Programmatic Systems Engineering Approach in the Procurement of the Ontario Line

14 June, 2024

“Civil infrastructure should not be part of a System Breakdown Structure”

“Interface Management can only be performed on elements with an electrical component”

“Concrete is concrete”

Ontario Line | Project Key Parameters

$14 billion
15 kilometres system
8.7 km of tunnels
3.2 km of bridges
15 stations
7 above-ground stations
8 underground stations
6 interchange stations
1 Maintenance & Storage Facility
14,200 m of yard track
1500 V DC traction power
Overhead catenary system
Driverless trains (CBTC GOA4)
43 trains
24,000 peak-hr ridership

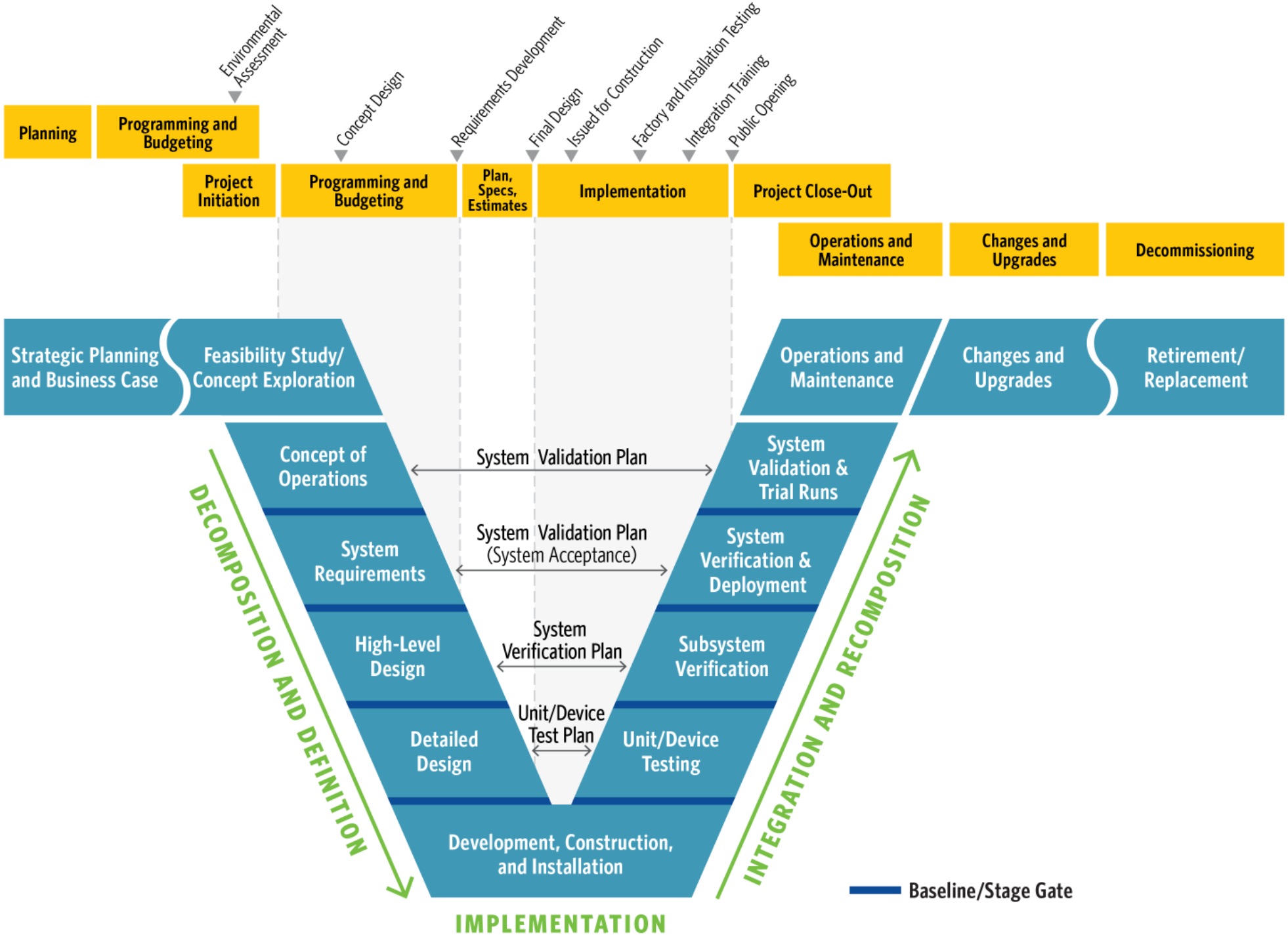
HDR’s Role

Technical Advisor

- Responsibilities include program management, planning, requirements engineering, preliminary designs, conformance reviews, and construction administration
- Engineer of Record, 100% design for Don Valley Crossing, Don Yard Portal, and Pape SOE, and 20+ Advance Works Projects
- Scope includes over 45 design disciplines and staff across Canada, US, Europe, and Australia

Artist’s rendering – subject to change. Transit-Oriented Community

The size, contracting strategy, and complexity of this new subway running through Toronto drove the need for Systems Engineering from the start

