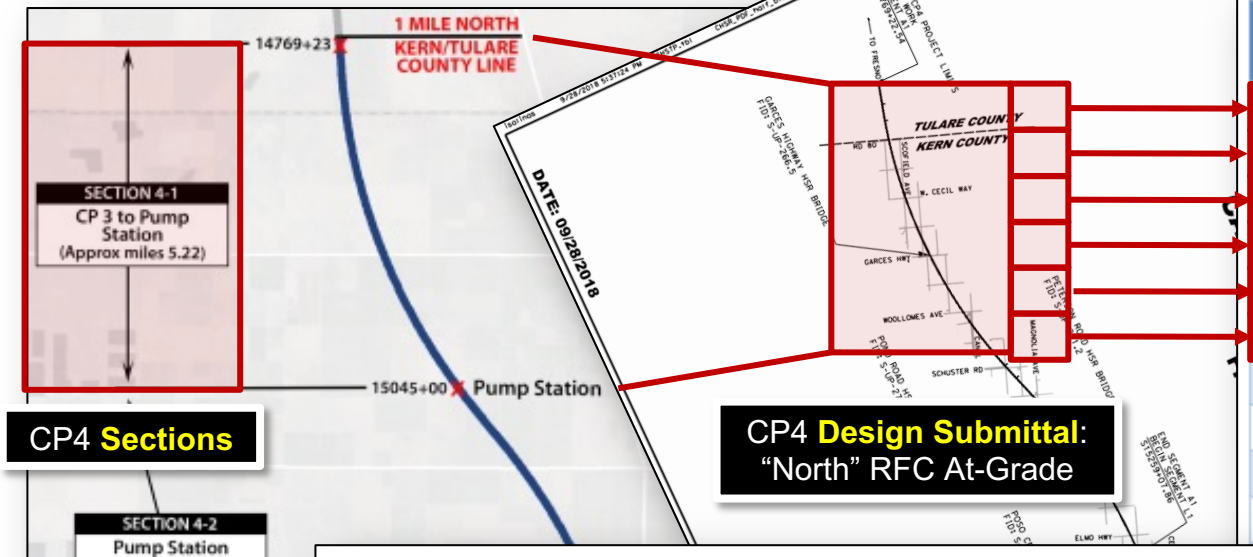
Geotechnical

Retaining Walls



RECOMMENDATIONS

PLANNED CONST. SECTIONS



CP4 **Sections**

CP4 **Design Submittal**: "North" RFC At-Grade

CONFLICT NO.	FACILITY	OWNER	QUALITY MILESTONE	STA (START)	STA (END)	CROSS STREET
6052	Irrigation	Semitropic	QMDP02	14822+00	14872+00	Scofield
6000	GW Well	Semitropic	QMDP02	14848+00	14848+00	Scofield
6001	Irrigation	Semitropic	QMDP02	14848+00	14875+25	Scofield
6050	Irrigation	Semitropic	QMDP02	14848+75	14848+75	Scofield
6002	Irrigation	Semitropic	QMDP02	14849+00	14875+00	Scofield
6051	Irrigation	Semitropic	QMDP02	14849+00	14849+00	Scofield
12000	Elec Dist.	PG&E	QMDP02	14849+20	14849+20	Scofield
12001	Elec Dist.	PG&E	QMDP02	14864+75	14876+25	Scofield
6053	Irrigation	Semitropic	QMDP02	14875+50	14875+50	Scofield
6054	Irrigation	Semitropic	QMDP03	14903+00	14903+00	North of Garces
6081	Farm Turnout	Semitropic	QMDP03	14903+00	14903+00	North of Garces
12003	Elec Dist.	PG&E	QMDP03	14903+50	14903+50	North of Garces
6083	Irrigation	Semitropic	QMDP03	14930+25	14930+25	Garces
6084	Farm Turnout	Semitropic	QMDP03	14930+25	14930+25	Garces

CP4 **Third Party** Submittals

QMDP: Quality Milestone Data Pack

#	Activity ID	QMDP #	Activity Name	Stationing
1	MIL_1285	QMDP 01	EOP to County Line	14769+23 - 14822+00
2	MIL_1290	QMDP 02	County Line to S Scofield	14822+00 - 14877+00
3	MIL_1295	QMDP 03	S Scofield to Garces Abut1	14877+00 - 14931+21
4	MIL_1145	QMDP 04	Garces Hwy Underpass	14931+21 - 14932+23
5	MIL_1300	QMDP 05	Garces Abut. 2 to Woollomes Ave	14932+23 - 14989+50
6	MIL_1305	QMDP 06	Woollomes Ave to Pump S	14989+50 - 15055+00
7	MIL_1310	QMDP 07	Pump Stat ion to S. Magnolia	15055+00 - 15096+50
8	MIL_13		Rd. Abut. #1	15096+50 - 15119+73
9	MIL_11			15119+72 - 15120+94
10	MIL_1320	QMDP 10	Pond Rd. Abut. 2 to Peterson Rd. Abut. 1	15120+94 - 15182+09
11	MIL_1155	QMDP 11	Peterson Rd Underpass	15182+09 - 15183+11
12	MIL_1325	QMDP 12	Peterson Rd. Abut. 1 to Elmo Hwy	15183+12 - 15242+00
13	MIL_1330	QMDP 13	Elmo Hwy to Sherwood Ave	15242+00 - 15294+50
14	MIL_1335	QMDP 14	Sherwood Ave to Poso Creek Abut. 1	15294+50 - 15329+88
15	MIL_1105	QMDP 15	Poso Creek Overpass	15329+89 - 15332+27
		MDP 16	Poso Creek Abut. 1 to Taussig Ave.	15332+27 - 15375+50
		MDP 17	Taussig Ave to Canal 9-22	15375+50 - 15426+88
		QMDP 18	Canal 9-22 to McCombs Ave.	15426+88 - 15505+00
19	MIL_1185	QMDP 19	McCombs Ave Overpass	15501+55 - 15501+95
20	MIL_1355	QMDP 20	McCombs Ave.to SR-46 Abut. 1	15509+00 - 15560+89
21	MIL_1095	QMDP 21	SR 46 Underpass	15560+89 - 15562+12
22	MIL_1360	QMDP 22	SR-46 Abut. 1 to Pedestrian Underpass	15563+00 - 15587+00
23	MIL_1085	QMDP 23	HST Pedestrian Underpass	15588+25 - 15590+25
24	MIL_1365	QMDP 24	Pedestrian Underpass to Poso Ave	15590+00 - 15614+00

