SoSECIE Webinar

Welcome to the
2020 System of Systems Engineering Collaborators
Information Exchange (SoSECIE)

We will start at 11AM Eastern Time

You can download today's presentation from the SoSECIE Website:

https://mitre.tahoe.appsembler.com/blog

To add/remove yourself from the email list or suggest a future topic or speaker, send an email to sosecie@mitre.org

NDIA System of Systems SE Committee

- **Mission**
  - To provide a forum where government, industry, and academia can share lessons learned, promote best practices, address issues, and advocate systems engineering for Systems of Systems (SoS)
  - To identify successful strategies for applying systems engineering principles to systems engineering of SoS
- **Operating Practices**
  - Face to face and virtual SoS Committee meetings are held in conjunction with NDIA SE Division meetings that occur in February, April, June, and August

NDIA SE Division SoS Committee Industry Chairs:
Mr. Rick Poel, Boeing
Ms. Jennie Horne, Raytheon
OSD Liaison:
Dr. Judith Dahmann, MITRE

Simple Rules of Engagement

- I have muted all participant lines for this introduction and the briefing.
- If you need to contact me during the briefing, send me an e-mail at sosecie@mitre.org.
- Download the presentation so you can follow along on your own
- We will hold all questions until the end:
  - I will start with questions submitted online via the CHAT window in Teams.
  - I will then take questions via telephone; State your name, organization, and question clearly.
- If a question requires more discussion, the speaker(s) contact info is in the brief.

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2021-2022 System of Systems Engineering Collaborators Information Exchange Webinars

Sponsored by MITRE and NDIA SE Division

January 26, 2021
Addressing the Sustainable Development Goals with a System-of-Systems for Monitoring Arctic Coastal Regions
Evelyn Honoré-Livermore, Roger Birkeland and Cecilia Haskins

February 23, 2021
Interface Management- the Neglected Orphan of Systems Engineering
Paul Davies

March 9, 2021
Distributed Architecture for Monitoring Urban Air Quality: A Systems Engineering Approach
Adrián Unger, Tom McDermott and Philip Dewire

April 6, 2021
Holistic architecture description for a future Global Health Assurance Systems of Systems
Adrián Unger

30th Annual INCOSE
international symposium

Virtual Event
July 20 - 22, 2020

July 22, 2020: 17:50-18:30 South Africa Standard Time (Track 2, Session 9.2.3)

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

Oliver Hoehne, PMP, CSEP, CSM
Technical Fellow, Systems Engineering
WSP USA
oliver.hoehne@wsp.com

www.incose.org/symp2020

AGENDA

- **Introduction**
  - System of Systems (SoS)
  - California High-Speed Rail System (CHSRS) Program
  - CHSRS as a System of Systems
- **SoSE Challenges Faced**
  - Traditional Industry Approach to Systems Integration
  - SoS Engineering Challenges
- **SoSE Activities Performed**
  - International Best Practice Analysis of HSR System Integration
  - SoS Integration Strategy
  - Step by Step Process Description
- **Summary, Achieved Outcomes & Conclusion**

Introduction: System of Systems

SoS Definition & Characteristics

ISO/IEC/IEEE 15288, 2015, Annex G

ISO/IEC/IEEE 15288:2015(E)

Annex G
(informative)

Application of system life cycle processes to a system of systems

G.1 Introduction

A system of systems (SoS) is a system-of-interest (SOI) whose elements are themselves systems. A SoS brings together a set of systems for a task that none of the systems can accomplish on its own. Each constituent system keeps its own management, goals, and resources while coordinating within the SoS and adapting to meet SoS goals. In the context of terminology discussed in subclause 5.2.3 (as shown in Figure 3), the composite set of systems including the original SOI, enabling systems and interacting systems, together constitute an SoS. Where there are concerns that affect the composite set, the system of systems becomes the SOI, which is considered to satisfy some business or mission objective that cannot be satisfied by the individual constituent systems, or to understand emergent behavior of the combination.

This annex addresses the application of system life cycle processes to such SoS. It describes general characteristics, the common types of SoS, and the implications throughout the life cycle.

G.2 SoS characteristics and types

SoS are characterized by managerial and operational independence of the constituent systems, which in many cases were developed and continue to support originally identified users concurrently with users of the SoS. In other contexts, each constituent system itself is a SOI; its existence often predates the SoS, while its characteristics were originally engineered to meet the needs of their initial users. As constituents of the SoS, their consideration is expanded to encompass the larger needs of the SoS. This implies added complexity particularly when the systems continue to evolve independently of the SoS. The constituent systems also typically retain their original stakeholders and governance mechanisms, which limits alternatives to address the needs of the SoS.

SoS have been characterized into four types based on the governance relationships between the constituent systems and the SoS (Figure G.1). The strongest governance relations apply to directed system of systems, where the SoS organization has authority over the constituent systems despite the fact that the constituent systems may not have originally been engineered to support the SoS. Somewhat less control is afforded for acknowledged SoS, where allocated authority between the constituent systems and the systems of systems has an impact on application of some of the systems engineering processes. In collaborative SoS, which lack system of systems authorities, application of systems engineering depends on cooperation among the constituent systems. Virtual systems of systems are largely self organizing and offer much more limited opportunity for systems engineering of the SoS.

Emergence is a key characteristic of SoS – the unanticipated effects at the systems of systems level attributed to the complex interaction dynamics of the constituent systems. In SoS, constituent systems are intentionally considered in their combination, so as to obtain and analyze outcomes not possible to obtain with the systems alone. The complexity of the constituent systems and the fact they may have been designed without regard to their role in the SoS, can result in new, unexpected behaviors. Identifying and addressing unanticipated emergent results is a particular challenge in engineering SoS.

Definition: A system of systems (SoS) is a system-of-interest (SOI) whose elements are themselves systems.

A SoS brings together a set of systems for a task that none of the systems can accomplish on its own.

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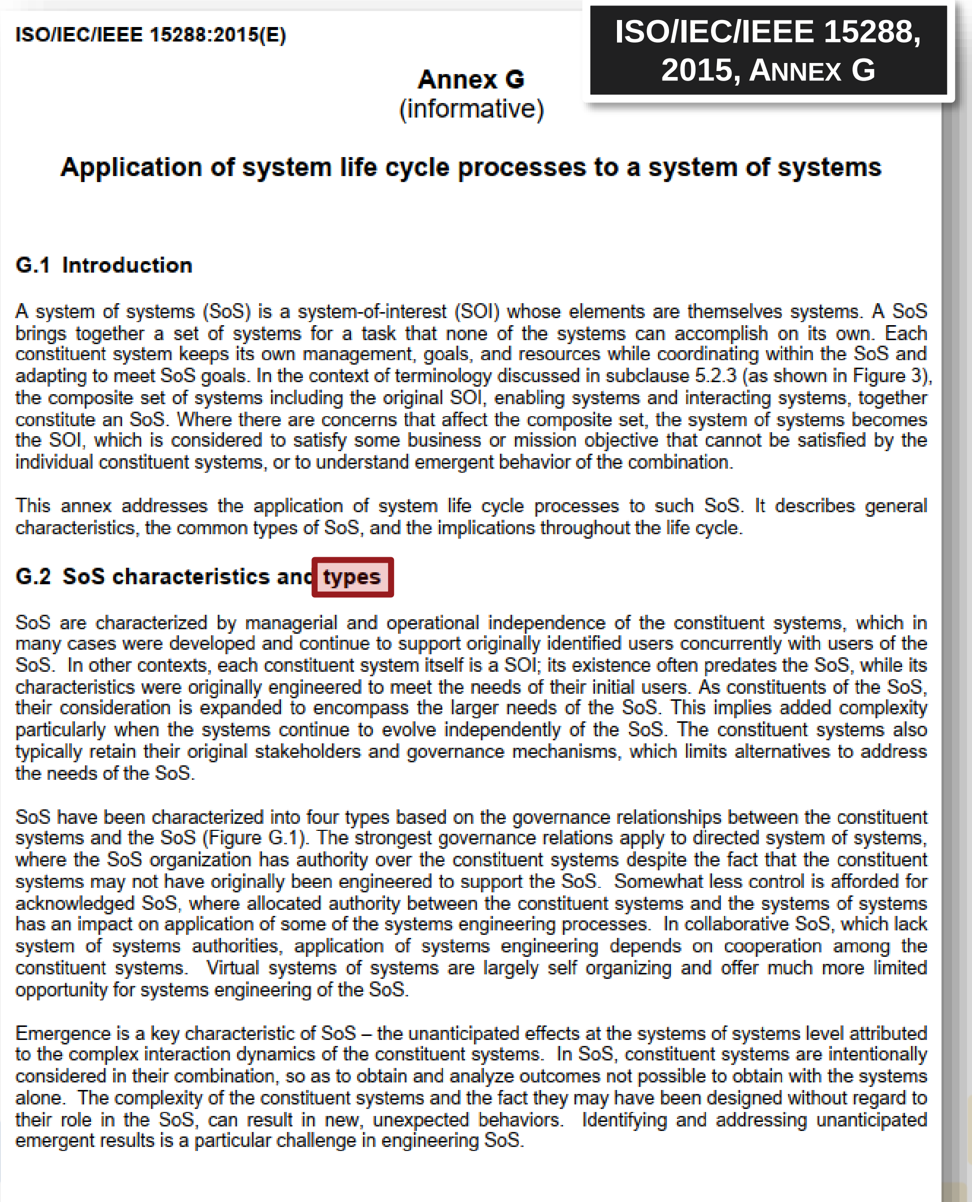
SoS Characteristics: SoS are characterized by managerial and operational independence of the constituent systems, which in many cases were developed and continue to support originally identified users of the constituent concurrently with users of the overall SoS.

INTRODUCTION: SYSTEM OF SYSTEMS

SOS TYPES



ISO/IEC/IEEE 15288:2015(E)

Annex G
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ISO/IEC/IEEE 15288, 2015, ANNEX G

SoS Types	Governance Relationships between SoS & CS
Directed SoS	❖ SoS created to fulfill specific purpose ❖ Dedicated SoS manager ❖ Subordinated constituent systems
Acknowledged SoS	❖ Recognized SoS objectives ❖ Designated SoS manager & resources ❖ Independent constituent systems
Collaborative SoS	❖ Agreed upon central purpose ❖ Voluntary interaction ❖ Independent constituent systems
Virtual SoS	❖ Lacks central management ❖ Lacks agreed upon purpose ❖ Large scale emergent behavior

INTRODUCTION: SYSTEM OF SYSTEMS

SOS EMERGENCE

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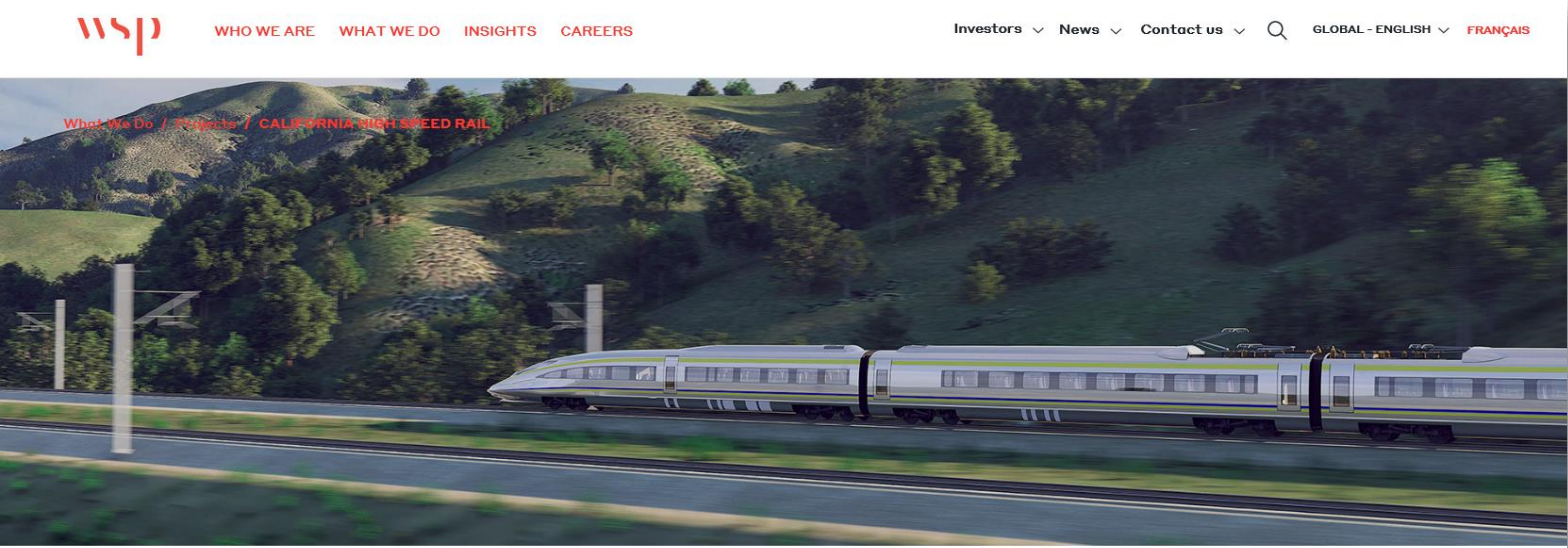
INTRODUCTION: SYSTEM OF SYSTEMS

INCOSE SoS PRIMER – FURTHER READING

California High-Speed Rail System (CHSRS)

Brief Introduction



Source: https://www.wsp.com/en-GL/projects/california-high-speed-rail

CALIFORNIA HIGH SPEED RAIL

CALIFORNIA HIGH-SPEED RAIL SYSTEM (CHSRS)

KEY HIGHLIGHTS

- One of the largest and most ambitious public transportation programs in U.S. history
- Will allow passengers to travel from Los Angeles to San Francisco at speeds of up to 220 miles (354 kilometers) per hour
- Trip in just 2 hours and 40 minutes, compared to almost 6 hours by automobile
- Connects California's megaregions, contributes to economic development and a cleaner environment, creates jobs and preserves agricultural and protected lands
- Using federal and state funds, including Cap and Trade, Authority plans to begin high-speed operations to begin in the Central Valley by 2028
- Will eventually connect San Francisco to Los Angeles in under three hours at speeds of 350km/h (220mph) by 2033, extending to Sacramento and San Diego, totaling 800 miles with up to 24 stations
- Improves local and regional rail lines