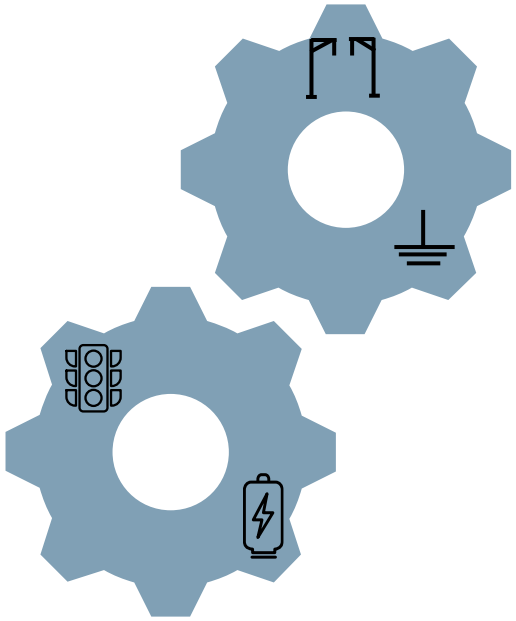

Environmental Assessment
Concept Design
Requirements Development
Final Design
Issued for Construction
Factory and Installation Testing
Integration Training
Public Opening
Planning
Programming and Budgeting
Project Initiation
Programming and Budgeting
Plan, Specs, Estimates
Implementation
Project Close-Out
Operations and Maintenance
Changes and Upgrades
Decommissioning
Strategic Planning and Business Case
Feasibility Study/ Concept Exploration
Operations and Maintenance
Changes and Upgrades
Retirement/ Replacement
Concept of Operations
System Validation Plan
System Validation & Trial Runs
System Requirements
System Validation Plan (System Acceptance)
System Verification & Deployment
High-Level Design
System Verification Plan
Subsystem Verification
Detailed Design
Unit/Device Test Plan
Unit/Device Testing
Development, Construction, and Installation
DECOMPOSITION AND DEFINITION
INTEGRATION AND RECOMPOSITION
IMPLEMENTATION
Baseline/Stage Gate

Many INCOSE processes applied on Ontario Line

Technical Processes	Technical Management Processes	Agreement Process	Organizational Project-Enabling Processes
– Business/Mission Analysis – Stakeholder Needs and Requirements Definition – System Requirements Definitions – Architecture Definition Design Definition – Implementation Integration – Verification – Transition – Validation – Operations – Maintenance	– Project Planning – Project Assessment and Control – Design Management – Risk Management – Configuration Management – Information Management – Quality Assurance	– Acquisition	– Life Cycle Model – Quality Management – Knowledge Management

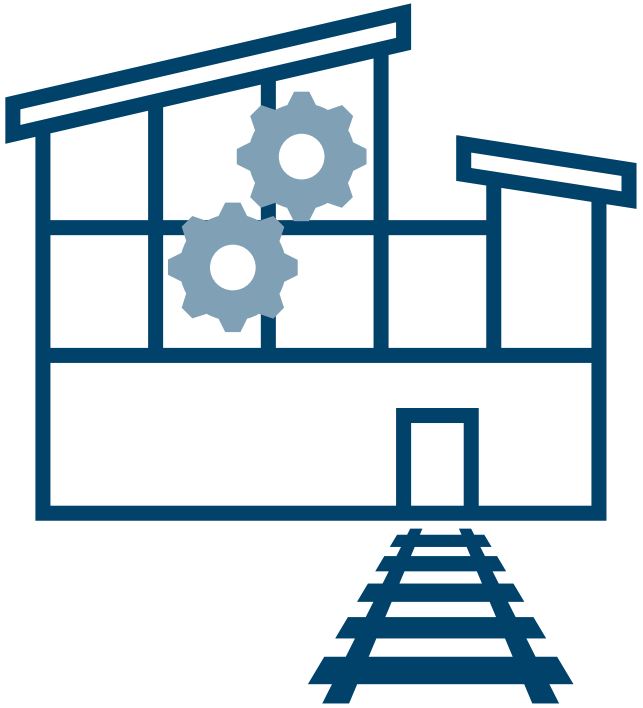
Programmatic Systems Engineering Works!