HSR Earthworks

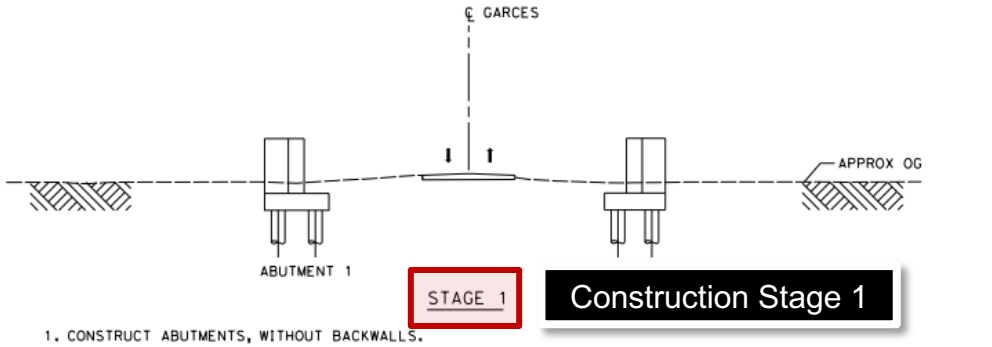
HSR Aerial Structure

HSR Earthworks

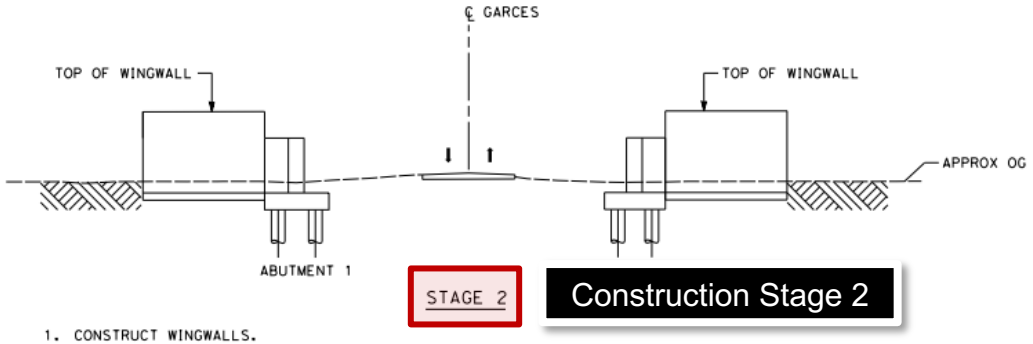
CP4 **Construction Submittals**: QMDP 01 ... QMDP 35