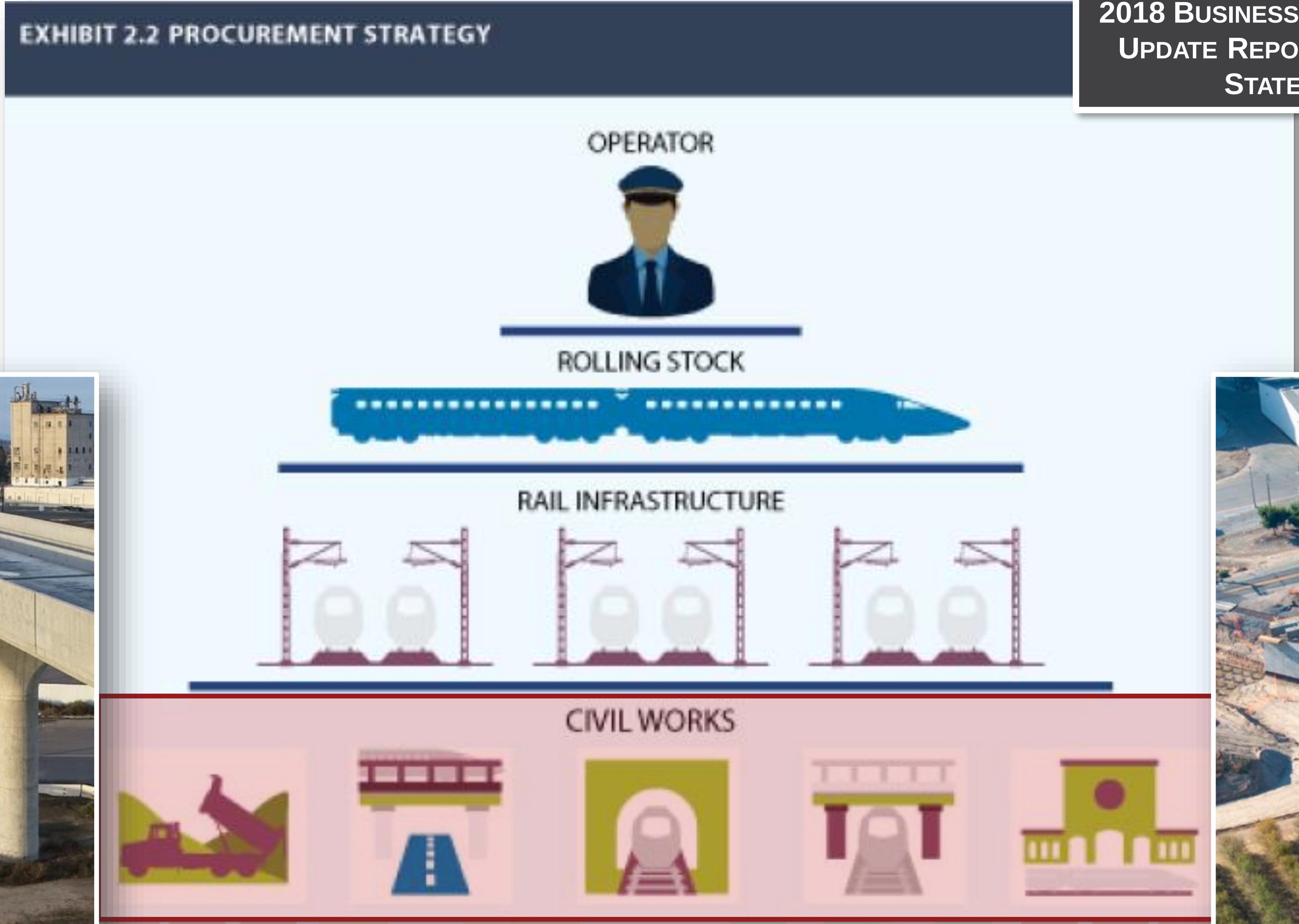
2019 PROJECT UPDATE REPORT TO THE CALIFORNIA STATE LEGISLATURE

California High-Speed Rail System (CHSRS)

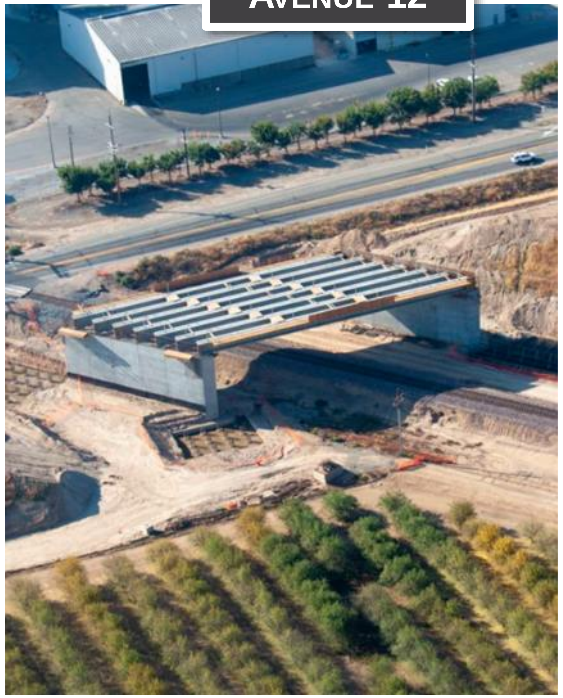
Procurement Strategy / Contract Packaging

2018 Business Plan & 2019 Project Update Report to the California State Legislature

Cedar Viaduct



Avenue 12



CHSRS AS A SYSTEM OF SYSTEMS

CHSRS AS A CONSTITUENT SYSTEM WITHIN A LARGER SOS

Interfacing Systems & Organization

Interfacing Systems & Organization

Adjacent Railroads

Power Utilities

Seismic Detection

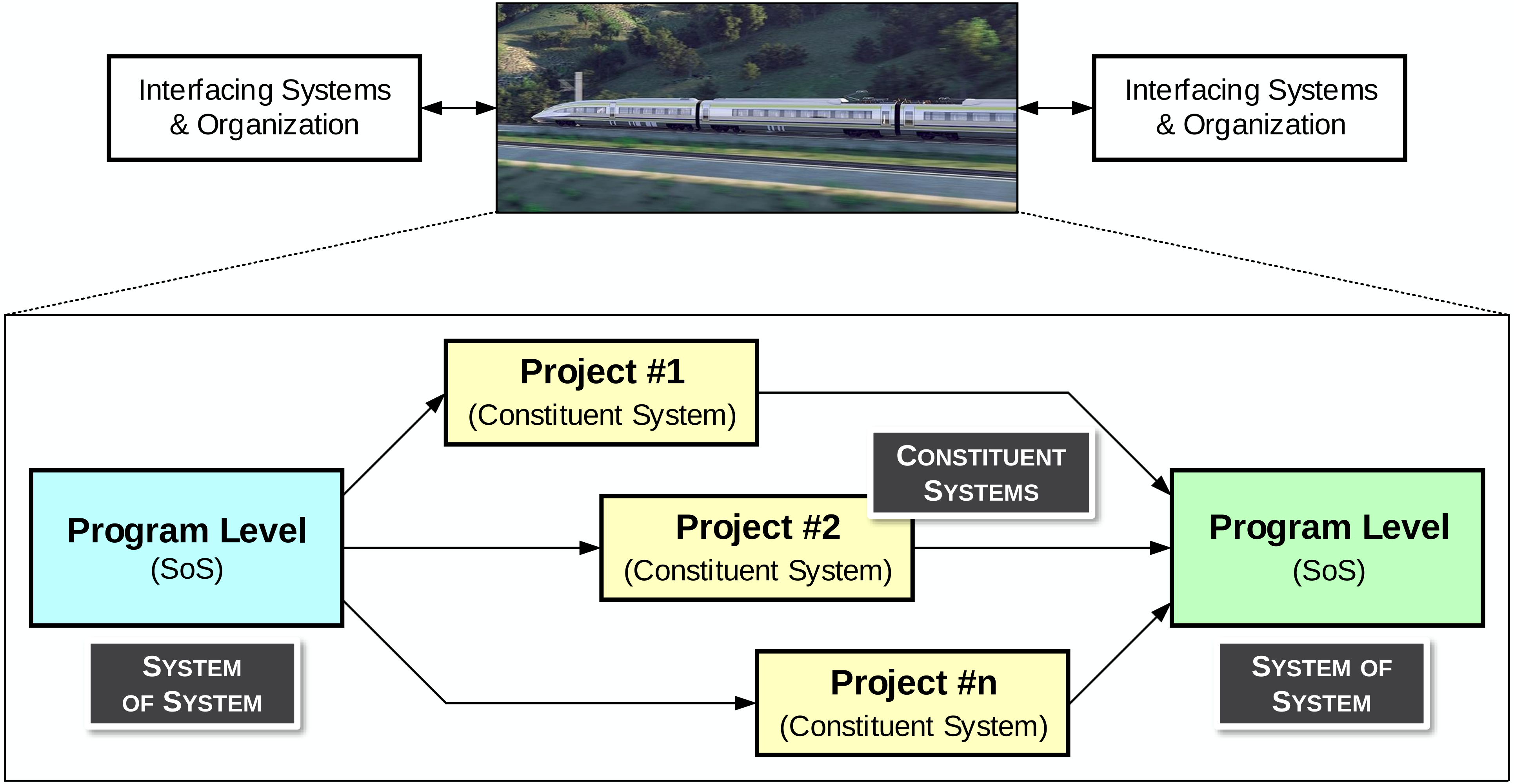
Adjacent Roadways

Shared Corridors

Source: https://www.youtube.com/watch?v=AKsjqu3l0xA

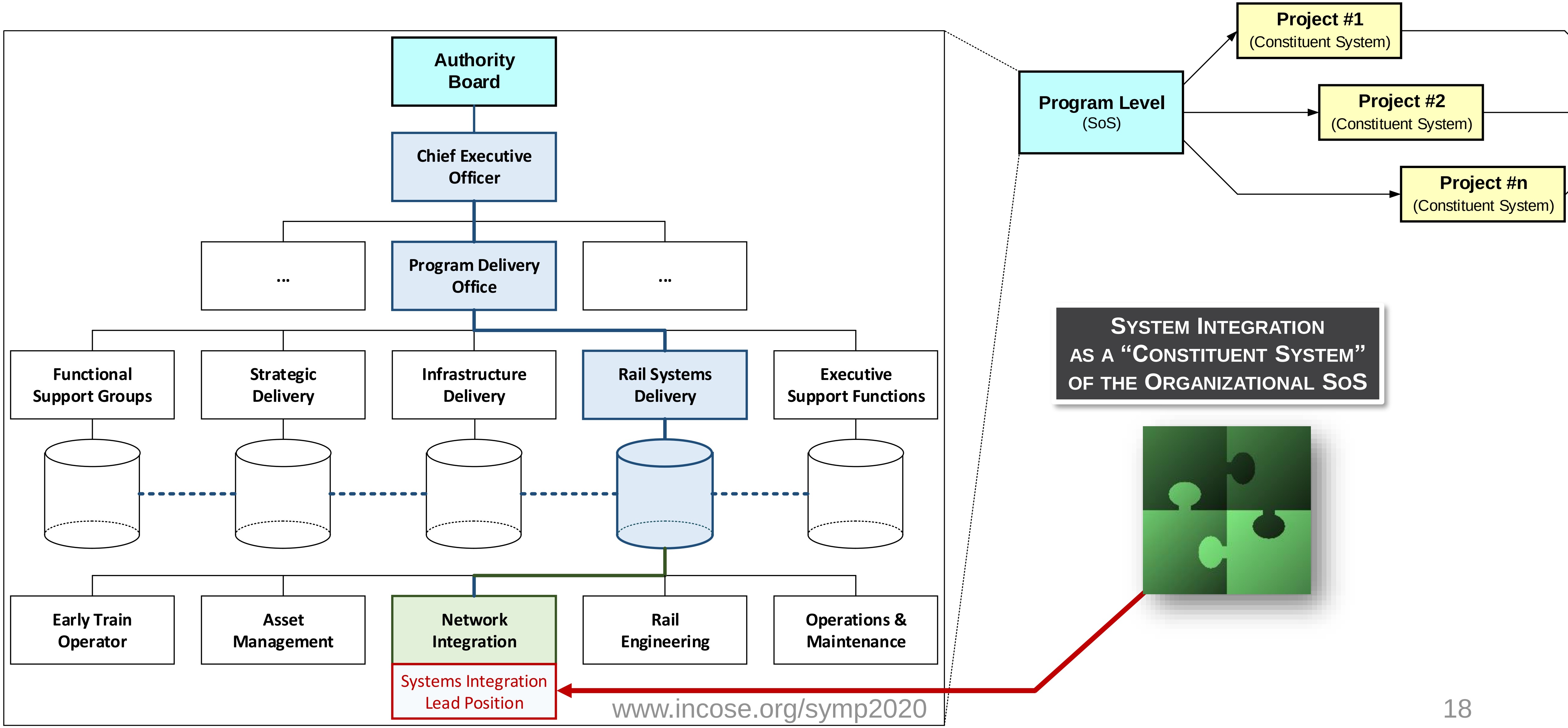
CHSRS as a System of Systems

CHSRS as a Program (SoS) of Projects (Constituent Systems)



CHSRS AS A SYSTEM OF SYSTEMS

CHSR PROGRAM ORGANIZATION AS AN ORGANIZATIONAL SOS



PROGRESS

- **Introduction**
  - System of Systems (SoS)
  - California High-Speed Rail System (CHSRS) Program
  - CHSRS as a System of Systems
- **SoSE Challenges Faced**
  - Traditional Industry Approach to Systems Integration
  - SoS Engineering Challenges
- **SoSE Activities Performed**
  - International Best Practice Analysis of HSR System Integration
  - SoS Integration Strategy
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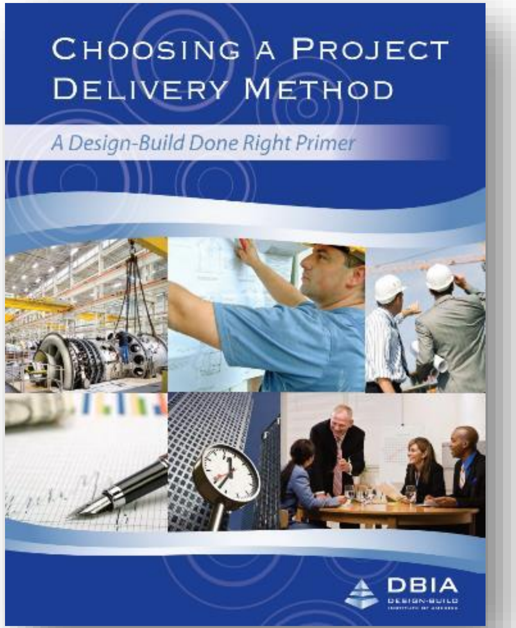
Traditional Industry Approach to Systems Integration

Project Delivery Methods

Traditional Method
(Design / Bid / Build)



Today's Preferred Method
(Design / Build)

Project Initiation | Bid | Project Closeout

Planning	Preliminary Engineering	Final Design		Construction	Operations & Maintenance

Owner Organization
(Functional Structure)

Integration Challenges & Change Orders

Construction Firm

Project Initiation | Project Closeout

Planning	Preliminary Engineering	→	Final Design	Construction	Operations & Maintenance

Bid

(Integration) Risk Transfer to Design & Construction Firm

Traditional Industry Approach to Systems Integration

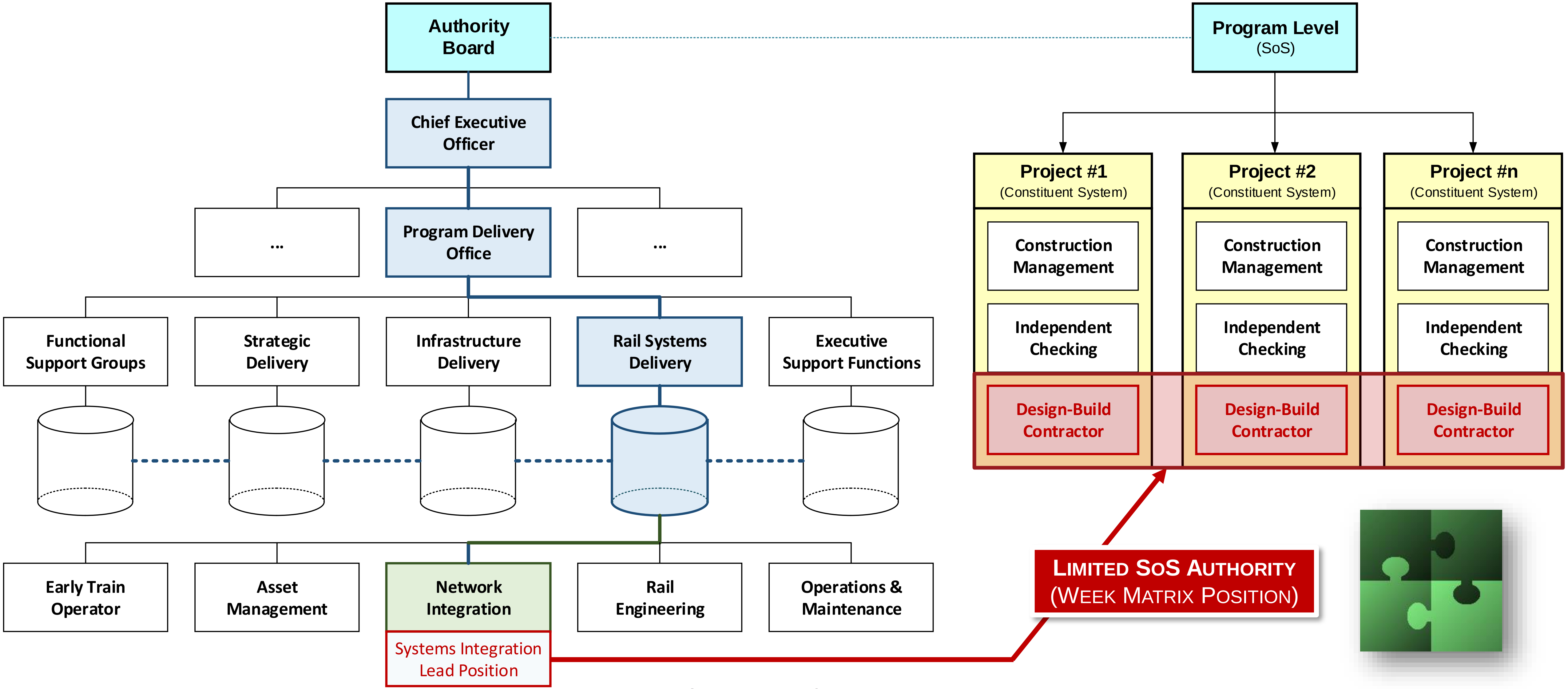
Consequences of Design / Build (DB)