Traditional Electrical Subsystems



“Traditional” Systems Engineering

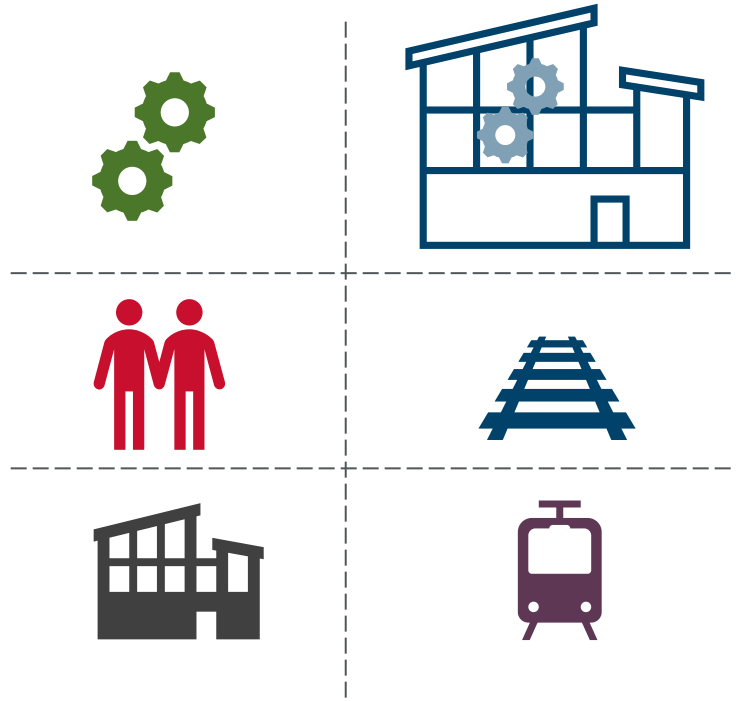
Civil + Systems Integration



Multi-Disciplinary Systems Engineering

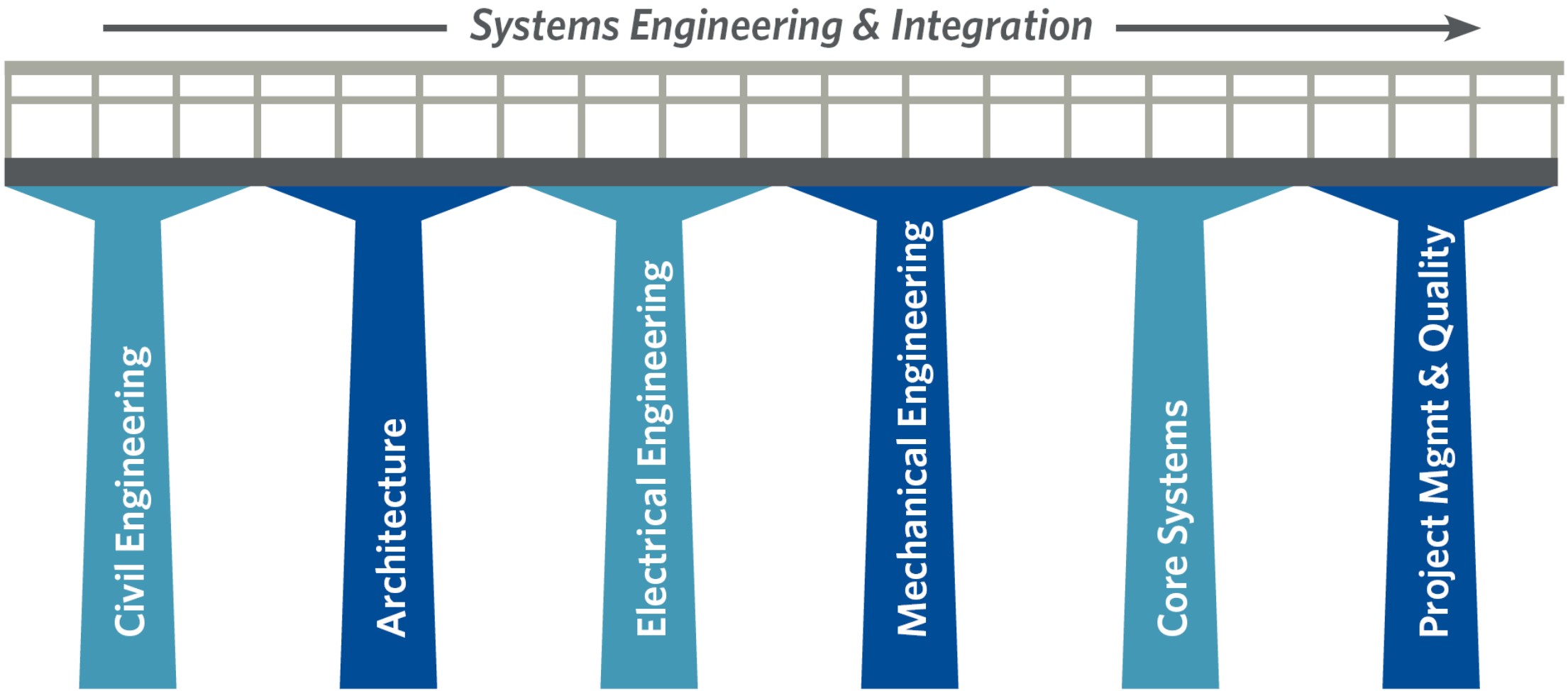
Third Parties Adjacent Systems

Multiple Contractors