RECOMMENDATIONS: BY SDLC PHASE

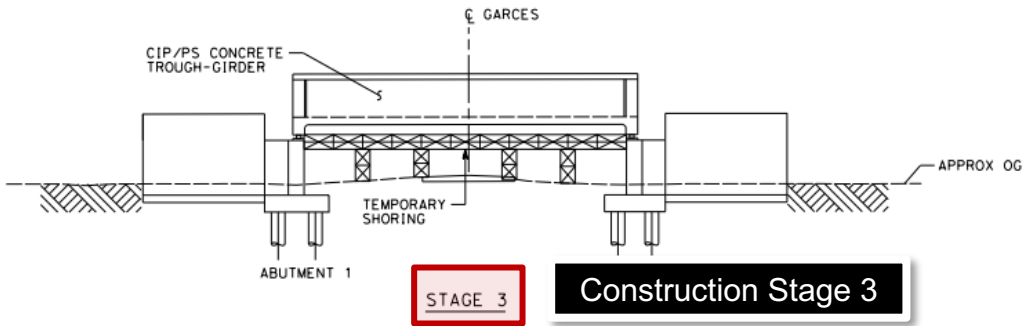
DA PHASE: PLANNED CONSTRUCTION STAGES



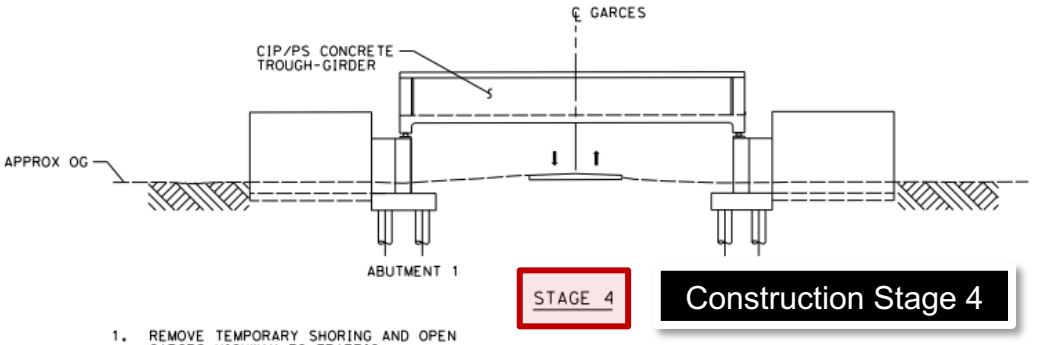
Construction Stage 1



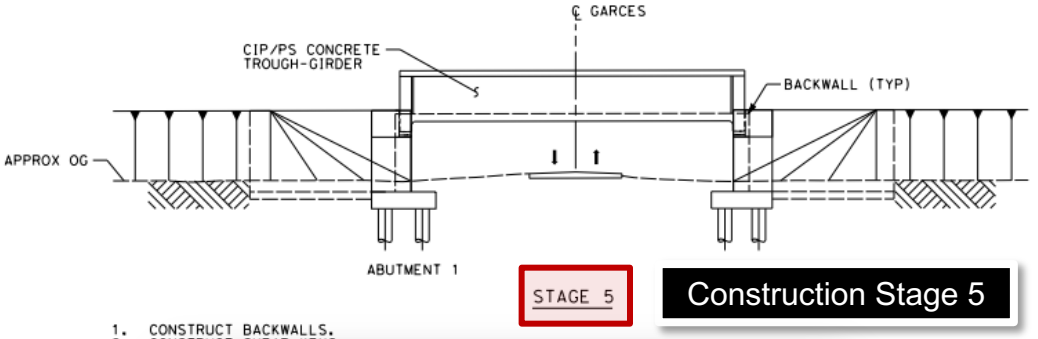
Construction Stage 2



Construction Stage 3



Construction Stage 4

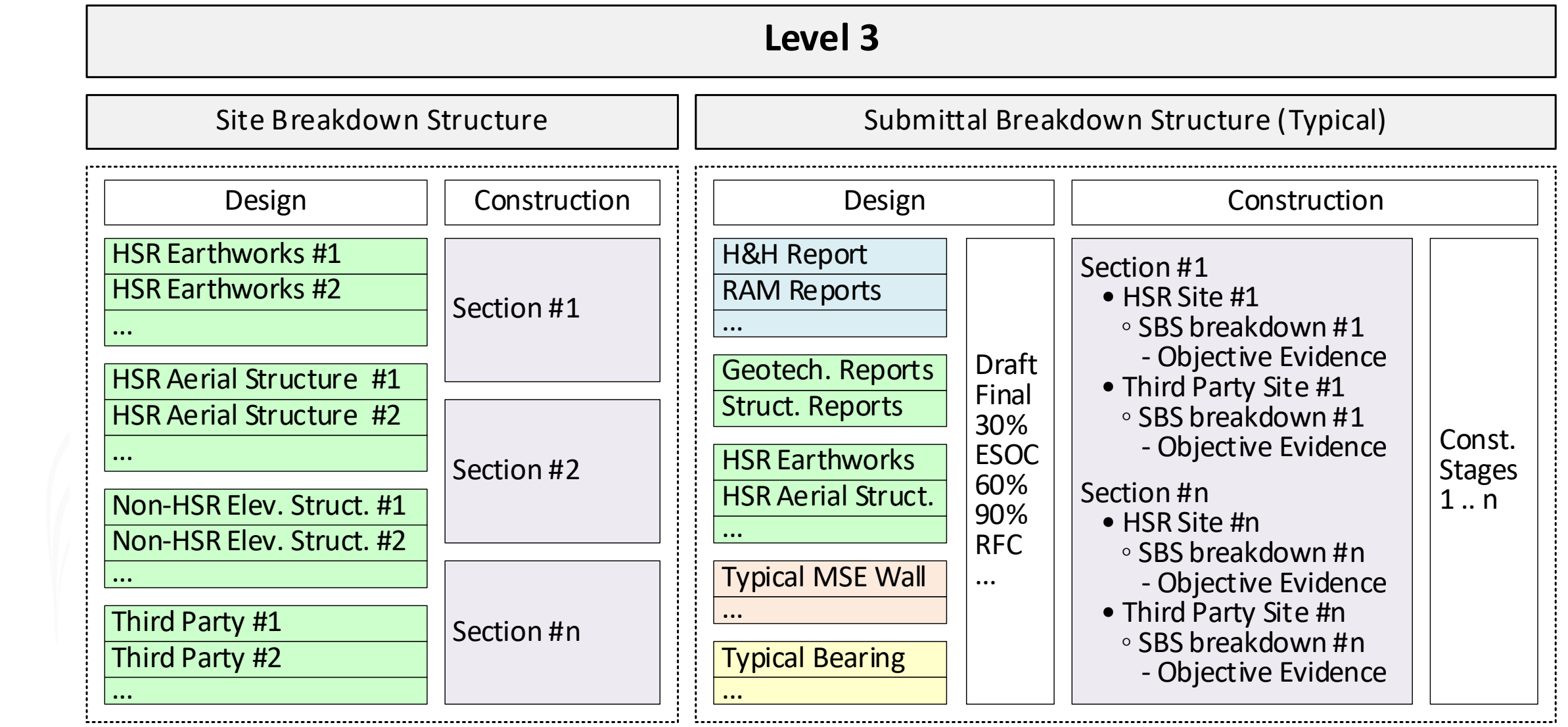


Construction Stage 5

Completed Structure

RECOMMENDATIONS: BY SDLC PHASE

DA PHASE: SITE & SUBMITTAL BREAKDOWN STRUCTURE (SSBS)



RECOMMENDATIONS: BY SDLC PHASE

DA PHASE: SUMMARY

- **Key Recommendations:**
  - **Do** decompose the system level requirements into smaller, better manageable and typical requirements subsets aligned with the planned design and construction submittals
  - **Do** break down the project (“system”) into subsystems, system elements, and lowest level replacement units using the system breakdown structure (SBS)
  - **Do** identify all planned design and construction sites and associated submittals using the site and submittal breakdown structure (SSBS)
  - **Do** use the SBS & SSBS as the basis for system level requirements analysis and allocation, resulting in the allocated requirements baseline (ABL)
  - **Do** integrate the resulting (derived) engineering analyses requirements (e.g., from hydrology & hydraulics reports, type selection reports, RAM analysis, etc.) into the requirements subsets (ABL)
  - **Do** update the initial MTP (developed during the RA phase) with planned objective evidence
  - **Do** use the ABL as the basis for design (by the Contractor)
  - **Do** use the ABL as the basis for performing design reviews, inspections and testing (by Oversight)
  - **Do** lock down (baseline) all breakdown structures (e.g., SBS, SSBS), engineering analyses, requirement baselines (e.g., SBL, ABL), and other key deliverables (e.g., MTP)
  - **Do** enforce strict configuration management, allowing only controlled changes
  - **Do not** accept any preliminary or final design submittals before the design analysis has been completed