- **Reluctance to be Specific:**
  - Interference with design / construction firm's business, possibility of "re-owning" the risk
  - Detailed directions may result in additional work order claims
- **Unknown System Integration Scope:**
  - Design / construction firm responsible for final design & construction
  - Limited knowledge of final solution at time of bid (i.e. system architecture & interfaces)
  - Resulting in hesitance to provide detailed interfaces lists & descriptions (see above)
  - Risk of omitted interfaces may be subject to additional work order claims
- **Innovative Design & Construction:**
  - Saving time and money by encouraging collaboration and innovation
  - May result in (emerging) unanticipated and/or unintended design solutions
- **Design / Build Impact to Systems Integration:**
  - Systems integration becomes "coordination" responsibility (scope)
  - Risk avoidance approach (hands-off, "leave it to the contractor")
  - Often reactive, late interface identification during final design & construction

Emerging Solutions

SoSE Challenges Faced

SoS Authority



SoSE Challenges Faced

SoS Architecture (Contract Packaging) & Leadership

Design-Build Construction Packages

The high-speed rail system is being built through a series of design-build contracts. Work within a design-... egi... until a project section has been environmentally cleared. Currently, the Authority has identified four desi... Central Valley. Construction updates and road closure alerts are posted on [BuildHSR.com.](BuildHSR.com)

Civil Works

- Contracts Out for Bid
- **Design-Build Construction Packages**
- Track & Systems

- **Construction Package 1 (HSR 13-06)** — **Started in 2013**

  Construction Package 1 (CP 1) is the first significant construction contract executed on the Initial Operating Section of the high-speed rail program. The CP1 construction area is a 32-mile stretch between Avenue 19 in Madera County to East American Avenue in Fresno County. It includes 12 grade separations, 2 viaducts, 1 tunnel and a major river crossing over the San Joaquin River.

- **Construction Package 2-3 (HSR 13-57)**

  Construction Package 2-3 (CP 2-3) is the second significant construction contract executed on the Initial Operating Section of the high-speed rail program. The CP 2-3 construction area extends approximately 60 miles from the terminus of Construction Package 1 at East American Avenue in Fresno to one mile north of the Tulare-Kern County line. CP 2-3 will include approximately 36 grade separations in the counties of Fresno, Tulare and Kings, including viaducts, underpasses and overpasses.

- **Construction Package 4 (HSR 14-32)**

  Construction Package 4 (CP 4) is the third significant construction contract executed on the Initial Operating Section of the high-speed rail program. The CP 4 construction area is a 22-mile stretch bounded by a point approximately one mile north of the Tulare/Kern County Line at the terminus of Construction Package 2-3 and Poplar Avenue to the south. CP 4 will include construction of at-grade, retained fill and aerial sections of the high-speed rail alignment and the relocation of four miles of existing Burlington Northern Santa Fe (BNSF) tracks.

RESOURCES

- Cal eProcure

Source: https://hsr.ca.gov/business/contractors/contracts_out.aspx

SoSE Challenges Faced

SoS Architecture & Leadership (Cont'd)

Track & Systems

The Track and Systems procurement is proposed to be a design-build-maintain contract with a scope of work that includes design and construction of trackwork, railway systems, and electrification, as well as testing and commissioning. The Track and Systems contract, as proposed, will also include a 30-year term of maintenance for both the underlying civil works a TRACK & SYSTEMS The Track and Systems work would be issued through multiple Notices to Proceed (NTP) for the Centr nt

The anticipated schedule for this procurement is as follows:

- RFQ Release: July 17, 2019
- SOQ Due Date: November 4, 2019
- RFP Release: December 19, 2019
- Proposal Due Date: September 15, 2020 TO BE STARTED

RFP for Track and Systems

The Authority released the Request for Proposals (RFP HSR19-13) to three shortlisted teams on December 19, 2019. California High-Speed Rail Constructors notified the Authority on February 27, 2020 that their team has withdrawn from the Track and Systems RFP procurement process.
Please find below the small-business and non-small business contact information:

Contracts Out for Bid

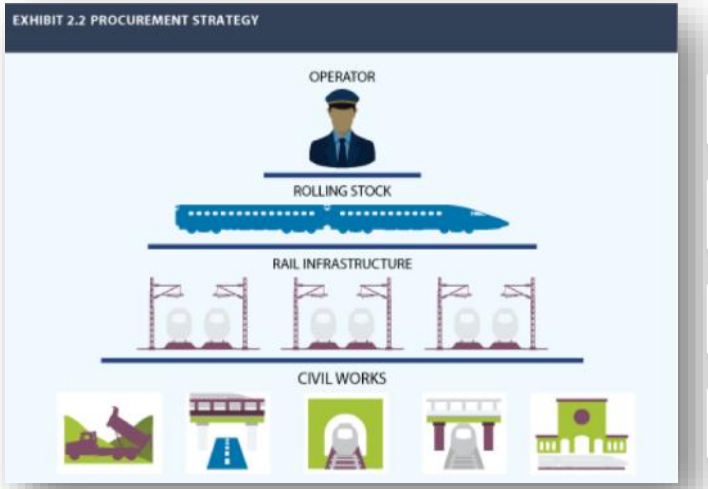
Design-Build Construction Packages

Track & Systems

Source: https://hsr.ca.gov/business/contractors/contracts_out.aspx

SoSE Challenges Faced

SoS Architecture & Leadership (Cont'd)



Train Operator

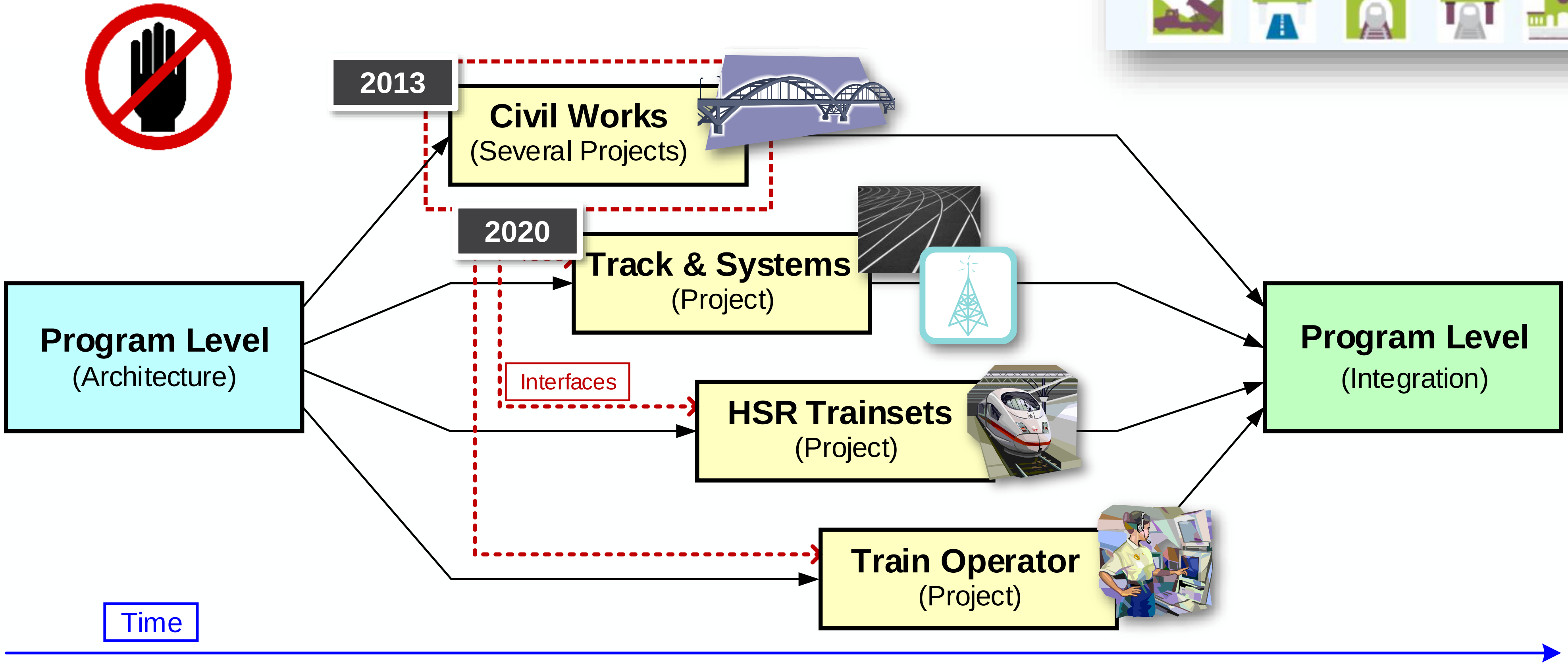
HSR Trainsets

Track & Systems

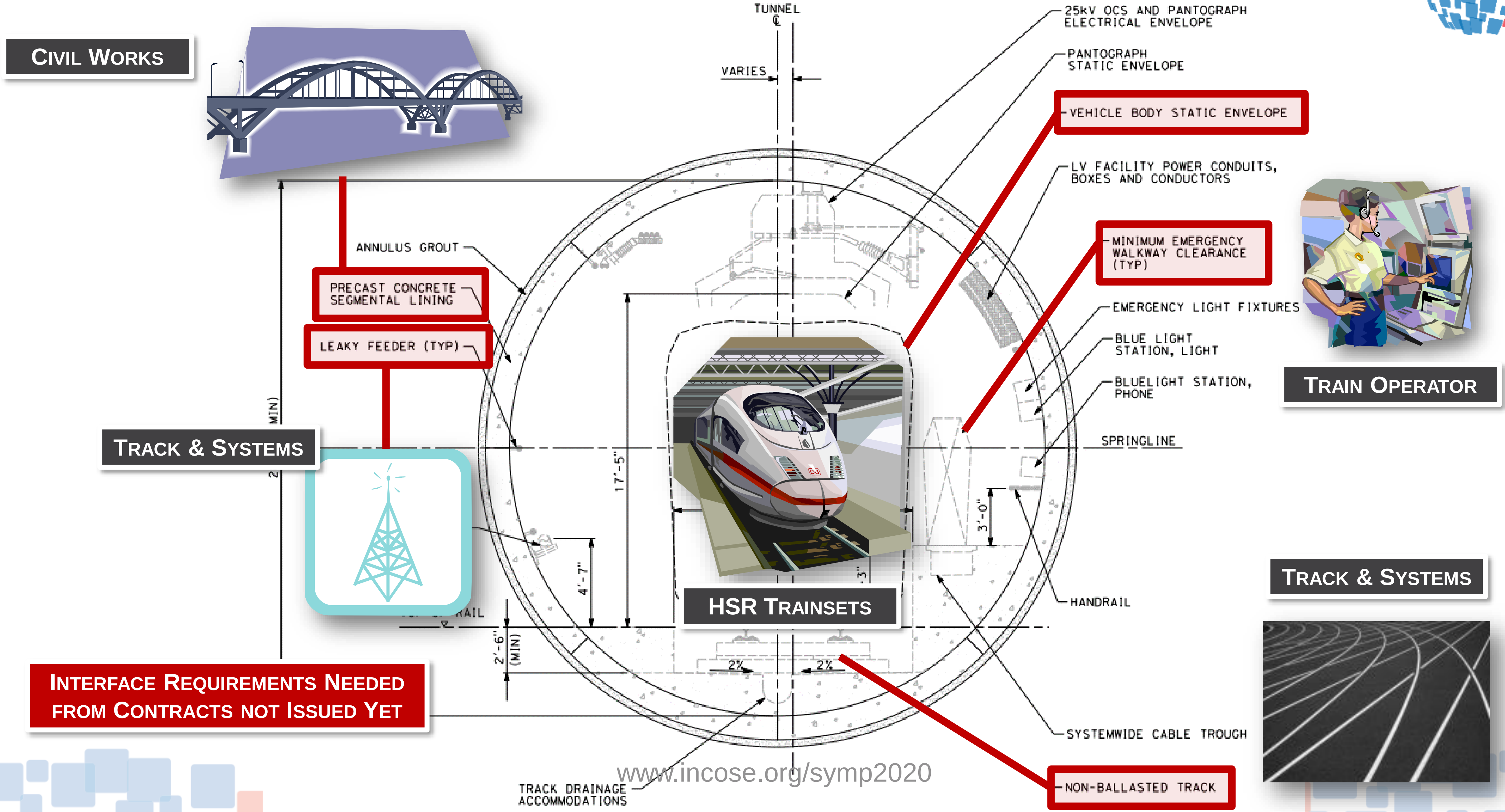
Civil Works

SoS Leadership
("Leave it to the Contractor")

SoS Architecture
(Contracts & Interfaces)



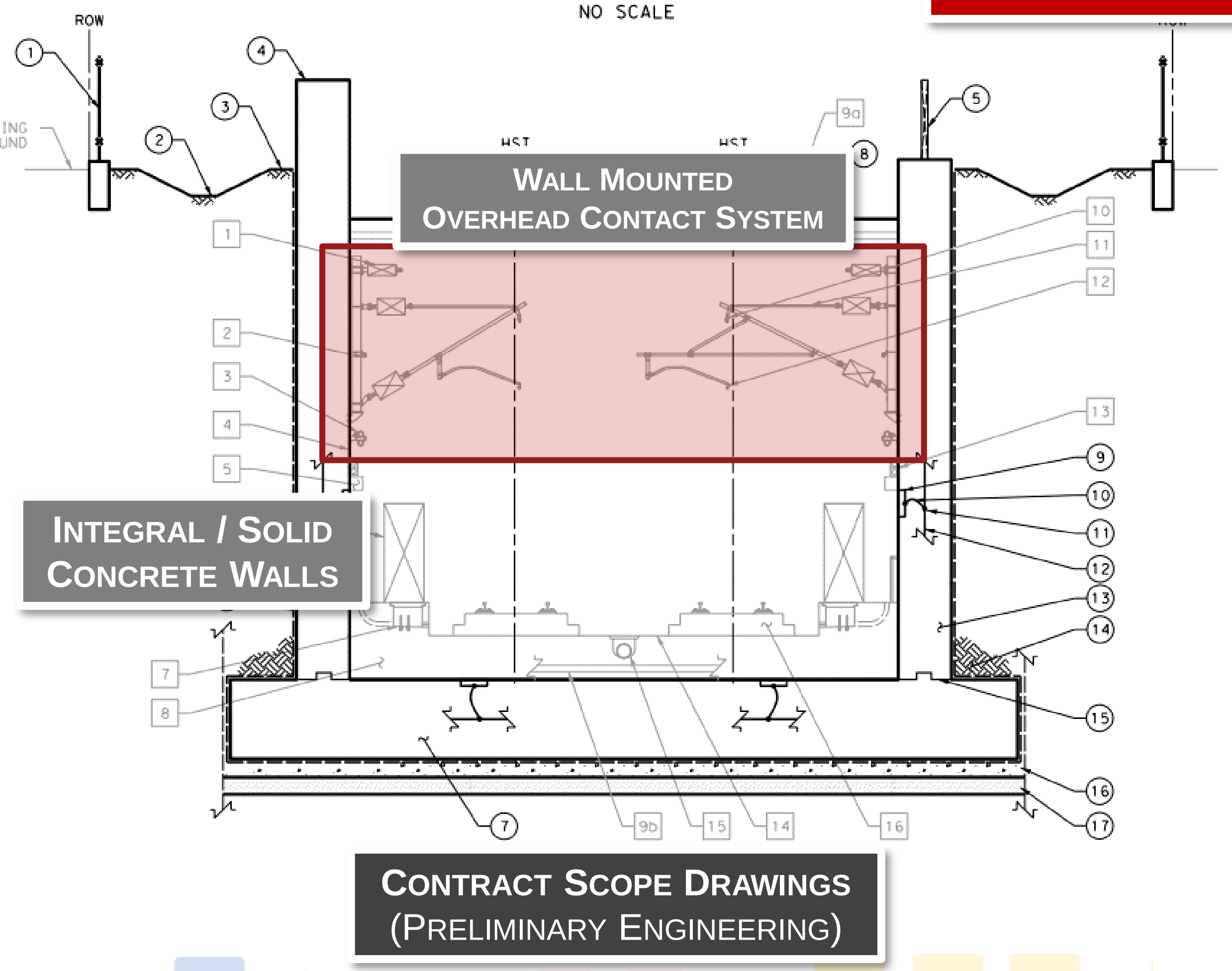
SoS Collaboration & Integration (Early Interface Needs)