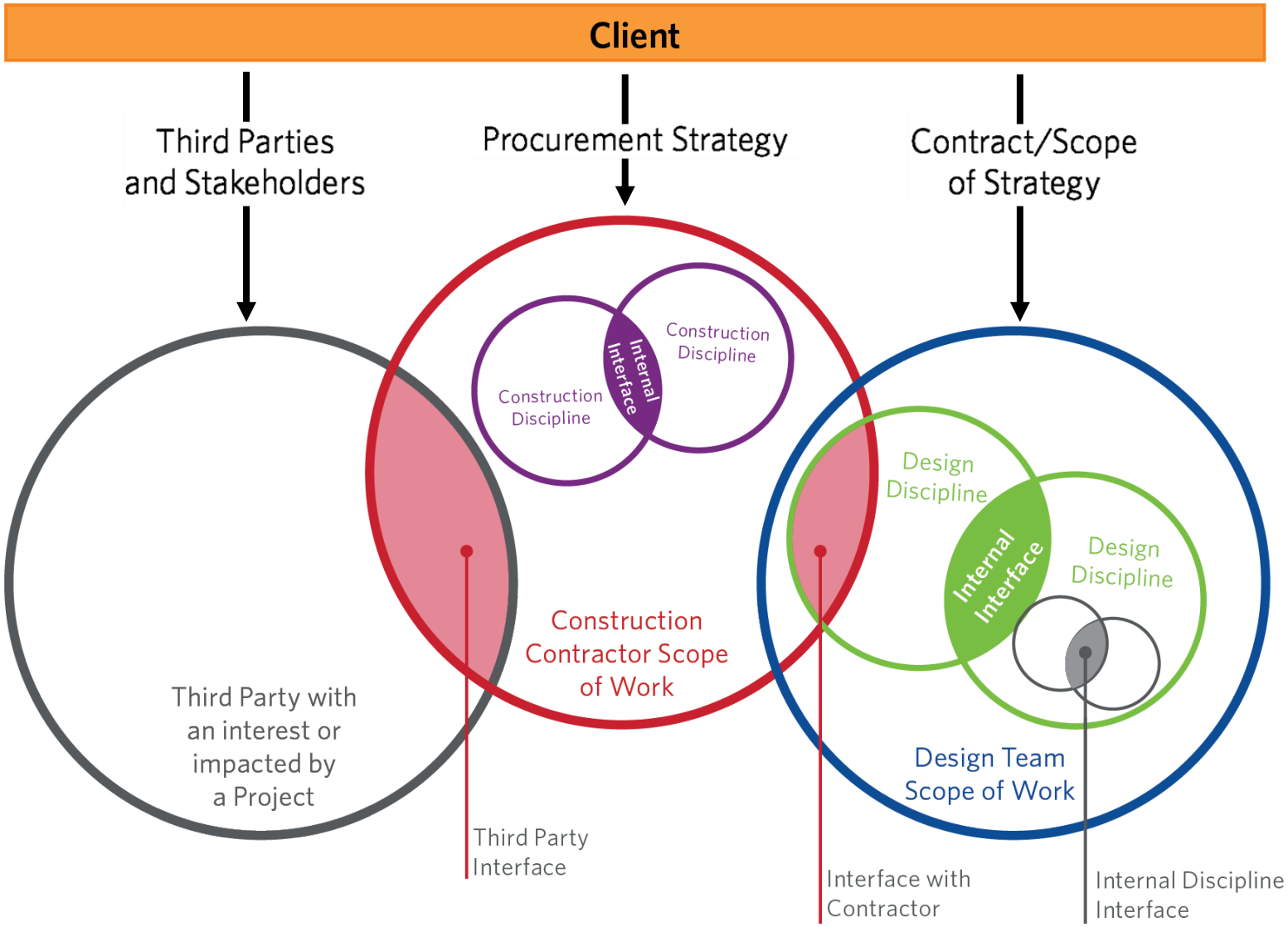


Programmatic Systems Engineering

Using SE to bridge disciplines across Ontario Line



Multiple contracts and partners work best when integrated



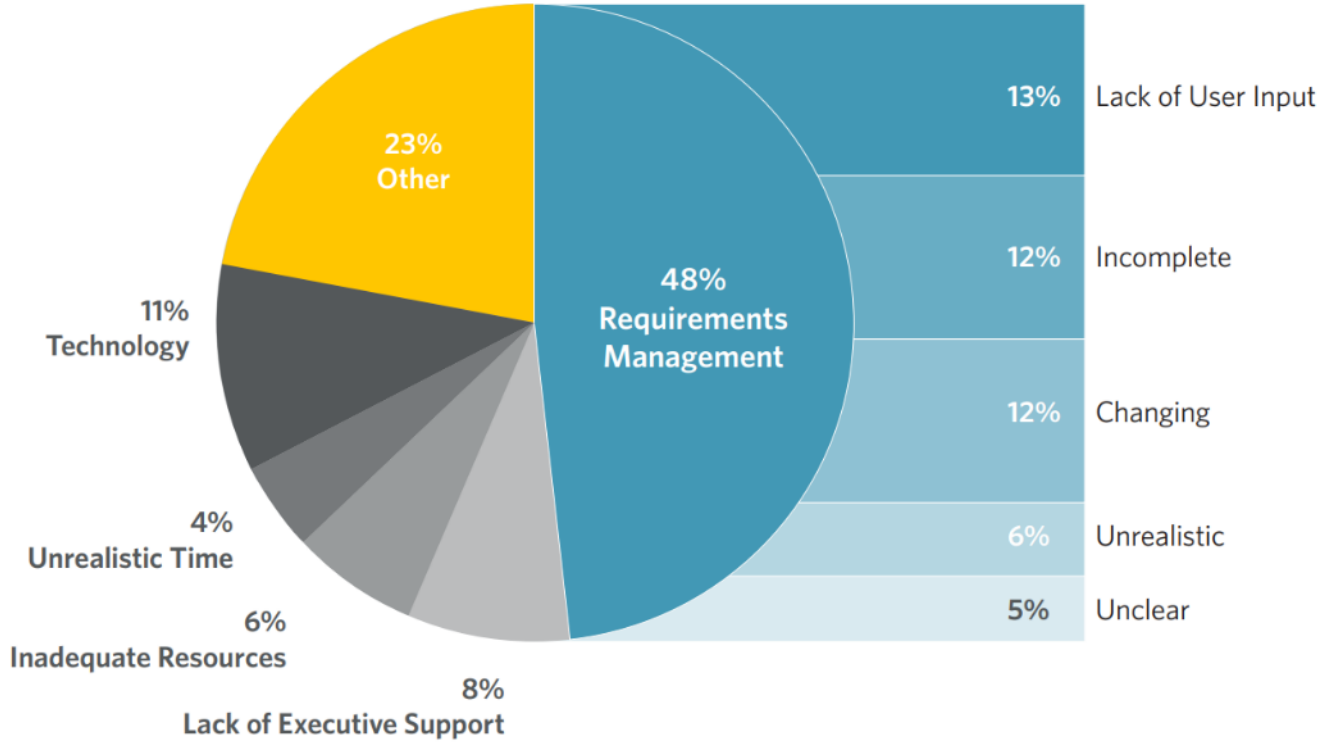
48%

of project failures are linked to Requirements Management