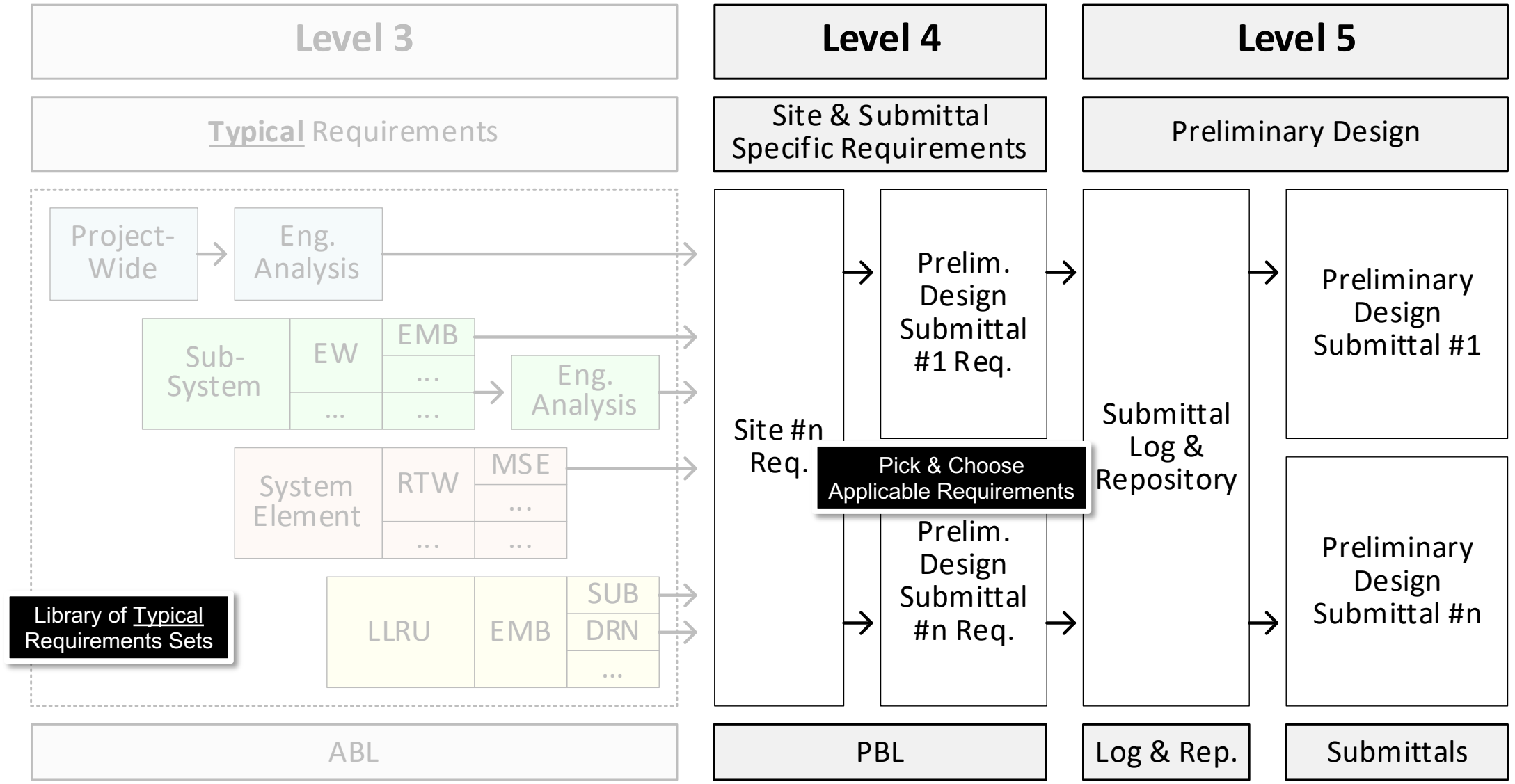
Recommendations: By SDLC Phase

Preliminary Design (PD) Phase: Overview

- **Key Purpose & Activities:**
  1. Develop the preliminary design in conformance with the allocated site and submittal-specific requirements
  2. Preliminary design may range from anywhere in between 10% to 90% design development
  3. Perform infrastructure typical engineering analyses and incorporate the resulting requirements
- **Key (SE) Deliverables:**
  1. PD phase specific engineering analyses (e.g., draft construction specifications)
  2. Preliminary design requirements baseline (PBL, site & submittal specific requirements subsets)
  3. Updated MTP (inspection & test plan [ITP] allocations)
  4. Submittal log & repository
  5. Preliminary design submittals
- **Review Milestone:**
  - Preliminary Design Review (PDR)

RECOMMENDATIONS: BY SDLC PHASE

PD PHASE: OVERVIEW (CONT'D)



Recommendations: By SDLC Phase

PD Phase: Requirements Traceability to Submittals

Requirements Verification Traceability Matrix (RVTM), Certifiable Items List (CIL)

Requirements				Planned OE (per MTP)		Actual OE (Submittal)			
ID	**Doc**	**Sec.**	**Req.**	**V&V Method**	**Obj. Evidence**	**ID**	**Name**	**Reference**	**Rev.**
1	GP	1.0 ...	TCR #1	Inspection	Cross Sections	1	Subm. U	DG-CS-01	1.0
2	SoW	2.0 ...	TCR #2	Analysis	Calcuation	2	Subm. V	Section X	2.0
3	DCM	3.0 ...	TCR #3	Demonstration	Witness Report	3	Subm. W	Section Y	3.0
4	EA	4.0 ...	TCR #4	Test	Test Report	4	Subm. X	Section Z	4.0
n	Other	x.0 ...	TCR #n	...	...	m	...	...	x.0

Technical Contract Requirements (TCR), Critical Items (CI)

Planned Objective Evidence (OE)

Submittal Log

Reference & Traces to Actual Submittal

RECOMMENDATIONS: BY SDLC PHASE

PD PHASE: REQUIREMENTS TRACEABILITY TO SUBMITTALS (CONT'D)

	Subm-ID	Subm-Name	Drwg-ID	Drawing Name	Drwg-Rev
1 Design Criteria					
1.2 Basis of Design					
1.2.2 Design Criteria Elements					
1.2.2.3 Train Operation					
1.2.2.3.6 Operating and Design Speed					
The System design speed shall be 250 mph.	14060	GDW01	TT-D0001	TRACK GUIDEWAY - HORIZONTAL ALIGNMENT DATA TABLE	0
			TT-E6001	TRACK CHART - SHEET 1 OF 13	0
			TT-E6002	TRACK CHART - SHEET 2 OF 13	0
			TT-E6003	TRACK CHART - SHEET 3 OF 13	0
			TT-E6004	TRACK CHART - SHEET 4 OF 13	0
1.29 Geotechnical					
1.29.2 Design Criteria Elements					
1.29.2.6 Earthworks					

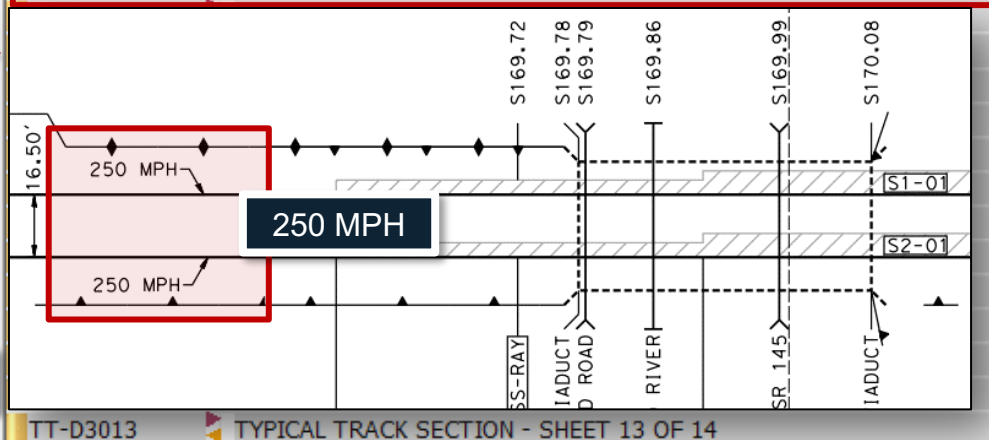
Submittal

Reference & Trace to Drawings, Document Sections, etc.