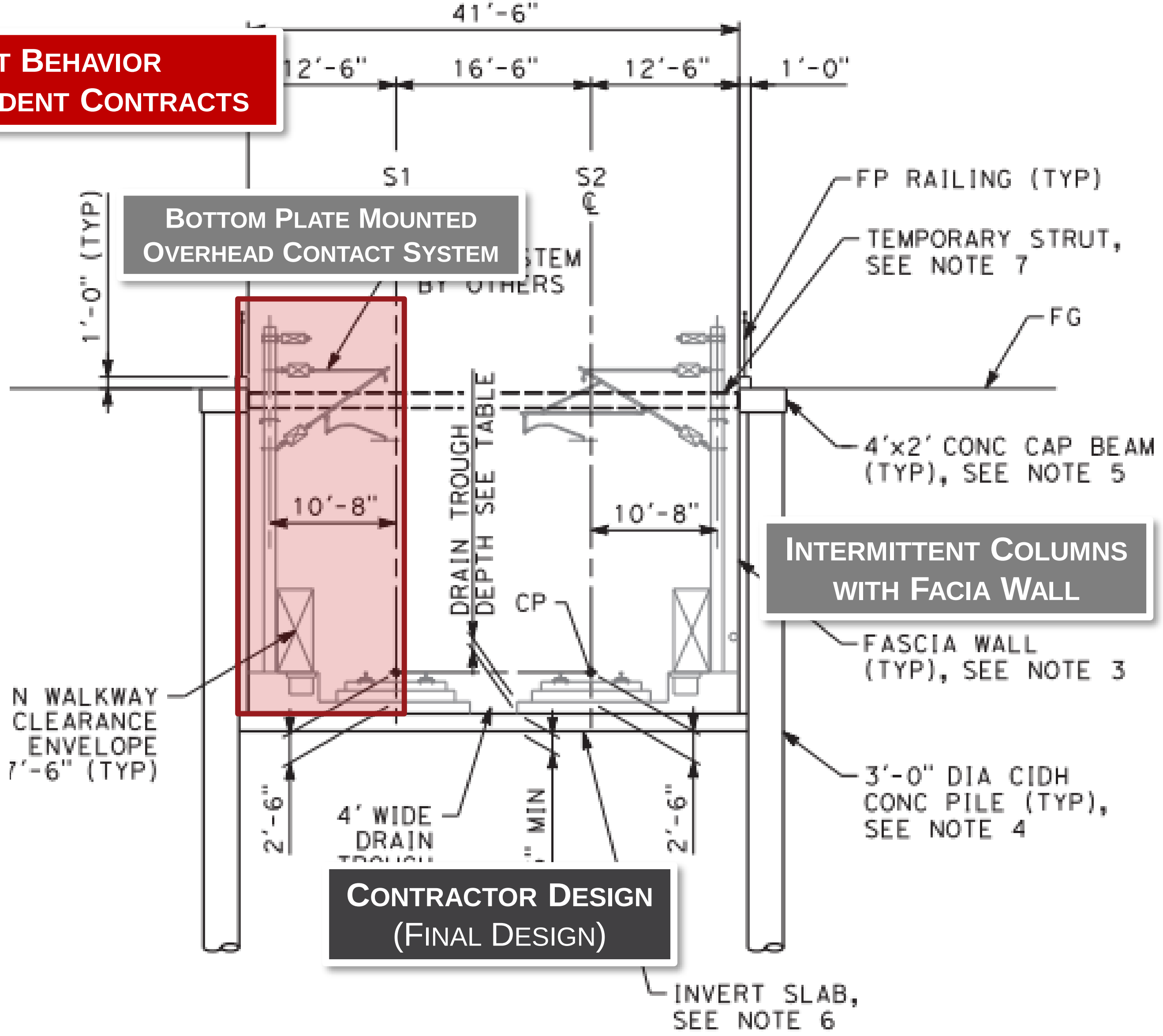


SoSE Challenges Faced

SoS Autonomous Constituent Systems & Emergence

Emergent Behavior due to Independent Contracts





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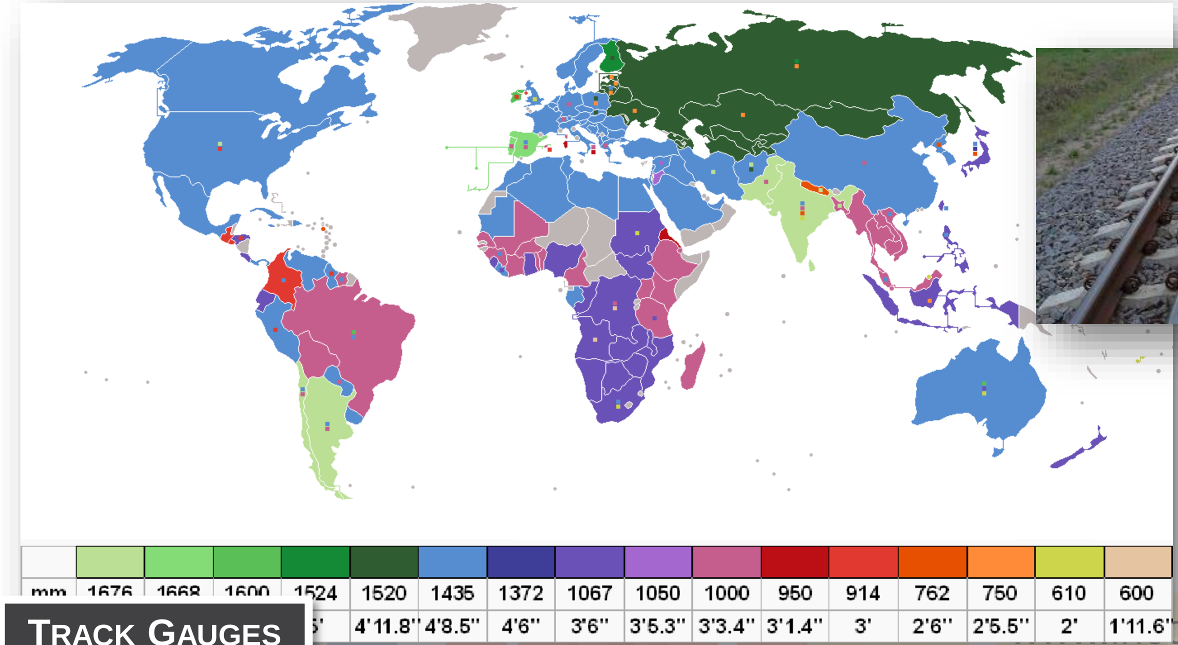
International Best Practice Analysis

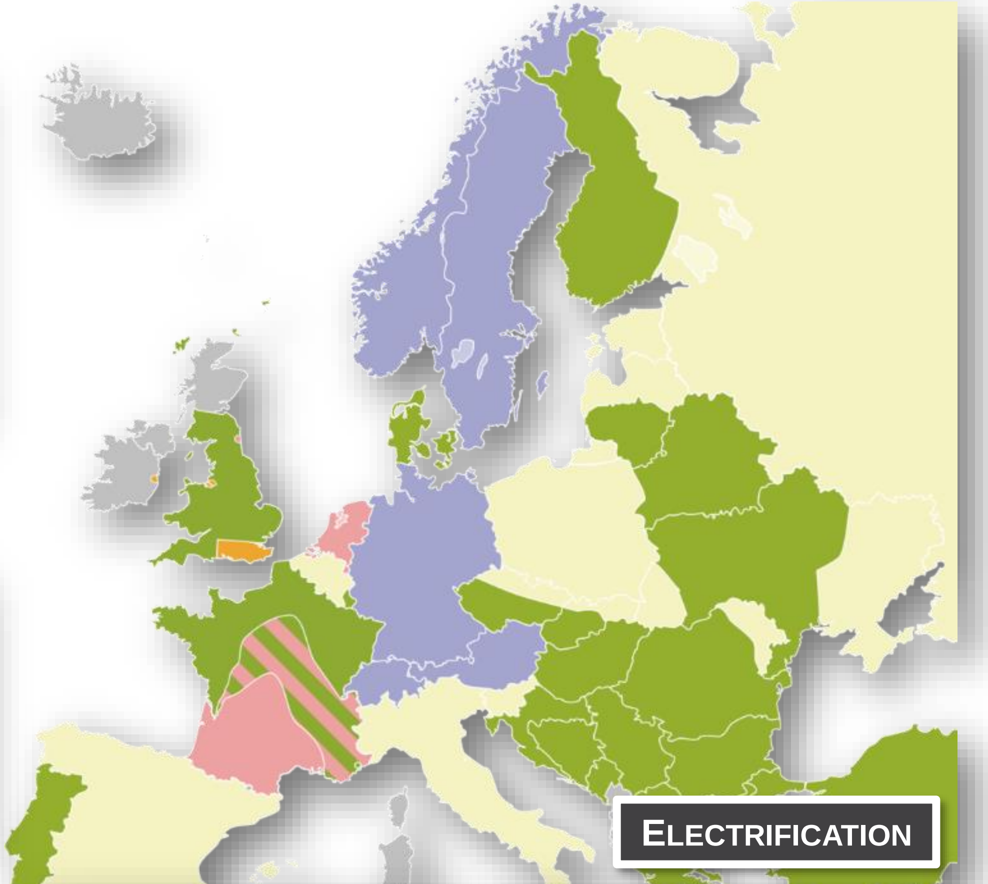
Trans European High-Speed Rail System – Integration Challenges

Structure Gauges

Track Gauges

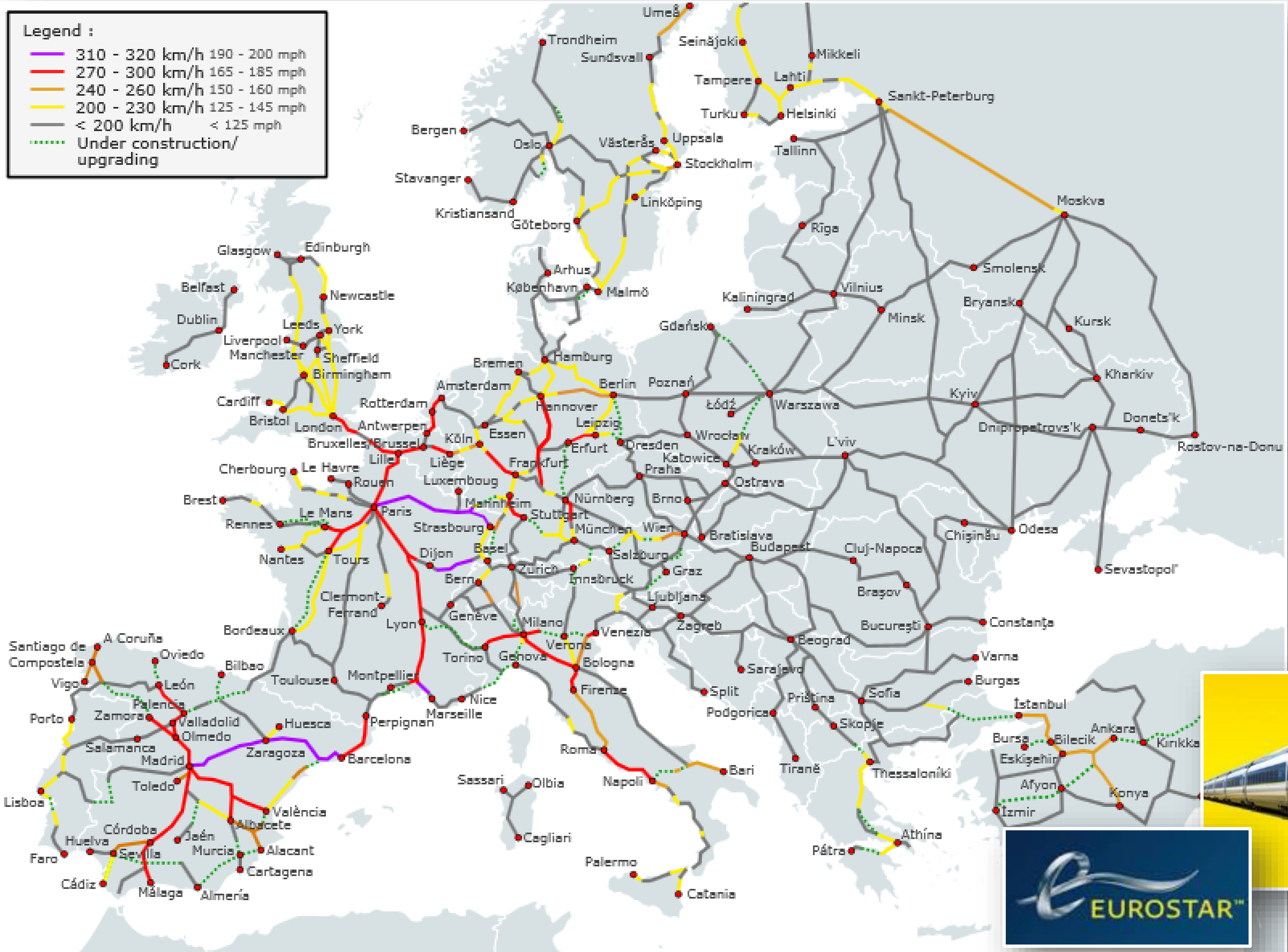


Electrification



International Best Practice Analysis

Technical Specifications for Interoperability (TSI)

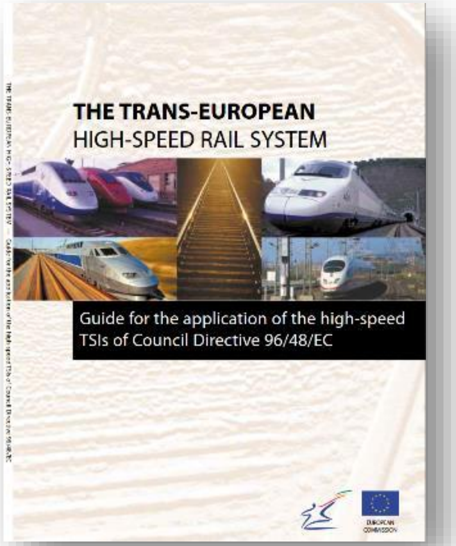


Technical Specifications for Interoperability (TSI)

EUROSTAR™

International Best Practice Analysis

TSIs – Subsystems & Interfaces



8 Subsystems, incl. 4 Structural Subsystems:

1. Infrastructure
2. Energy
3. Control-Command & Signalling
4. Rolling Stock

Infrastructure Subsystem TSI

4.3 Functional and technical specification of the interfaces

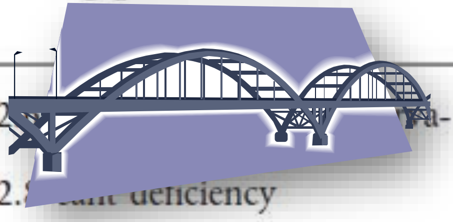
From the standpoint of technical compatibility, the interfaces of the infrastructure domain with the other subsystems are the following:

4.3.1 Interfaces with the rolling stock subsystem

Interfaces between Infrastructure & Rolling Stock

Interface	Reference High-Speed Infrastructure TSI	Reference High-speed Rolling Stock TSI
Structure gauge Infrastructure gauge	4.2.3 minimum infrastructure gauge	4.2.3.1 kinematic gauge 4.2.3.3. Rolling stock parameters, which influence ground based train monitoring systems
gradients	4.2.5 maximum rising and falling gradients	4.2.3.6 maximum gradients 4.2.4.7 Bra[illegible]ce on st[illegible]
Minimum radius	4.2[illegible]a- 4.2.[illegible]ant deficiency	4.2.3.7 M[illegible]radius
Equivalent conicity	4.2.9 equivalent conicity 4.2.11 rail inclination 5.3.1.1 railhead profile	4.2.3.4 Rolling stock dynamic behaviour; 4.2.3.4.7 design values for wheel profiles

Specific Interfaces



International Best Practice Analysis

TSIs – Interoperable Interface Specification

Infrastructure (INF) Subsystem

Infrastructure

4.2.3 Minimum infrastructure gauge

The infrastructure must be constructed so as to allow safe clearance for the passage of trains complying with the High-Speed Rolling Stock TSI.