Unclear

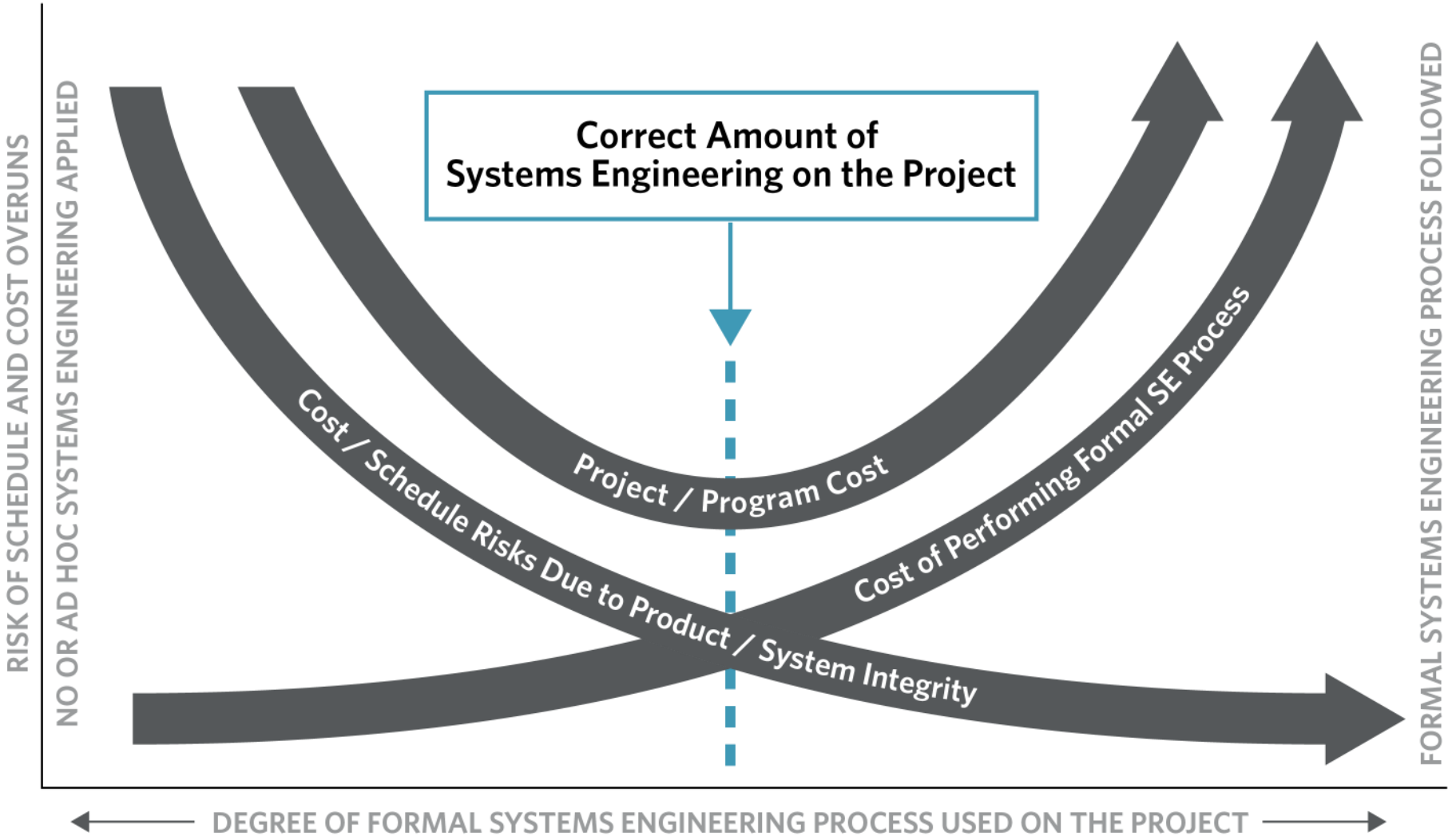
Undefined

Misunderstood

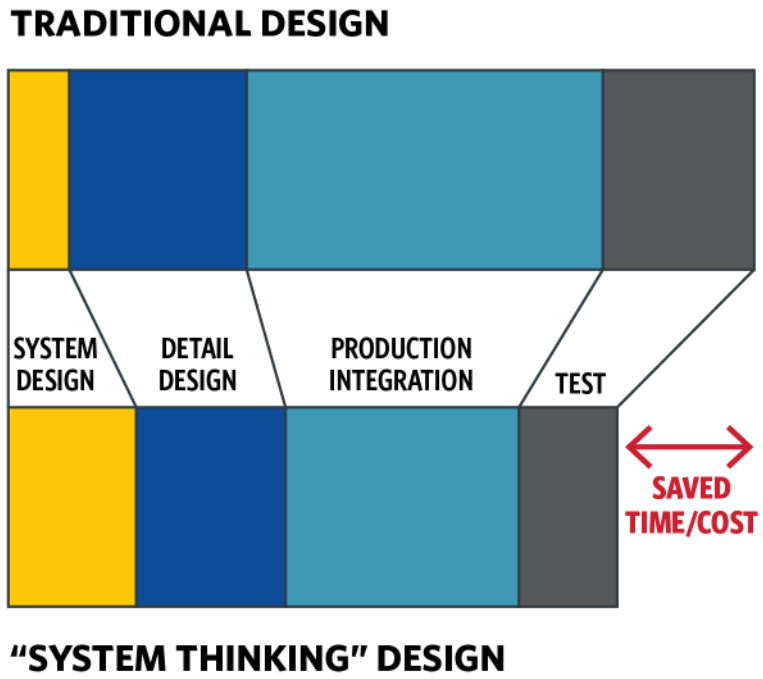


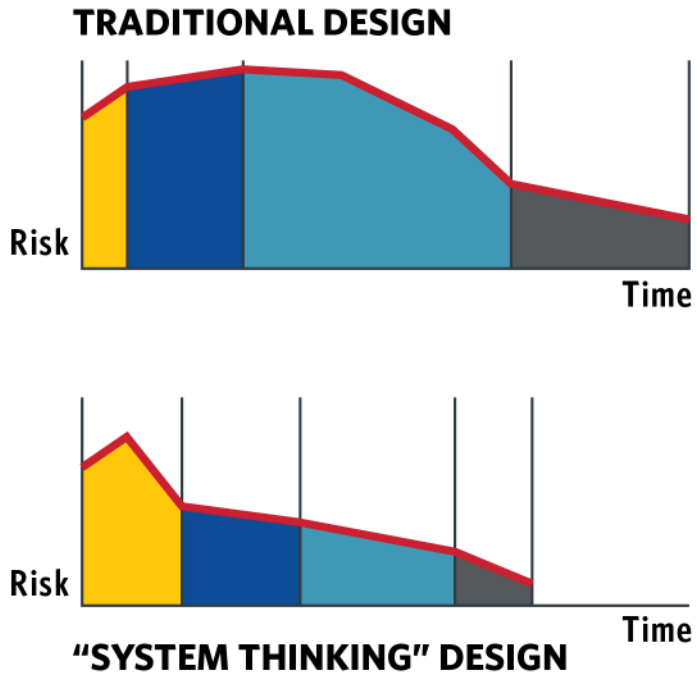
** Standish CHAOS Report*

Finding the right balance



The results of “Systems Thinking”