Submittal Log	Subm-ID	Sub Name (Short)	Sub Name (Full)
1 Submittal Log			
1.3 HSR Earthworks			
1.3.1 EW-EMB-SITE01	---	---	---
RFC	14060	GDW01	Guideway Package 1, RFC
1.4 HSR Aerial Structure			
1.4.1 AS-VD-SITE01	---	---	---
RFC	11893	FRV, RFC	Fresno River Viaduct, RFC
Drawings			
V&V Submittal			
Certification of Compliance			

Submittal Log

Drawing #	Drawing Name
GE-D0001	COVER SHEET
...	...
TT-D0001	TRACK GUIDEWAY - HORIZONTAL ALIGNMENT DATA TABLE
TT-E6001	TRACK CHART - SHEET 1 OF 13
TT-E6002	TRACK CHART - SHEET 2 OF 13
TT-E6003	TRACK CHART - SHEET 3 OF 13
TT-E6004	TRACK CHART - SHEET 4 OF 13



Submittal Repository

RECOMMENDATIONS: BY SDLC PHASE

PD PHASE: SUMMARY

- **Key Recommendations:**
  - **Do** develop site & submittal specific requirements from the typical requirements set (by Contractor)
  - **Do not** accept any design submittal before the RA and DA phase have been completed
  - **Do not** accept preliminary design submittals for elements (e.g., HSR aerial structures, bridge bearings) and sites (e.g., Fresno River Viaduct) that have not previously been identified in the SBS and SSBS
  - **Do** require preliminary design submittals to be accompanied by a V&V report including completed RVTMs and CILs (see prior slides)
  - **Do** insist that RVTM and CIL references and traces are being provided to the lowest practical level (i.e., to a specific drawing number, document section, page numbers, etc.).
  - **Do** check that the referenced and traced objective evidence (design submittal) demonstrates compliance to the respective requirements
  - **Do** not allow objective evidence "data dumps", where more evidence is provided than needed, with the burden on the owner to search for relevant evidence, having to identify potential errors and omissions
  - **Do not** allow references to other submittals ("spaghetti" tracing)
  - **Do** require a well-organized and hierarchically structured submittal log in the RM tool
  - **Do** require a submittal repository in the RM tool, containing for each submittal a digital RM tool representative in form of a simple document outline (e.g., table of contents), drawing list, etc.
  - **Do** define the maximum number of submittals allowed at any given time

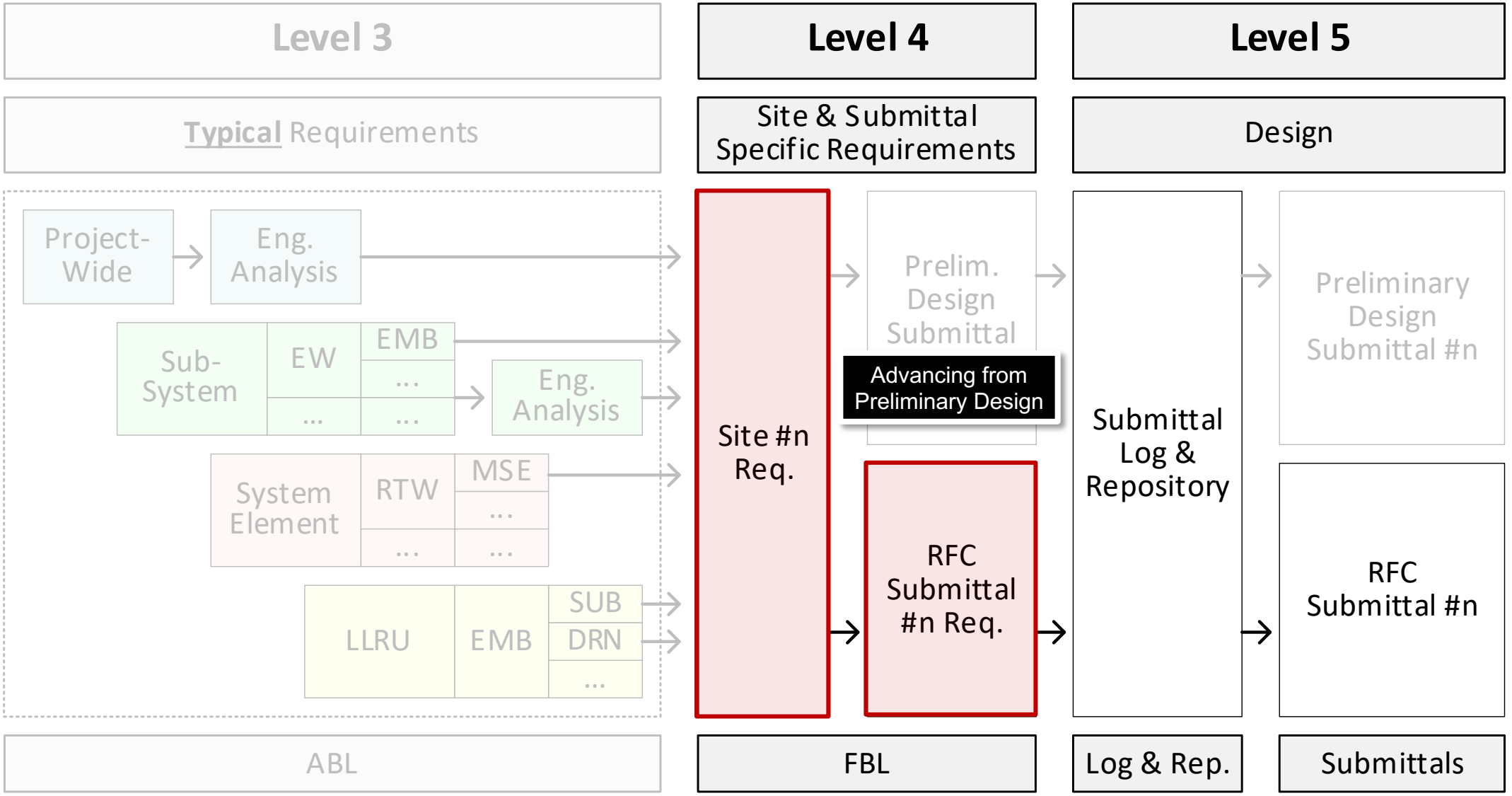
Recommendations: By SDLC Phase

Ready for Construction (RFC) Phase: Overview

- **Key Purpose & Activities:**
  1. Advance the preliminary design into the final design documents required for construction, including:
     a) Construction plans (drawings), and
     b) Construction specifications
  2. Provision of RFC certifications
- **Key (SE) Deliverables:**
  1. RFC phase specific engineering analyses (e.g., final construction specifications)
  2. Final design requirements baseline (FBL)
  3. Updated MTP (inspection & test procedure allocations)
  4. Updated submittal log & repository
  5. RFC submittals
  6. RFC certifications
- **Review Milestone:**
  - Final Design Review (FDR)