Minimum infrastructure gauge is defined by given swept volume inside which no obstacle must be located or intrude. This volume is determined on the basis of a reference kinematic profile and takes into account the gauge of catenary and the gauge for lower parts.

The relevant kinematic profiles are specified in the High-Speed Rolling Stock TSI.

elating to gauges, the Infrastructure Manager
infrastructure gauge.

Interface	Reference High-Speed Infrastructure TSI	Reference High-speed Rolling Stock TSI
Structure gauge Infrastructure gauge	4.2.3 minimum infrastructure gauge	4.2.3.1 kinematic gauge 4.2.3.3. Rolling stock parameters, systems

Interoperable Interface

Reference INF TSI

Reference RST TSI

Trainsets

4.2.3.1. Kinematic gauge

Rolling stock shall comply with one of the kinematic vehicle gauges defined in Annex C of the Conventional Rail Rolling Stock Freight Wagon TSI 2005.

Interoperable Standard(s)

The pantograph gauge shall comply with Clause 5.2 of prEN 50367:2006

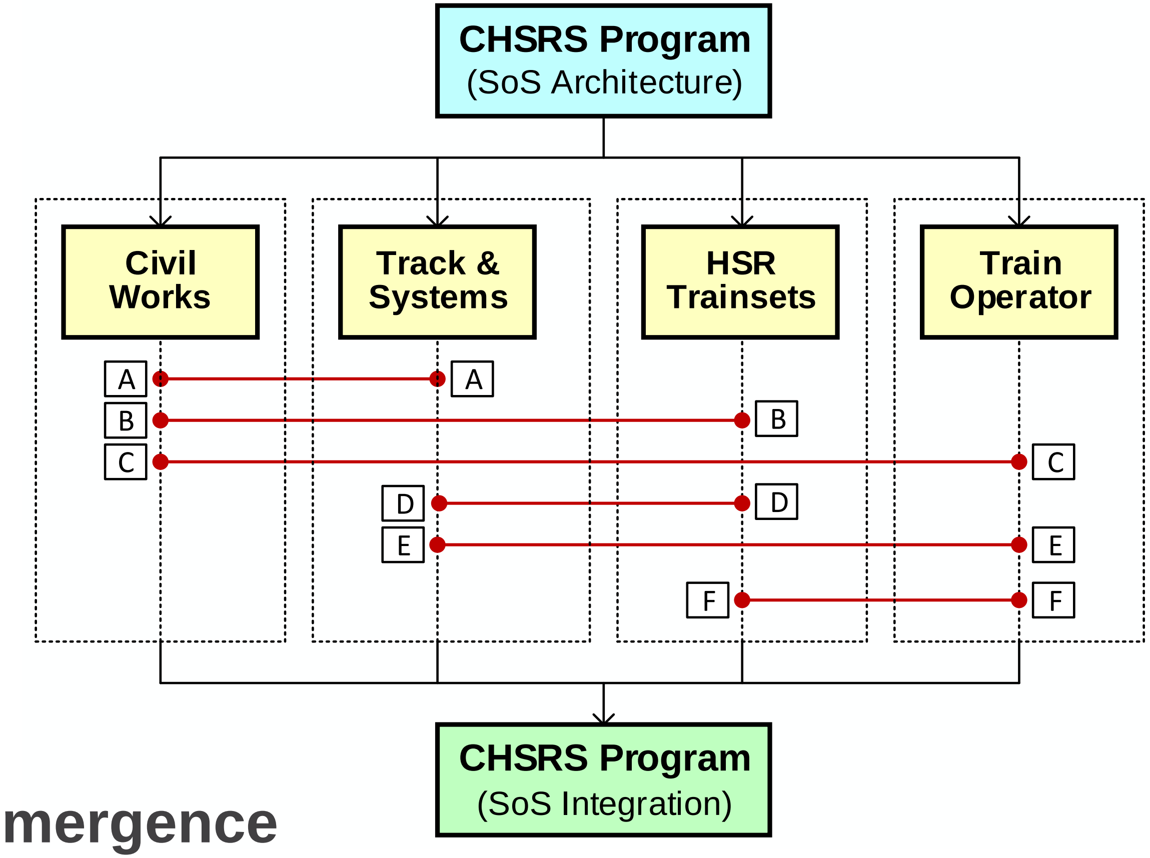
The type or design examination certificate of 'EC' verification of the rolling stock and the rolling stock register shall indicate the assessed gauge.

Rolling Stock (RST) Subsystem

SoS Integration Strategy

Addressing the SoSE Challenges: Interoperability Approach

- **SoS Leadership & Authority**
  - Leadership: CHSRS system integration team
  - Authority: Integration team authorized to identify & manage technical Interfaces
- **SoS Architecture**
  - SoS: CHSRS program
  - Constituent systems: CHSRS projects
- **SoS Collaboration & Integration**
  - SoS: Interface identification & specification
  - Constituent systems: Interface implementation
- **SoS Autonomous Constituent Systems & Emergence**
  - SoS: Defines interoperable interface standards
  - Constituent systems: Allowed innovate, emergent solutions …
  - … as long as they meet interoperable interfaces standards



SoS Integration Strategy

Seven (7) Step Process

Step 1: SoS architect (systems integration team) identifies key interfaces

Step 2: HSR trainset subject matter expert (SME) identifies candidate HSR trainsets

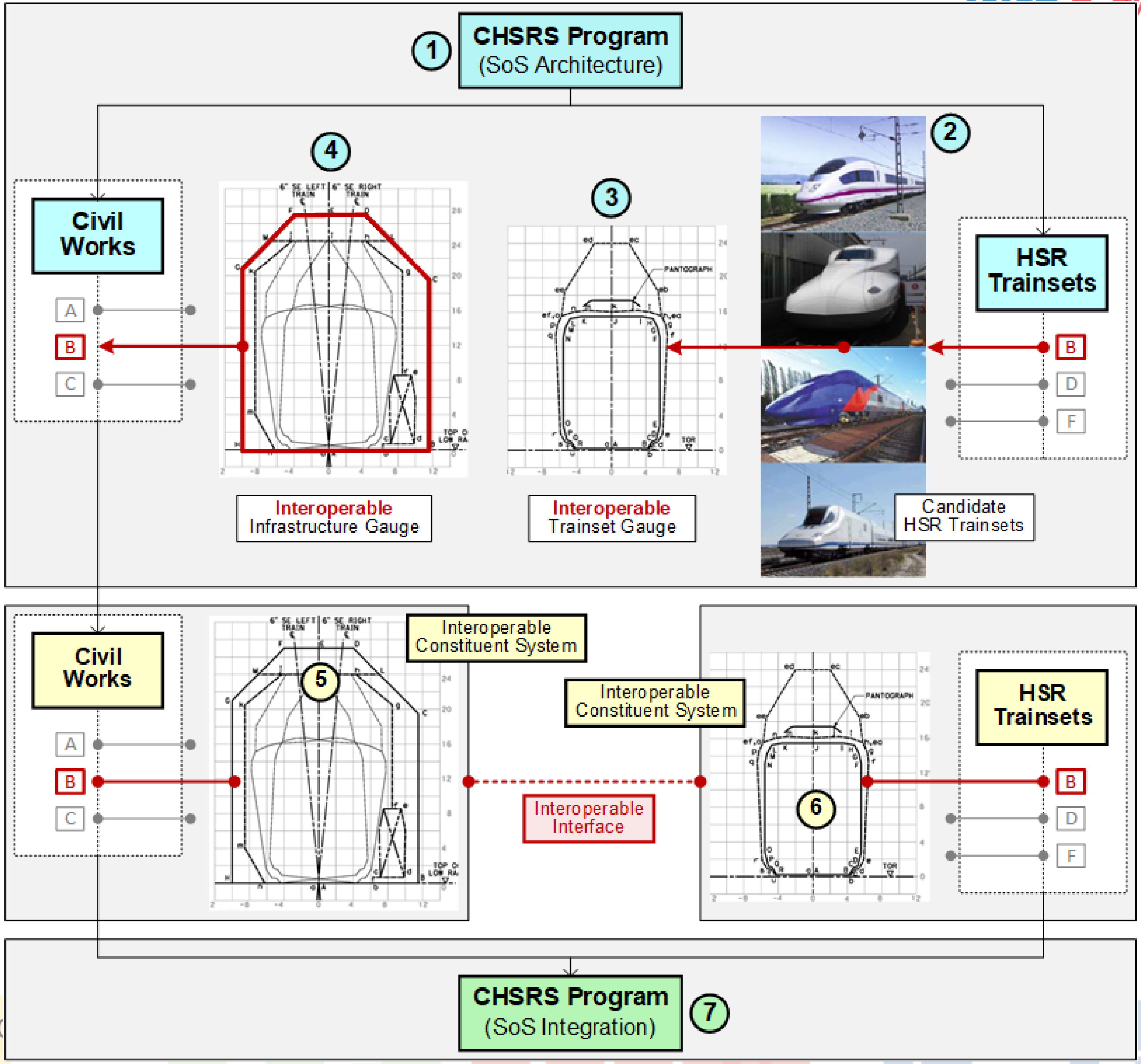
Step 3: HSR trainset SME determines interoperable interface requirements

Step 4: Civil works SME develops corresponding interoperable interface design

Step 5: Civil works contractor implements interoperable civil works contract

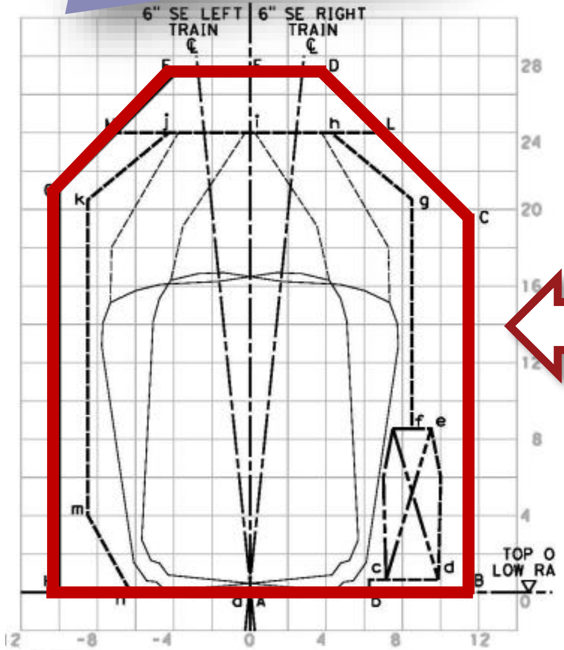
Step 6: HSR trainset contractor implements interoperable HSR trainset contract

Step 7: SoS system integrator (track & systems contractor) integrates, tests, and commissions (taking into service) the interoperable contracts

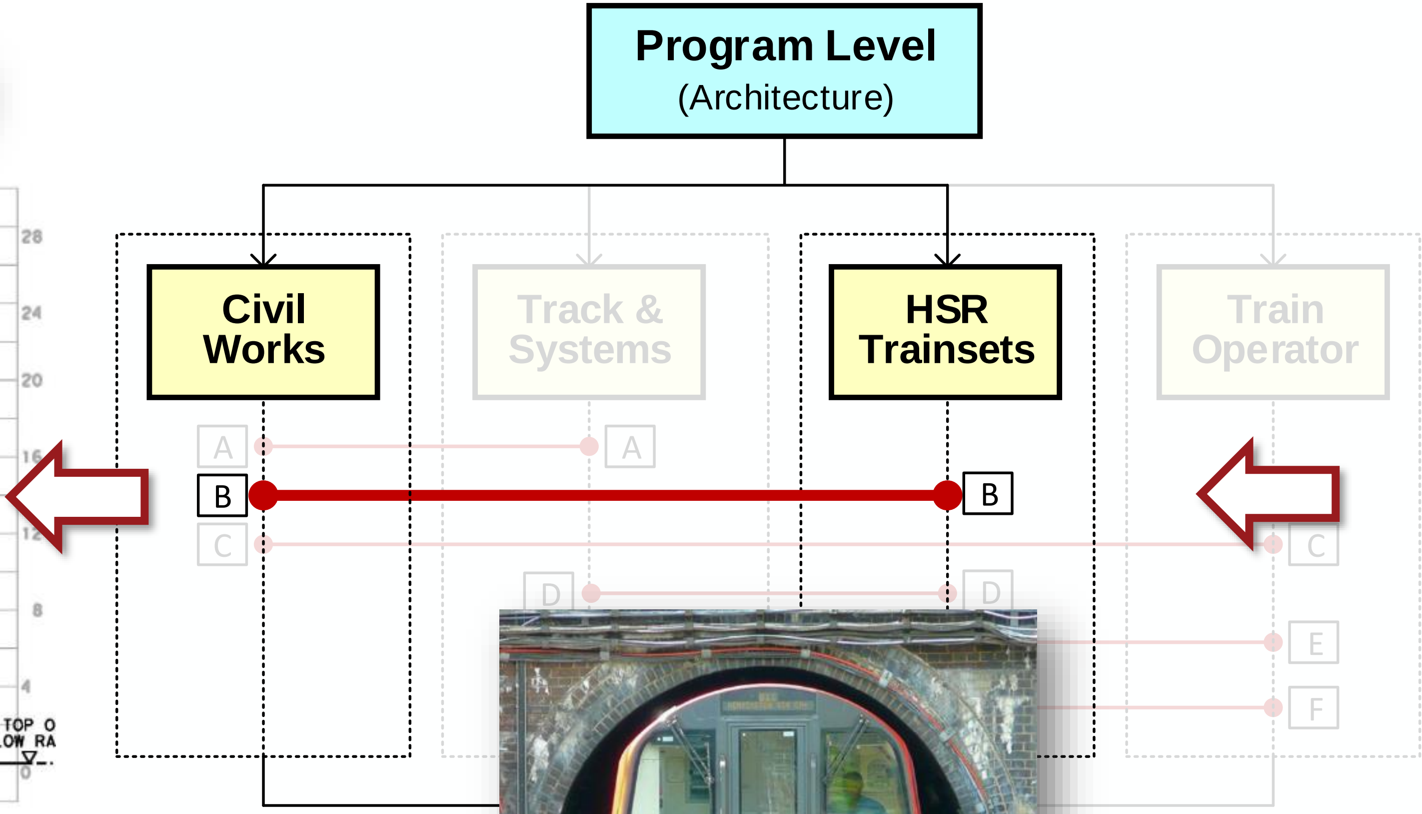


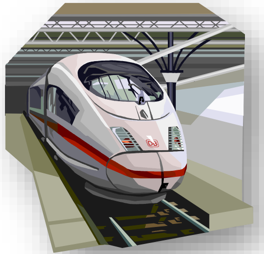
Step 1: Identification of Key Interfaces