	Systems Cost Factors
Requirements	1x
Design	3 - 8x
Build	7 - 16x
Test	21 - 78x
Operations	29 - 1615x

COST TO CORRECT MISTAKES

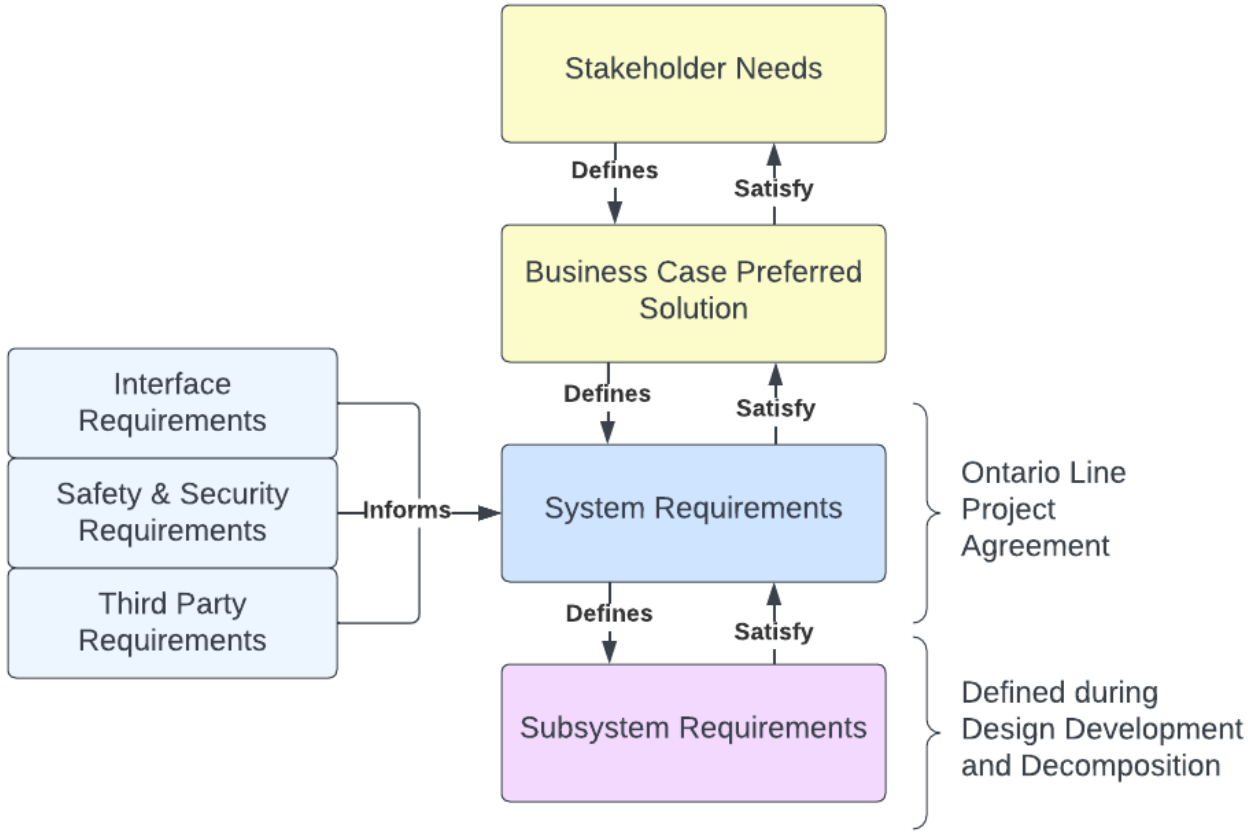
** Understanding the Value of Systems Engineering, 2004*

Magnitude of requirements management

21,054 requirements across all contracts:

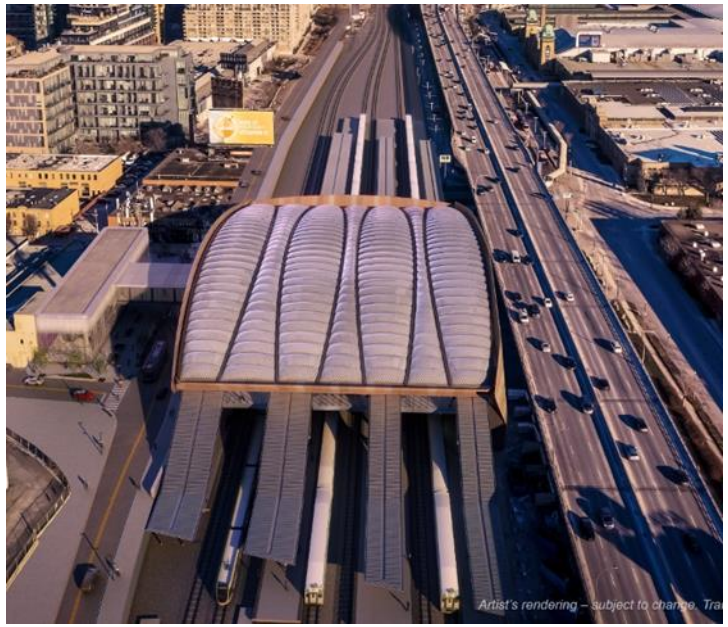
- 8,286 for the RSSOM P3 Contract
- 6,690 for the South Civil P3 Contract
- 6,708 for the North Civil PDB/DBB Contracts

All requirements are captured and managed using DOORS, categorized using various attributes.