RECOMMENDATIONS: BY SDLC PHASE

RFC PHASE: OVERVIEW (CONT'D)



RECOMMENDATIONS: BY SDLC PHASE

RFC PHASE: SUMMARY

- **Key Recommendations:**
  - **Do** apply all preliminary design phase recommendations
  - **Do** expect Contractors to declare “ready for construction” early with only partial design submittals (e.g., early start of construction [ESOC], early foundation packages, early construction work [e.g., demolition], or similar)
  - **Do** ensure that “early construction” submittals have been identified in the SSBS (DA phase), the corresponding typical requirements subsets have been prepared (DA phase) and are being used as the submittal specific requirements for the early RFC design submittals (RFC phase)
  - **Do** require RFC design certifications (by both contractor and independent V&V, if available), certifying compliance with all contract requirements
  - **Do** apply a “trust but verify” approach, whereby the certifications (“trust”) are supported by objective evidence (“verify”), in the form of V&V reports containing the completed RVTMs & CILs
  - **Do** have the certification reports developed directly from the CIL, by attaching the referenced objective into standalone certification reports (e.g., safety & security certification report [SSCR], interface control documents [ICD], environmental certification reports, etc.)
  - **Do not** allow any critical engineering analysis (e.g., RAM) to slip beyond the PD and RFC phase(s). Once construction begins, there is practically no way to “check” new design requirements into the constructed structures

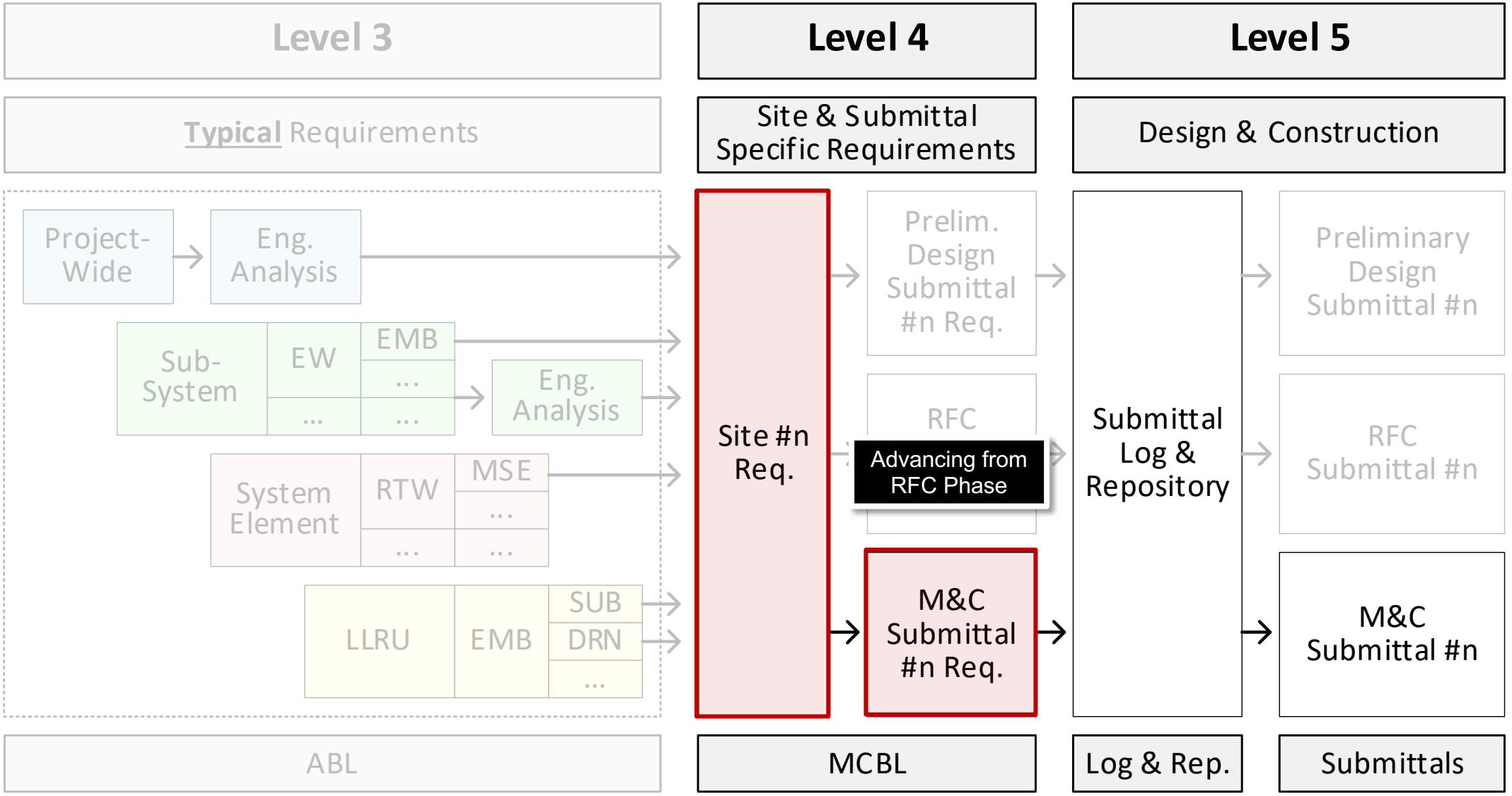
Recommendations: By SDLC Phase

Manufacturing and Construction (M&C) Phase: Overview

- **Key Purpose & Activities:**
  1. Manufacture and construct the project in conformance with the RFC design and contract requirements, followed by the construction certification.
  2. Manufacturing may occur in a/the factory or in the field (e.g., pre-cast concrete), while construction typically occurs on site (e.g., cast in place concrete)
  3. Provision of Construction certifications
- **Key (SE) Deliverables:**
  1. M&C requirements baseline (extended/updated FBL)
  2. Updated MTP (traces to inspection & test plans, procedures, and results)
  3. Updated submittal log & repository
  4. M&C phase and stage submittals (representing the constructed infrastructure)
  5. M&C certifications
- **Review Milestone:**
  - Construction Stage Reviews (CSR)

RECOMMENDATIONS: BY SDLC PHASE

M&C PHASE: OVERVIEW (CONT'D)