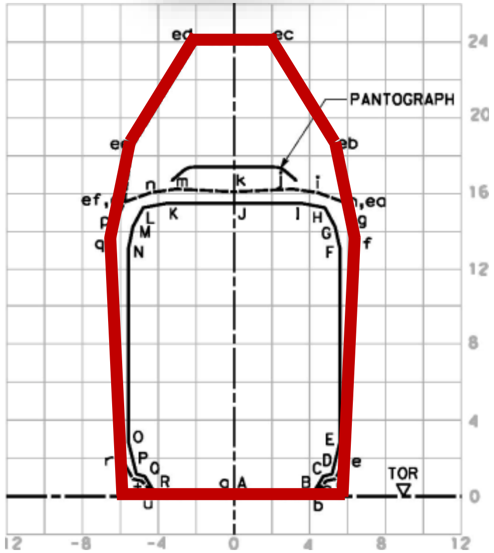
Example: Interface Between Trainset Envelope & Infrastructure Gauge



Infrastructure Gauges







Trainset Envelopes

Step 1: Identification of Key Interfaces

TSI Interface Analysis, Application & Tailoring to CHSRS

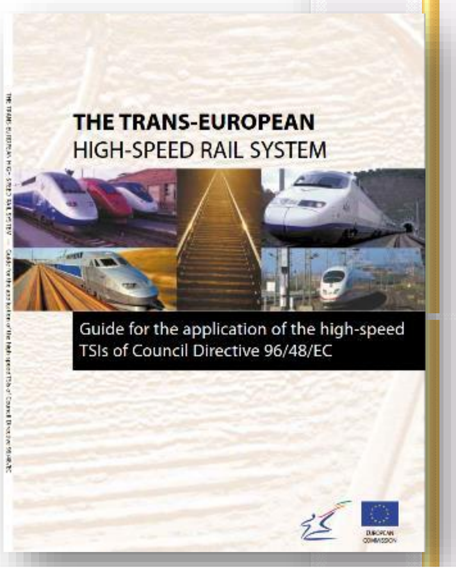
Interfaces between Infrastructure & Rolling Stock

Specific Interfaces

Tailored CHSRS Interfaces

_TSI-TYPE			Traced To: IF-REG (LM)
---	1 TSI Interface Register		
---	1.1 TSI Infrastructure		
---	1.1.1 Interfaces with the Rolling Stock Subsystem		
---	1.1.1.1 Structure Gauge and Infrastructure Gauge		
INF_A RST	1.1.1.1.1 Interface between INF Minimum Infrastructure Gauge and RST Kinematic Gauge TSI INF_A: Interface: Structure gauge • TSI INF: 4.2.3 Minimum • TSI RST: 4.2.3.1 Kinematic gauge TSI RST: Clause 4.2.3.1 of this TSI specifies that the rolling stock shall comply with one of the kinematic vehicle gauges that are specified in Annex C of the Conventional Rail Rolling Stock TSI 2005. The corresponding infrastructure gauges are specified in clause 4.2.3 of the Infrastructure TSI 2006, and the infrastructure register states for each line the kinematic gauge that shall be met by the rolling stock operating on this line.	[10 TSI-INF_A] ID: 30 4.2.3 Minimum infrastructure gauge (INF-3-03: Minimum Infrastructure Clearances) [10 TSI-INF_A] ID: 168 4.3.1 Interfaces with the rolling stock subsystem [30 TSI-RST] ID: 77 4.2.3.1 Kinematic gauge (RST-5-03.1: Kinematic gauge) [30 TSI-RST] ID: 398 4.3.2.3 Kinematic gauge	[IF-REG] ID: 481 Interface between RST HST Trainset Dynamic Envelope Requirements and GWY Infrastructure [IF-REG] ID: 490 Interface between RST HST Trainset Static Gauge Requirements and GWY Infrastructure
	1.1.1.1.2 Interface between INF Minimum Infrastructure Gauge and RST Rolling Stock Parameters which influence Ground Based Train Monitoring Systems TSI INF_A: Interface: Structure gauge, Infrastructure gauge • TSI INF: 4.2.3 Minimum infrastructure gauge • TSI RST: 4.2.3.3. Rolling stock parameters, which influe monitoring systems TSI RST: Clause 4.2.3.3.2 of this TSI details the specifications concerning the rolling stock related to axle bearing health monitoring by trackside hot axle boxes detectors. The minimum infrastructure gauge requirements concerning the infrastructure subsystem are set out in clause 4.2.3 of the Infrastructure TSI 2006. Clause 4.2.3.3.2.3 of this TSI details the specifications concerning the rolling stock related to parameters, which influence ground based train monitoring systems, and particularly electrical resistance of the wheelsets and axle bearing health monitoring. The corresponding specifications concerning the control-command and signalling subsystem are set out in clauses 4.2.10 and 4.2.11 of the Control-Command and Signalling TSI 2006 and in its Annex A Appendix 1 clauses 1 to 4.	[10 TSI-INF_A] ID: 30 4.2.3 Minimum infrastructure gauge (INF-3-03: Minimum Infrastructure Clearances) [30 TSI-RST] ID: 85 4.2.3.3.2.1 Class 1 trains (RST-5-03.3: Rolling stock parameters which influence ground based train monitoring systems) [30 TSI-RST] ID: 87 4.2.3.3.2.2 Class 2 trains (RST-5-03.3: Rolling stock parameters which influence ground based train monitoring systems) [30 TSI-RST] ID: 90 4.2.3.3.2.3.1 General (RST-5-03.3: Rolling stock parameters which	[IF-REG] ID: 600 Interface between SYS COM Wayside/Field Equipment Spatial Requirements and GWY Infrastructure S TCS Wayside/Field quirements and GWY Interface between SYS TCS Wayside Train Detection System and RST HST Trainset Wheelset Electrical Resistance [IF-REG] ID: 6341 Interface between SYS TCS Wayside Hazard Detection System and RST HST Trainset Axle Bearing Health Monitoring

Tailoring: 49 TSI infrastructure interfaces resulted in over 100 CHSRS guideway (GWY) infrastructure interfaces



Technical Specifications for Interoperability (TSI)

Step 1: Identification of Key Interfaces

Interface Register Using N^2 Chart Approach

ID	_TSI-TYPE		Traced To: IF-REG (LM)
1	---	1 TSI Interface Register	
5	---	1.1 TSI Infrastructure	
2	---	1.1.1 Interfaces with the Rolling Stock Subsystem	
3	---	1.1.1.1 Structure Gauge and Infrastructure Gaug	
4	INF_A RST	**1.1.1.1.1 Interface between INF Minimum Infrastructure Gauge and RST Kinematic Gauge** TSI INF_A: Interface: Structure gauge, Infrastructure gauge • TSI INF: 4.2.3 Minimum infrastructure gauge • TSI RST: 4.2.3.1 Kinematic gauge TSI RST: Clause 4.2.3.1 of this TSI specifies that the rolling stock shall comply with one of the kinematic vehicle gauges that are specified in Annex C of the Conventional Rail Rolling Stock TSI 2005. The corresponding infrastructure gauges are specified in clause 4.2.3 of the Infrastructure TSI 2006, and the infrastructure register states for each line the kinematic gauge that shall be met by the rolling stock operating on this line.	[IF-REG] ID: 481 Interface between RST HST Trainset Dynamic Envelope Requirements and GWY Infrastructure [IF-REG] ID: 490 Interface between RST HST Trainset Static Gauge Requirements and GWY Infrastructure
13	---	1.5 TSI Energy	
108	---	1.5.1 Interfaces with the Rolling Stock Subsystem	
113	---	1.5.1.1 Voltage and Frequency	
130	RST EGY	**1.5.1.1.1 Interface between EGY Voltage and Frequency and RST Energy Supply** TSI EGY: Interface: Voltage and frequency & Energy Supply • TSI EGY: 4.2.2 • TSI RST: 4.2.8.3.1.1 TSI RST: Clause 4.2.8.3 of this TSI details the specifications concerning the rolling stock related to power supply. The corresponding specifications concerning the energy subsystem are specified in clauses 4.2.2, ... of the Energy TSI 2006. The specifications concerning the energy subsystem, related to the position of ... 2006.	[IF-REG] ID: 6408 Interface between TRK TP Voltage and Frequency and RST HST Trainset
14	---	1.6 TSI Operations and Traffic Management	
244	---	1.6.3 Interfaces with the Rolling Stock TSI	
248	---	1.6.3.1 Braking	
272	RST OPE	**1.6.3.1.1 Interface between OPE Brake Performance and RST Brake System Requirements** TSI OPE: Interfaces exists between Subsection 4.2.2.5.1, 4.2.2.6.1 and 4.2.2.6.2 of this OPE TSI, and subsection 4.2.4.1 and 4.2.4.3 of the HS RST TSI. TSI RST:	[IF-REG] ID: 6672 Interface between O&M OPS Brake Performance Requirements and RST HST Trainset Brake System Performance

Interfaces between Infrastructure & Rolling Stock

Interfaces between Energy & Rolling Stock

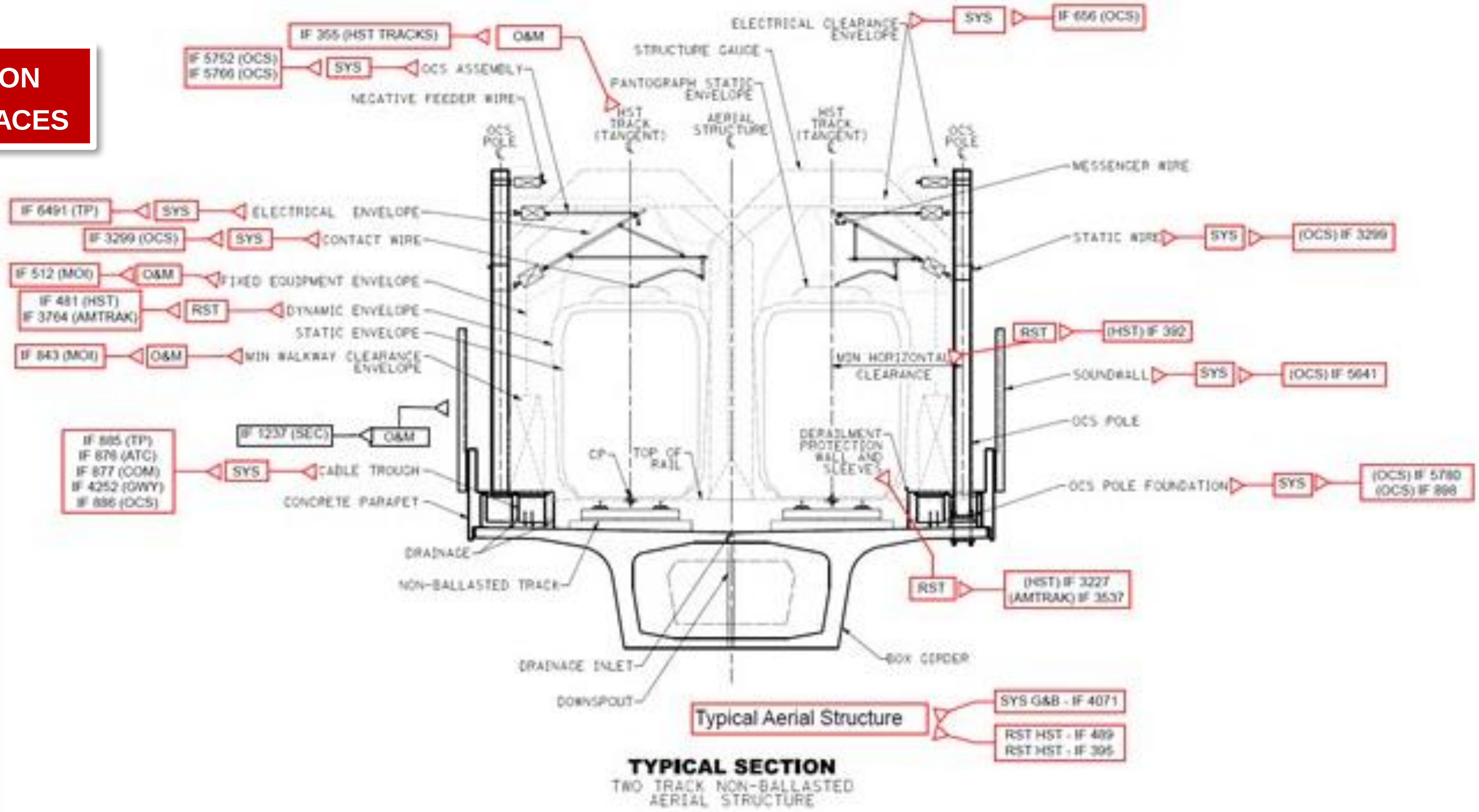
Interfaces between Operations & Rolling Stock

Step 1: Identification of Key Interfaces

Integrated Cross Sections: Example Aerial Structure

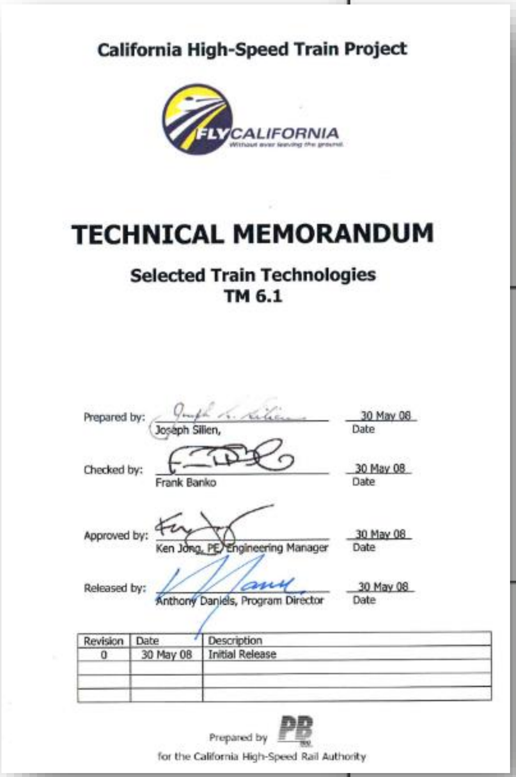
Improve Visibility, Recognition and Communication of Interfaces

Cedar Viaduct



Aerial Structure Integrated Cross Section

Step 2: Identify Candidate HSR Solutions


California High-Speed Train Project

FLY CALIFORNIA

TECHNICAL MEMORANDUM

Selected Train Technologies
TM 6.1

Prepared by: Joseph Silien, 30 May 08 Date

Checked by: Frank Banko 30 May 08 Date

Approved by: Ken Jong, PE, Engineering Manager 30 May 08 Date

Released by: Anthony Daniels, Program Director 30 May 08 Date

Revision	Date	Description
0	30 May 08	Initial Release

Prepared by PB for the California High-Speed Rail Authority

Selected Train Technologies

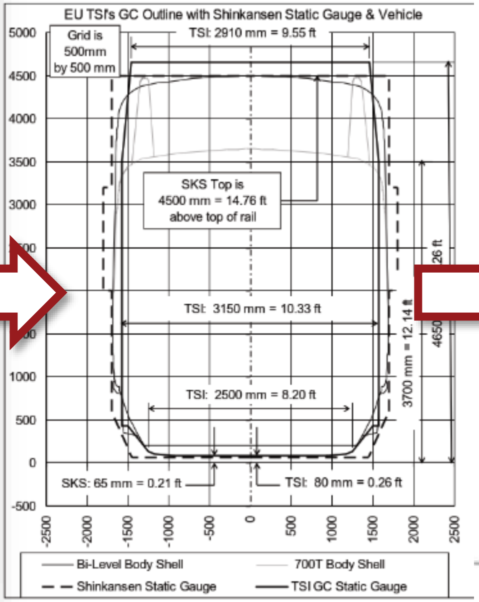
Model		Builder	Year Built	AW0 [UST]	Produced	Consist	Seats	Country	Length (m)	Width [m]	Train Length [m]	Height [m]	Maximum Operating Speed [kph]	Weigh [tonnes
		Siemens	2004	467	26 Trainsets	MCC-TC-MC-2TC-MC-TC-MCC	404	Spain	25.67 CC 24.77 C	2.95	200	3.89	350	425/T
		Hitachi/Kawasaki/ Nippon Sharyo	2005~	769	97 Trainsets by 2011	TCC-14MC-TCC	1323	Japan	25 C 27.35 CC	3.36	430.6	3.6 or 3.5	300	40/C
		Alstom	2008	270 to 510	1 Prototype	7C~14C	250~650	France	17.1 CC 17.3 C	2.9	130~250	/	360	270~51
AVE S-102Power Car (S-350 Trainset)		Bombardier	2004	92 Max. (Loco Only)	46	1L-12C-1L	318	Spain	20.87 L	2.96	366	4	330	Max 17t/Axl

Review of over 30 commercially available HSR trainsets operated in China, France, Germany, Italy, Korea, Japan, Russia, Spain, Taiwan, and the U.S.