The most comprehensive integration and interface management process of any Canadian transit program

Based on three pillars

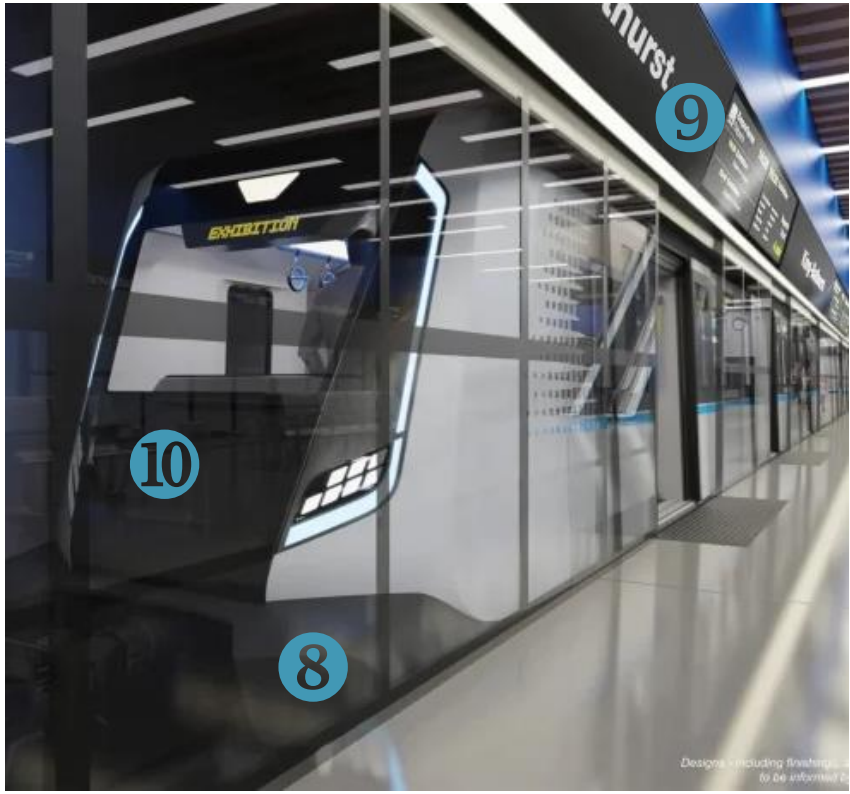


1 **Interface Control Forms (ICFs)**
defines interface boundaries and obligations between contractors

2 **Interface Drawings**
provides a visual representation of project and contractual interfaces

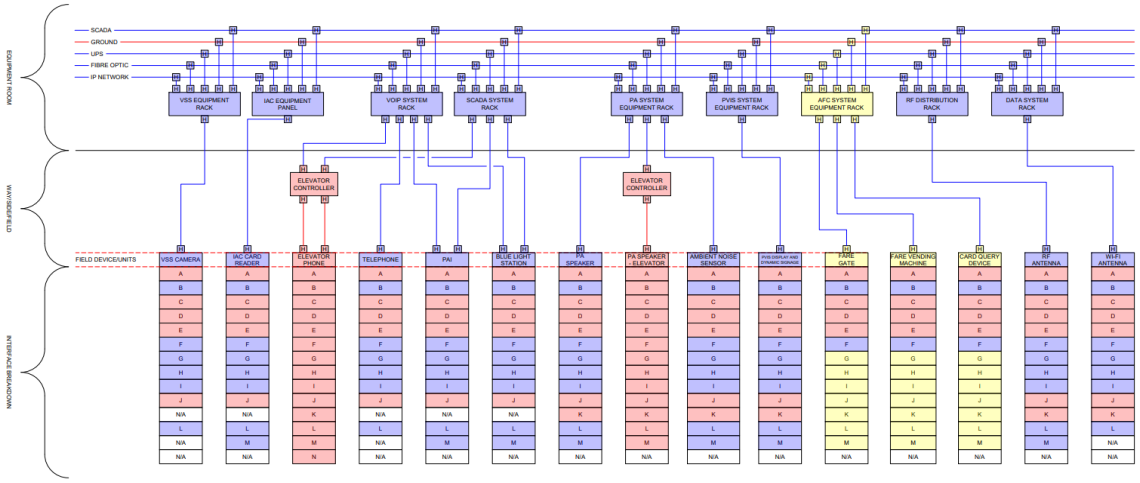
3 **Integration Requirements**
defines the work to be done

Proof: every design discipline is represented

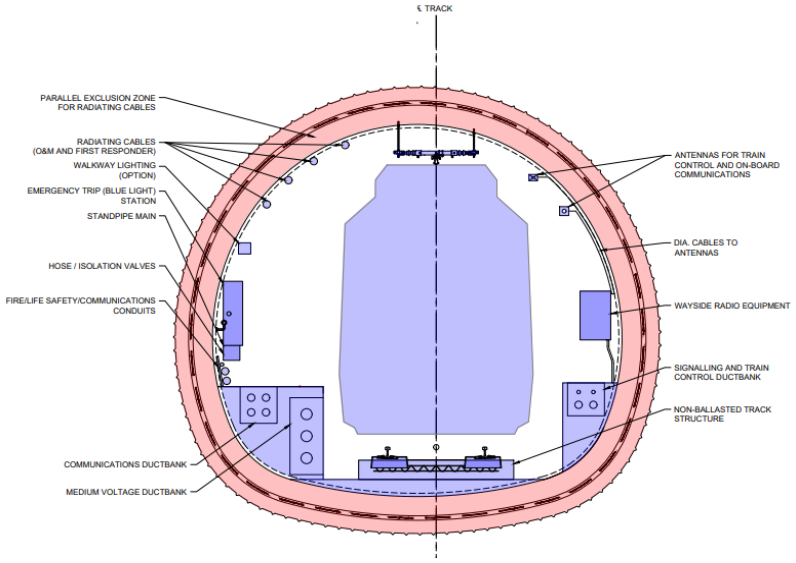


1. Trackwork and Bridge Interface
2. Equipment Circulation, Room Sizing, and Requirements
3. Grounding and Bonding
4. Multiple Contractors Scope of Work
5. Transit-Oriented Community (Condo) Development
6. OCS and Signalling Systems
7. Landscaping and Urban Design
8. Platform Screen Doors
9. Passenger Information Systems
10. Rolling Stock