RECOMMENDATIONS: BY SDLC PHASE

M&C PHASE: SUMMARY

- **Key Recommendations:**
  - **Do** recognize the project delivery method (e.g., design-bid-build, design-build, etc.)
  - **Do** facilitate a knowledge transfer from the designer to the builder (typically different firms)
  - **Do** clearly define the construction stages and associated requirements, the planned objective evidence, and the planned construction phase submittals demonstrating compliance to these requirements
  - **Do** expect that during construction requirements, breakdown structures, baselines, various test plans and procedures, and RFC designs will be subject to constant design and field changes. Establish and enforce a strict configuration management process
  - **Do** require all construction phase and stage submittals – including all inspection and test plans and procedures – to be accompanied by a submittal specific V&V report
  - **Do** create logically organized construction quality records in the format, order, and content as required to readily demonstrate compliance to the allocated requirements
  - **Do** assume there will be 1000+ construction quality records per structure. Establish a commonly shared, structured, and hierarchically organized construction quality record repository based on the system breakdown structure, making the quality records easily locatable and retrievable for V&V purposes
  - **Do not** wait until the end of construction to receive any official construction quality record submittal, including the as-built drawings. Require interim construction stage submittals
  - **Do** have enough “boots on the ground” to confirm that the construction quality records reflect the state of construction, and that no changes have occurred after the as-builts have been submitted.

Recommendations: By SDLC Phase

Certification and Handover (HOP) Phase: Overview

- **Key Purpose & Activities:**
  1. Certify to the owner and/or any authorities having jurisdiction (AHJ, e.g., fire marshals) that the designed and constructed infrastructure:
     a) Meets the contractual requirements
     b) Is safe and secure, and
     c) Is fit for purpose (e.g., operation, handover to other contractors in larger programs)
- **Key (SE) Deliverables:**
  1. Final/updated certification and handover plan
  2. Contractor certifications of compliance (CoC)
  3. Independent V&V (ICE/ISE) assessment reports & CoCs
  4. Updated submittal log & repository
  5. Certification metrics
- **Review Milestone:**
  - Certification and Handover Review (CHR).

RECOMMENDATIONS: BY SDLC PHASE

HOP PHASE: SUMMARY

- **Key Recommendations:**
  - **Do** plan ahead. Create a certification and handover plan, starting at the beginning of the project (RA phase)
  - **Do not** use this phase to identify certification stakeholders, discover late requirements, or review design and/or construction submittals for the first time
  - **Do** track the requirements subject to certification using the certifiable items list [CIL], starting at the beginning of the project (RA phase)
  - **Do** determine any particular certification report deliverable requirements (e.g., standalone safety & security certification report, interface control documents, environmental certification reports, etc.)
  - **Do** align the structures/elements subject to certification with the SBS and SSBS
  - **Do** consider that the project may not be certified and handed over in one activity at the project end
  - **Do** plan for partial use and possession prior to final completion, possibly even applied to individual structures (e.g., early openings), requiring partial or conditional certifications
  - **Do** enforce the “trust but verify” approach for certifications (see RFC phase)
  - **Do** include in the certification and handover plan any applicable operations and maintenance requirements (e.g., O&M documentation, procedures, training, asset management considerations, etc.)

PROGRESS

- **Background & Introduction**
  - Motivation
  - Infrastructure & Transportation Project
  - U.S. Infrastructure & Transportation Industry
  - Advice for Systems Engineers New to the Industry
  - Intended Audience
- **Lessons Learned**
  - Initial Systems Engineering Requirements & Results
  - Key Lessons Learned
- **Recommendations**
  - Refining & Tailoring the Systems Engineering Requirements
  - Systems Development Life Cycle (SDLC) Model & Phases
  - Recommendations by Phase
- **Summary & Conclusion**

SUMMARY & CONCLUSION

BACKGROUND & INTRODUCTION
MOTIVATION: MEMORIALIZING 10+ YEARS OF PRACTICAL EXPERIENCE

2012 — Entering a Brave New World
Applying Systems Engineering to American Infrastructure Projects
Case Study: California High-Speed Train Project

2014 — On Motivating People to Implement Systems Engineering
Getting from the Necessary to the Impossible

2017 — I DON'T NEED REQUIREMENTS – I KNOW WHAT I'M DOING!

2018 — SAN DIEGO, WE DO NOT HAVE A PROBLEM!
SE LEADERSHIP IN THE CONSTRUCTION INDUSTRY

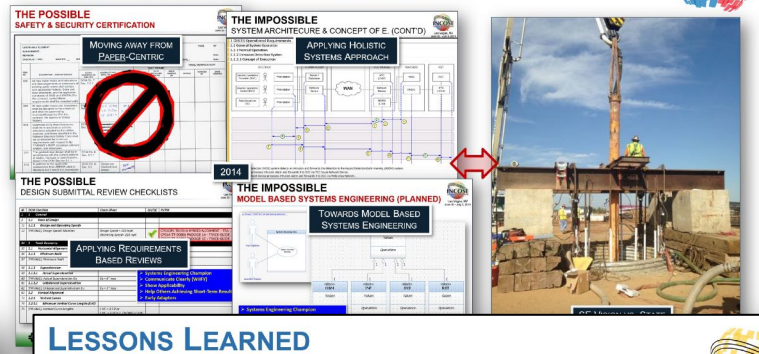
2020 — Case Study: Achieving System Integration through Interoperability in a large System of Systems (SoS)

2021 — Demonstrating the Value of Systems Engineering as the Professional Standard of Care

2022 — Case Study: Using Digital Threads in a large System of Systems (SoS) for System Certification

1. LESSONS LEARNED FROM CA-HIGH-SPEED RAIL CONSTRUCTION PACKAGES 1,2/3,4 (2010-2022)
2. REFINING SE PROCESS BASED ON LESSONS LEARNED
3. THREE NEW CONTRACTS ISSUED IN 2022
4. CHANGE IN HSR ENGINEERING CONSULTANTS
5. MEMORIALIZING PRACTICAL, HANDS-ON EXPERIENCE
6. $1 TRILLION U.S INFRASTRUCTURE BILL