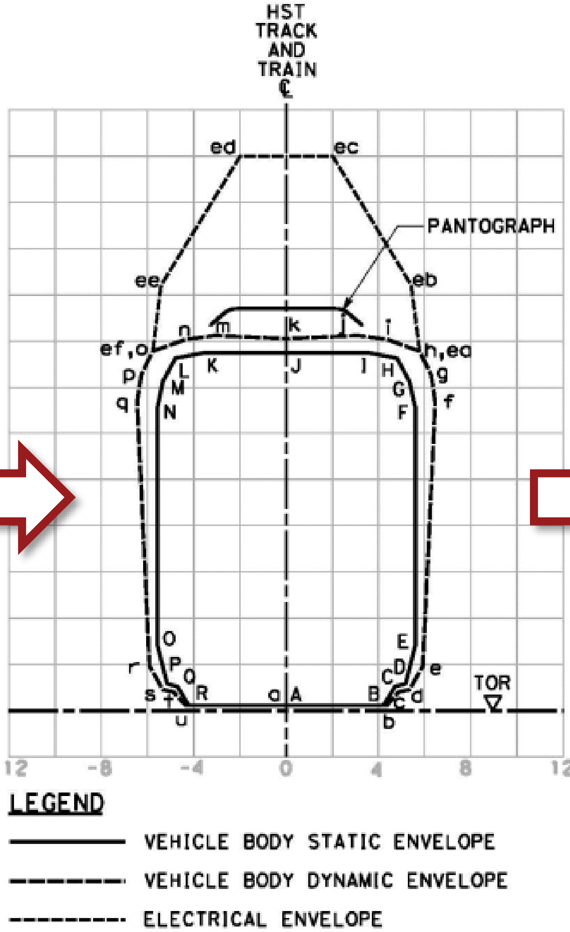
Step 3/4: Develop Interoperable Interface Standard

Candidate HSR Trainsets

Figure 3.1.4: EU TSI Static Gauges GC Compared with Shinkansen Gauge

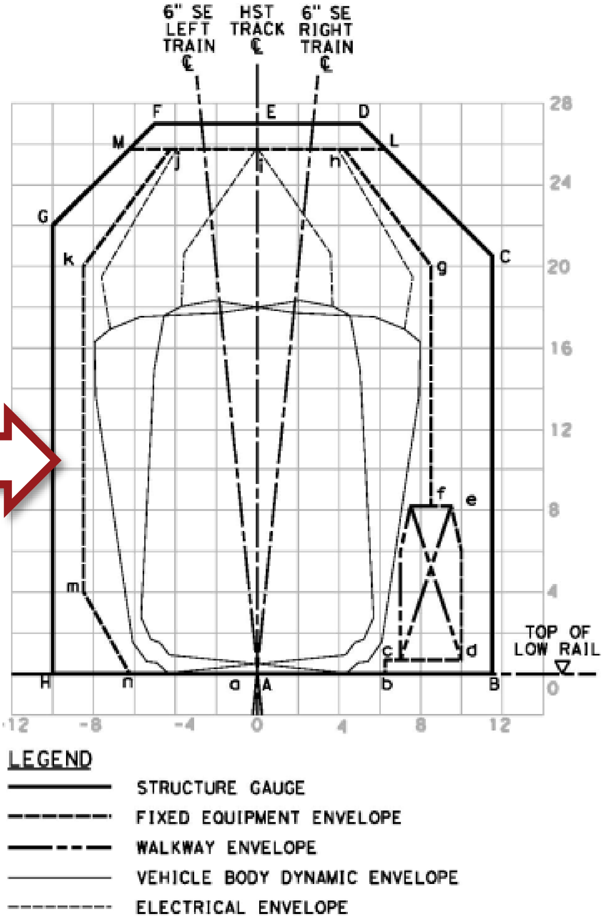


Overlaid Trainset Envelopes



Interoperable Trainset Envelopes

Appendix 3.G: All Passenger Equipment, Structure Gauge and Fixed Equipment Envelope, Open Sections



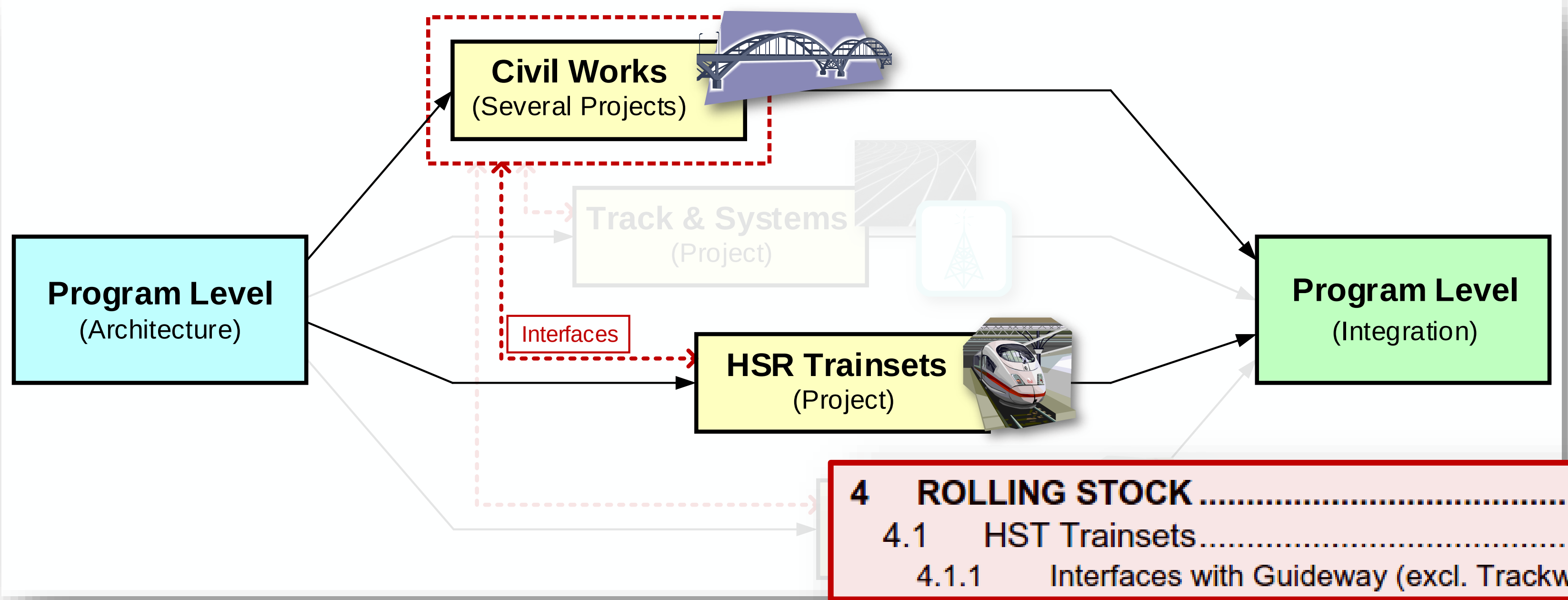
Interoperable Structure Gauges

Open Sections		
Point ID	Horizontal Distance from TCL (feet)	Vertical Distance from TOR (feet)
Structure Gauge		
Walkway Side (See Note 3 & 4)		
A	0.00	0.00
B	11.50	0.00
C	11.50	20.50
D	5.00	27.00
E	0.00	27.00
Non-Walkway Side		
A	0.00	0.00
H	-10.00	0.00
G	-10.00	20.50
F	-5.00	27.00
E	0.00	27.00
Under Existing Low Overhead Structures		
L	6.25	25.75
M	-6.25	25.75
Fixed Equipment Envelope		
Walkway Side (See Notes 1, 3, & 4)		
a	0.00	0.00
b	6.25	0.00
c	6.25	0.67
d	10.00	0.67
e	10.00	8.17
f	8.50	8.17
g	8.50	20.00
h	4.25	25.75
i	0.00	25.75
Non-Walkway Side		
a	0.00	0.00
n	-6.25	0.00
m	-8.50	4.00
k	-8.50	20.00
j	-4.25	25.75

Civil Works Design Criteria

Step 5: Civil Works Implementation

Communication of Interfaces & Interface Standards to Contractors

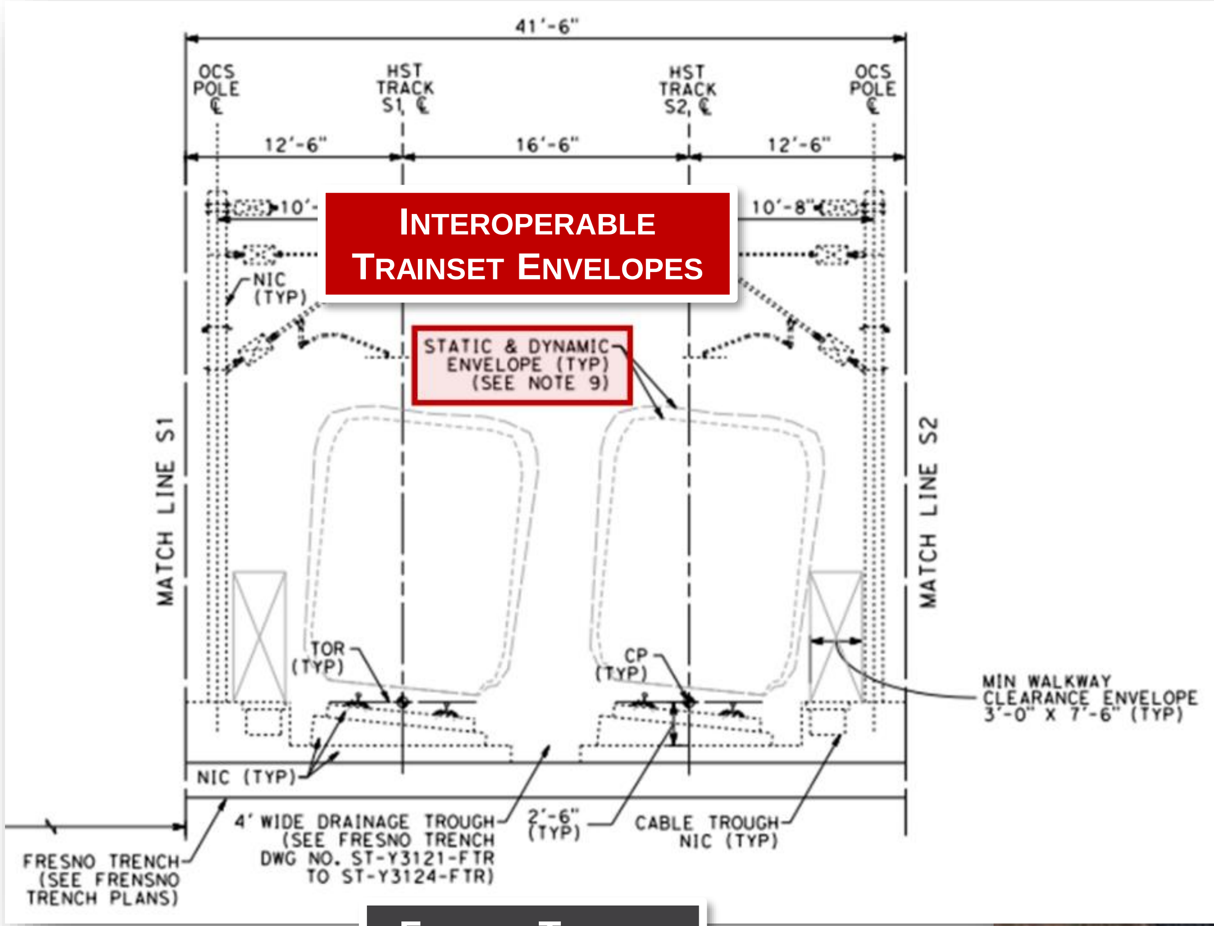


Imposed CHSRS Interfaces using N² Chart Approach

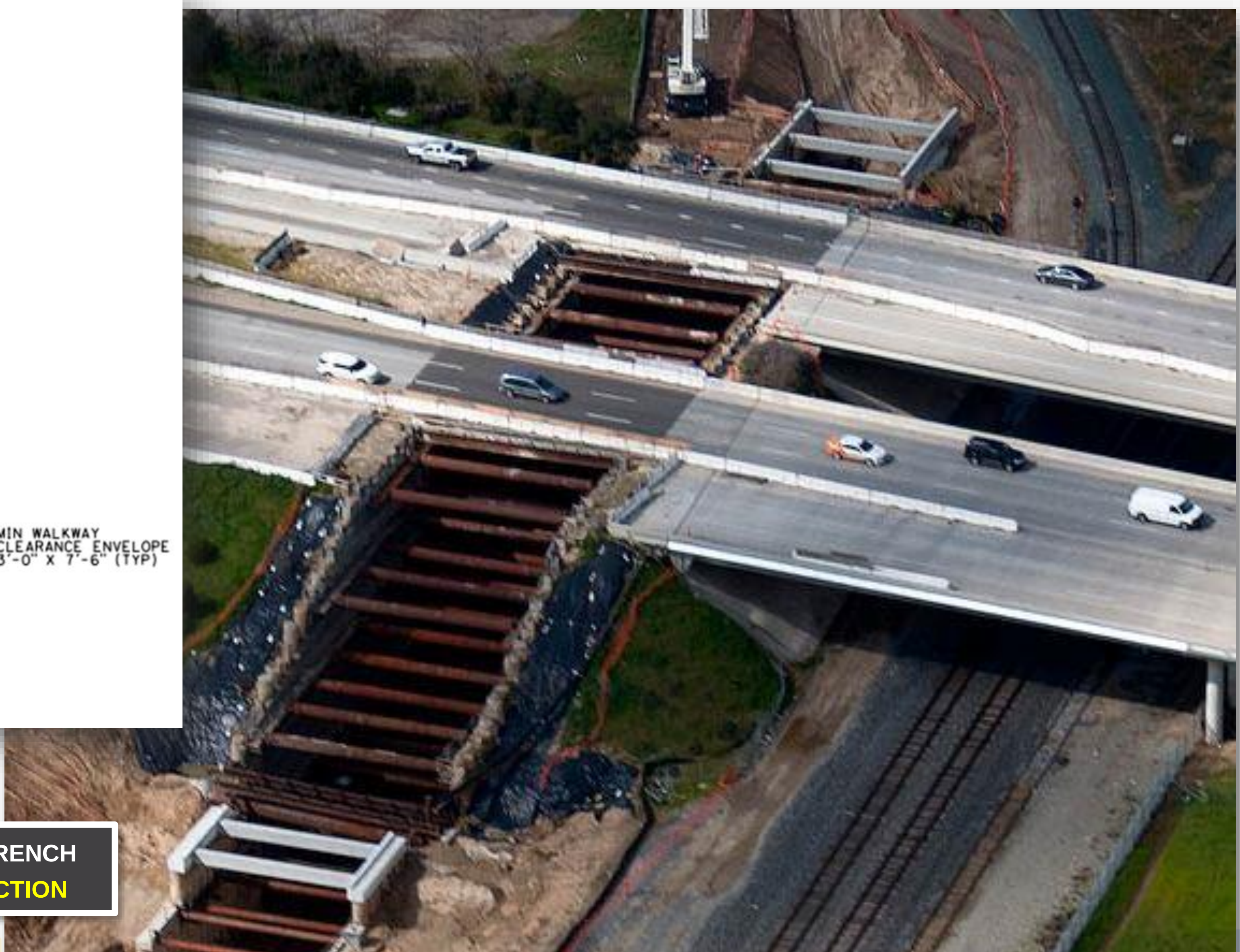
List of Interfaces Provided to Civil Works Including References to Design Criteria