BACKGROUND & INTRODUCTION
U.S. INFRASTRUCTURE & TRANSPORTATION INDUSTRY

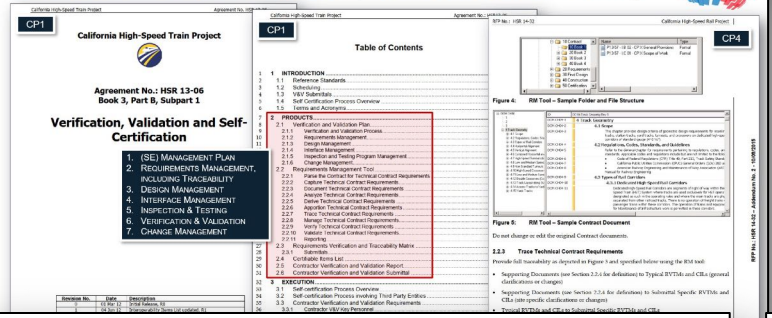


BACKGROUND & INTRODUCTION
ADVICE FOR SYSTEMS ENGINEERS NEW TO THE INDUSTRY

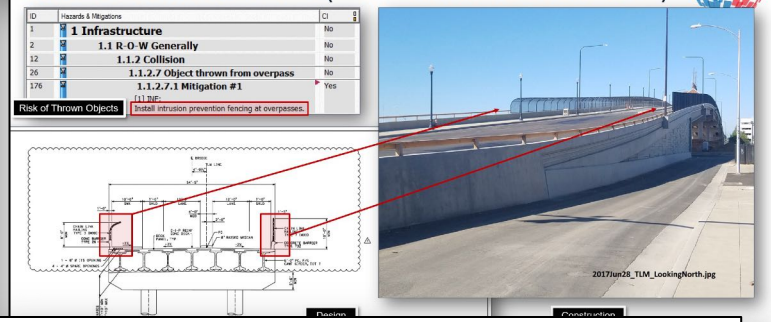
Disincentives for Systems Engineering: Any design & construction firm proposing additional, unsolicited work (i.e., SE as an upfront investment) in a firm-fixed price and low-bid environment will be at a **competitive disadvantage** due to increased bid costs and may consequently lose the bid.

Topic	Advice, Common Infrastructure & Transportation Observations
Nomenclature & Terminology	Learn the language to communicate effectively
Systems Engineering	Considered not applicable (misunderstood as the engineering of systems)
Systems Engineer Position/Role	Does not exist. Expect highly functional / stovepiped organizations
Stakeholders	Other/third parties requiring coordination with (e.g., regulators, utilities)
Operations & Maintenance	Happens after design and construction, taken care of "by others"
Requirements	Are expected "to be known" or "to be familiar with" ("I know what I am doing")
Architecture	The art or practice of designing and constructing buildings
Integration	Happens after design and construction, taken care of by an integrator
Verification & Validation (V&V)	Confusing to industry, use of quality mgmt. instead, avoidance of transparency
Fi… Fixed Price, Low Bid Contracts	Expect delivery of fixed scope and low bid quality, every change … big $$$
Pr…	

LESSONS LEARNED
INITIAL SYSTEMS ENGINEERING REQS. ("VERIFICATION & VALIDATION")



LESSONS LEARNED
RESULTS: SAFETY REQUIREMENTS (MITIGATIONS FROM HAZARD ANALYSIS)

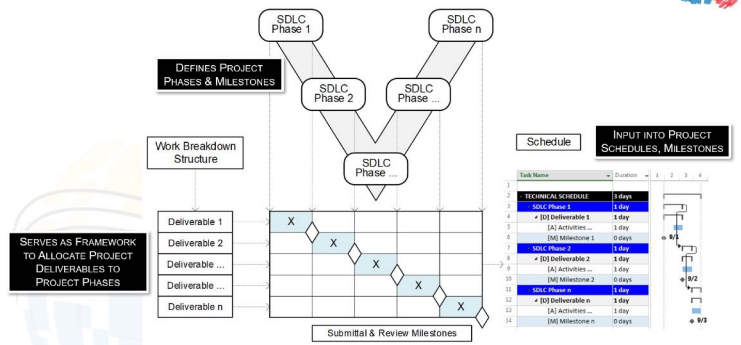


LESSONS LEARNED
KEY LESSONS

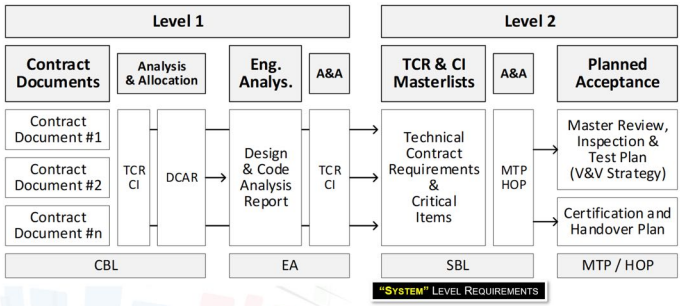
SDLC: SYSTEMS DEVELOPMENT LIFE-CYCLE REQUIREMENTS (UPDATED V&V REQUIREMENTS BASED ON LESSONS LEARNED)

Topic	Challenge(s)	Lesson Learned, SDLC Updates
Ability and willingness to implement SE	– Incomplete, incorrect, inconsistent, and/or delayed SE implementation	– Additional training requirements – Additional process detail – More detailed technical guidance – SDLC milestones tied to payment milestones (Enforcement)
"Leave it to the contractor" mentality	– Each CP developed differently, inconsistent SE implementations	– SDLC as CHSRS standard – RM tool handbook and model (CHSRS, 2022)
Governing requirements	– Continuous discussions of applicable requirements – Moving targets – Uncontrolled changes	– SDLC phases & associated requirements baselines – Strengthened configuration management
Breakdown structures, allocated requirements	– Incomplete and changing breakdown structures – Late discovery of system elements – Requirement allocation	– SDLC phases & associated deliverables – System breakdown structure – Site breakdown structure – Submittal breakdown structure
RAM	– See first bullet (SE)	– See first bullet (SE)

RECOMMENDATIONS: SDLC MODEL
SYSTEMS DEVELOPMENT LIFE CYCLE (SDLC) MODEL



RECOMMENDATIONS: BY SDLC PHASE
RA PHASE: OVERVIEW (CONT'D)



RECOMMENDATIONS: BY SDLC PHASE
RFC PHASE: SUMMARY

- **Key Recommendations:**
  - **Do** apply all preliminary design phase recommendations
  - **Do** expect Contractors to declare "ready for construction" early with only partial design submittals (e.g., early start of construction [ESOC], early foundation packages, early construction work [e.g., demolition], or similar)
  - **Do** ensure that "early construction" submittals have been identified in the SSBS (DA phase), the corresponding typical requirements subsets have been prepared (DA phase) and are being used as the submittal specific requirements for the early RFC design submittals (RFC phase)
  - **Do** require RFC design certifications (by both contractor and independent V&V, if available), certifying compliance with all contract requirements
  - **Do** apply a "trust but verify" approach, whereby the certifications ("trust") are supported by objective evidence ("verify"), in the form of V&V reports containing the completed RVTMs & CILs
  - **Do** have the certification reports developed directly from the CIL, by attaching the referenced objective into standalone certification reports (e.g., safety & security certification report [SSCR], interface control documents [ICD], environmental certification reports, etc.)
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