Step 5: Civil Works Implementation

Contractor Final Design & Construction



Fresno Trench
Final Design



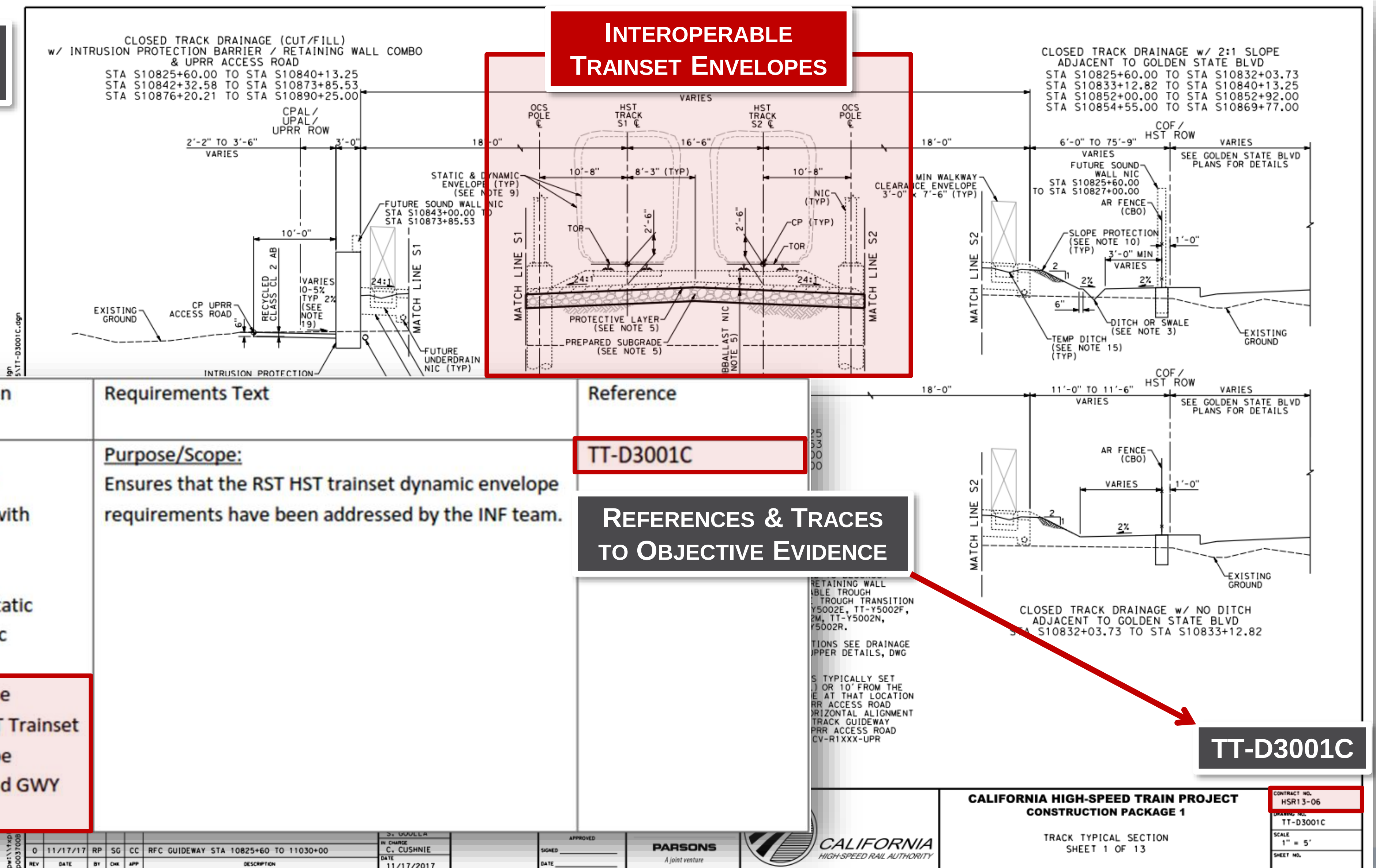
Fresno Trench
Construction

Step 5: Civil Works Implementation

Trust But Verify (CHSRS Verification & Validation Process)

Contractor Design Submittal

Interoperable Trainset Envelopes



Interface Traceability (Certifiable Items List)

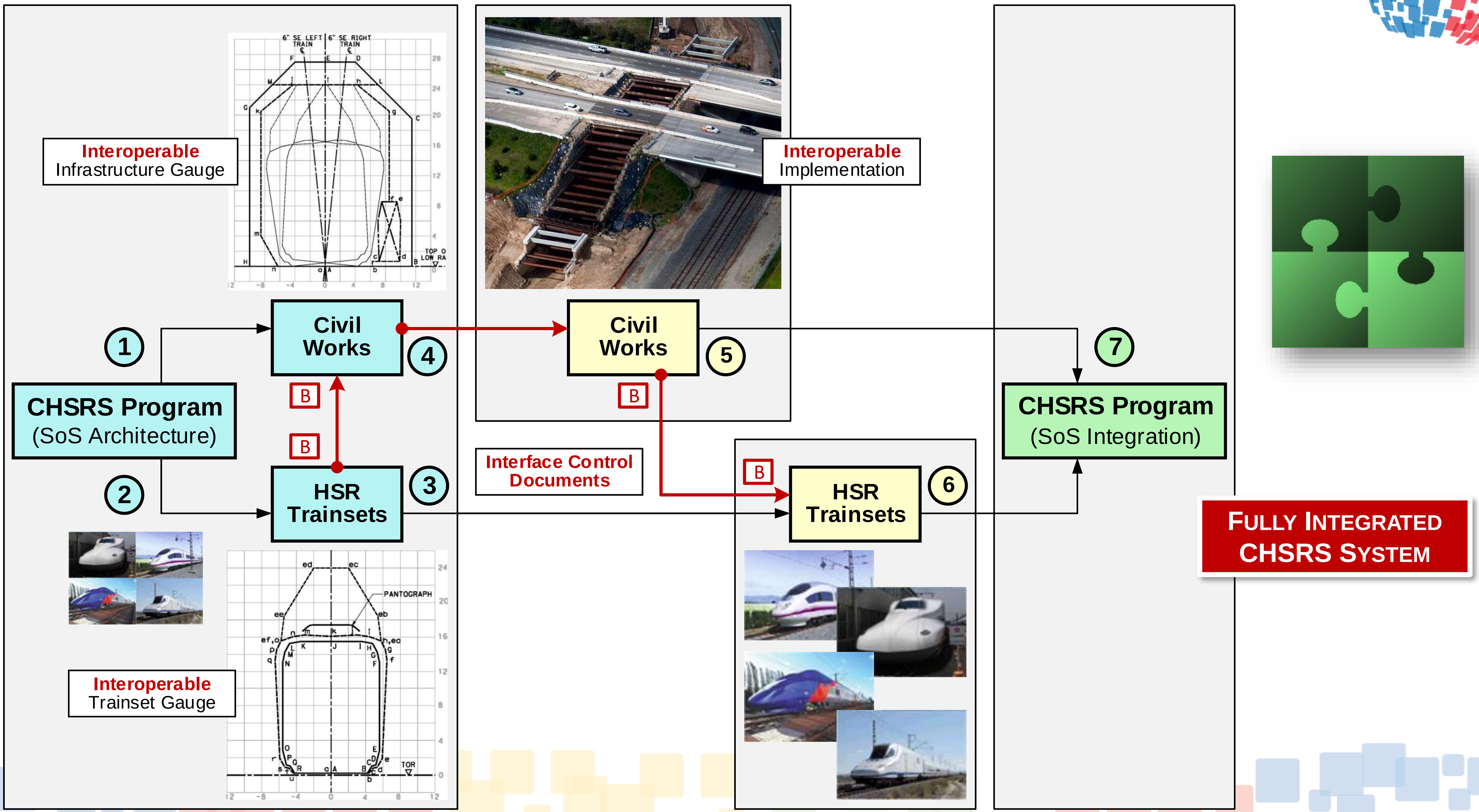
ID	DOC ID	CIL-Safety	Document Section	Requirements Text	Reference
71	Interoperability	CHSRIR329 (IF 481)	4 Rolling Stock 4.1 HST Trainset 4.1.1 Interfaces with Guideway (excl. [illegible]work) [illegible].2 Vehicle Static Gauge & Dynamic Envelope 4.1.1.2.2 Interface between RST HST Trainset Dynamic Envelope Requirements and GWY Infrastructure	<u>Purpose/Scope:</u> Ensures that the RST HST trainset dynamic envelope requirements have been addressed by the INF team.	TT-D3001C

Interoperable CHSRS Interface

References & Traces to Objective Evidence

TT-D3001C

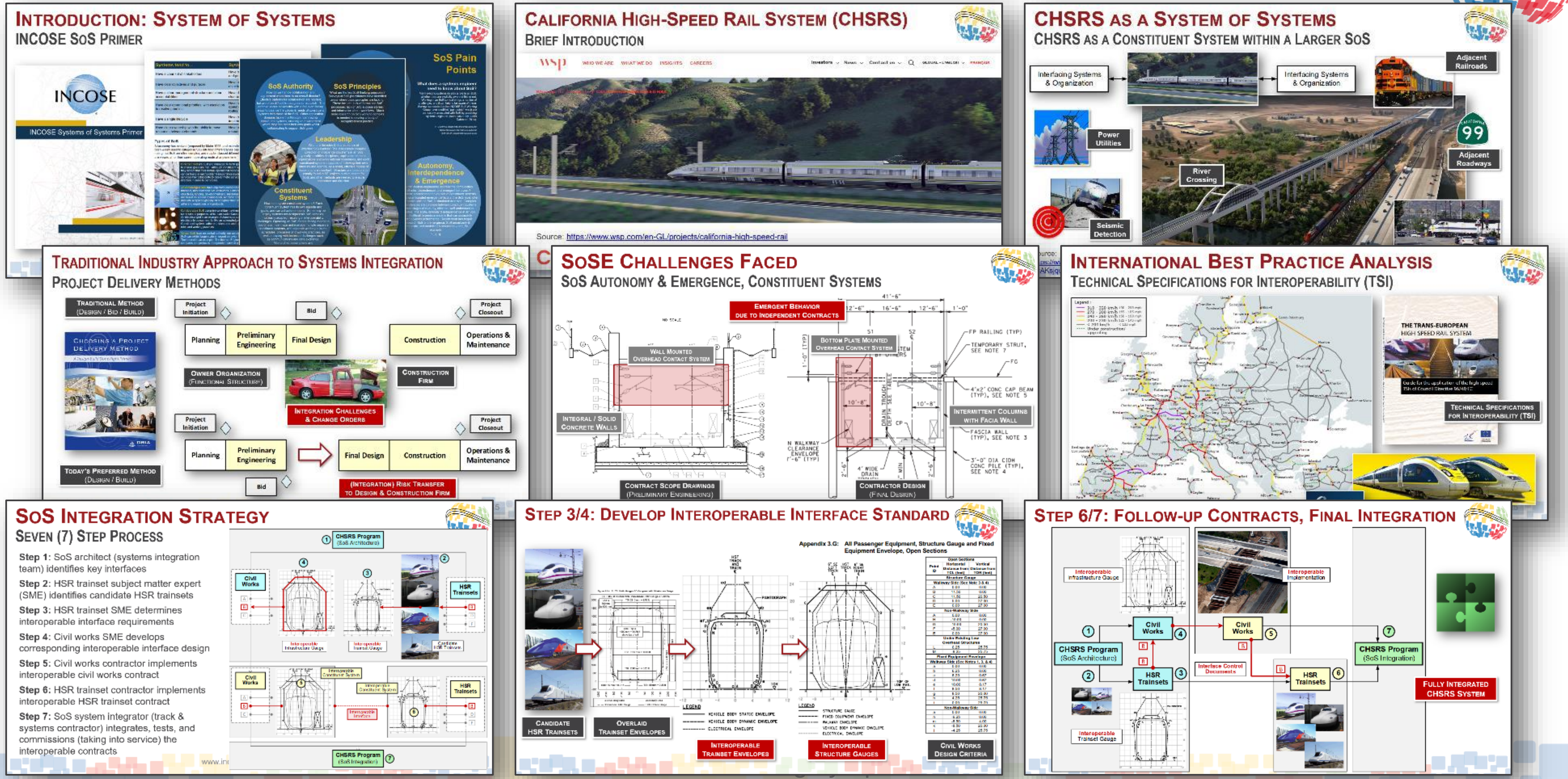
Step 6/7: Follow-up Contracts, Final Integration



PROGRESS

- **Introduction**
  - System of Systems (SoS)
  - California High-Speed Rail System (CHSRS) Program
  - CHSRS as a System of Systems
- **SoSE Challenges Faced**
  - Traditional Industry Approach to Systems Integration
  - SoS Engineering Challenges
- **SoSE Activities Performed**
  - International Best Practice Analysis of HSR System Integration
  - SoS Integration Strategy
  - Step by Step Process Description
- **Summary, Achieved Outcomes & Conclusion**

SUMMARY


Introduction: System of Systems
INCOSE SoS Primer
INCOSE
INCOSE Systems of Systems Primer
SoS Pain Points
SoS Authority
SoS Principles
Leadership
Constituent Systems
Autonomy, Interdependence & Emergence
California High-Speed Rail System (CHSRS)
Brief Introduction
Source: https://www.wsp.com/en-GL/projects/california-high-speed-rail
CHSRS as a System of Systems
CHSRS as a Constituent System within a Larger SoS
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Interfacing Systems & Organization
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Power Utilities
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Adjacent Roadways
River Crossing
Seismic Detection
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Project Delivery Methods
Traditional Method (Design / Bid / Build)
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Bid
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Planning
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Construction
Operations & Maintenance
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Choosing a Project Delivery Method
Today's Preferred Method (Design / Build)
(Integration) Risk Transfer to Design & Construction Firm
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SoS Autonomy & Emergence, Constituent Systems
Emergent Behavior due to Independent Contracts
Wall Mounted Overhead Contact System
Bottom Plate Mounted Overhead Contact System
Integral / Solid Concrete Walls
Intermittent Columns with Facia Wall
Contract Scope Drawings (Preliminary Engineering)
Contractor Design (Final Design)
International Best Practice Analysis
Technical Specifications for Interoperability (TSI)
The Trans-European High Speed Rail System
Technical Specifications for Interoperability (TSI)
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Seven (7) Step Process
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CHSRS Program (SoS Architecture)
Civil Works
HSR Trainsets
CHSRS Program (SoS Integration)
Step 3/4: Develop Interoperable Interface Standard
Appendix 3.G: All Passenger Equipment, Structure Gauge and Fixed Equipment Envelope, Open Sections
Candidate HSR Trainsets
Overlaid Trainset Envelopes
Interoperable Trainset Envelopes
Interoperable Structure Gauges
Civil Works Design Criteria
Step 6/7: Follow-up Contracts, Final Integration
Interoperable Infrastructure Gauge
Interoperable Implementation
Civil Works
CHSRS Program (SoS Architecture)
HSR Trainsets
Interface Control Documents
CHSRS Program (SoS Integration)
Fully Integrated CHSRS System
Interoperable Trainset Gauge

ACHIEVED OUTCOMES & CONCLUSION

- **SoS Authority & Leadership**
  - Maximized limited SoS authority by focusing on technical systems integration
  - Demonstrated SoS leadership by developing tailored SoS integration strategy based on proven internal best practices
- **SoS Architecture**
  - Developed SoS architecture based on procurement strategy with program as SoS and procurement contracts (projects) serving as constituent systems
  - Created easily understandable SoS architecture with key stakeholder buy-in
- **SoS Collaboration & Integration**
  - Worked closely with subject matter experts to communicate, specify and document key interfaces between the procurement contracts
- **SoS Autonomous Constituent Systems & Emergence**
  - Enabled individual Design / Build contract innovation and SoS emergence, without negatively affecting overall SoS integration
- **Conclusion:** The tailored CHSRS systems integration approach created modular and interoperable constituent systems that can be efficiently integrated into a SoS, successfully **achieving system integration through interoperability**

30th Annual INCOSE international symposium

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