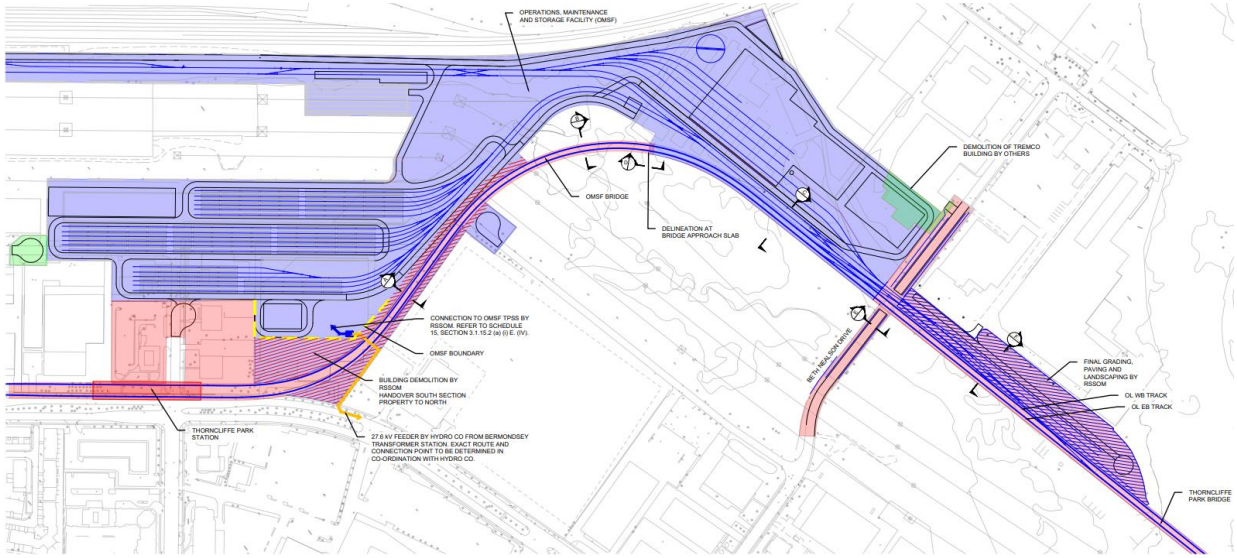
Contractors interfacing every step of the way



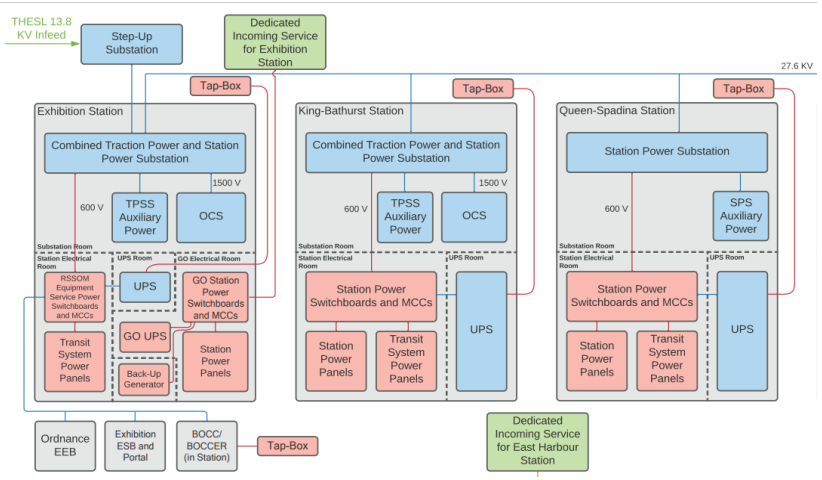
▲ Conduit and cabling diagram for communications systems



▲ Tunnel fit-out scope split



▲ Mainline and depot interface and contract scope split

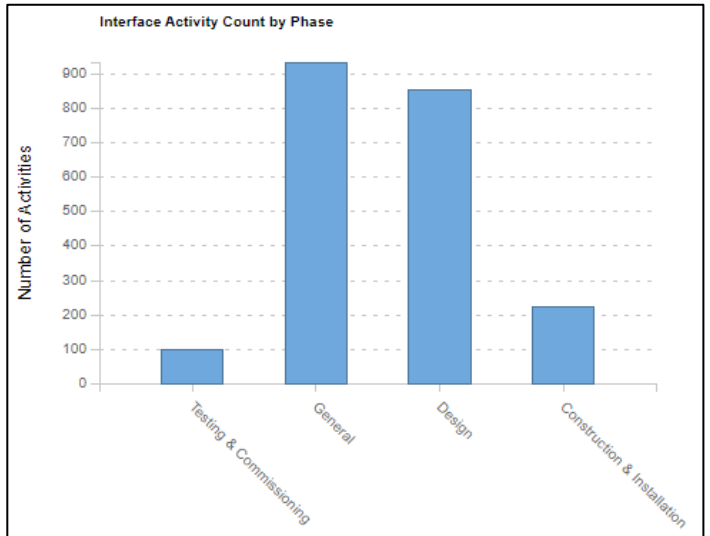


▲ Power supply schematic and scope split

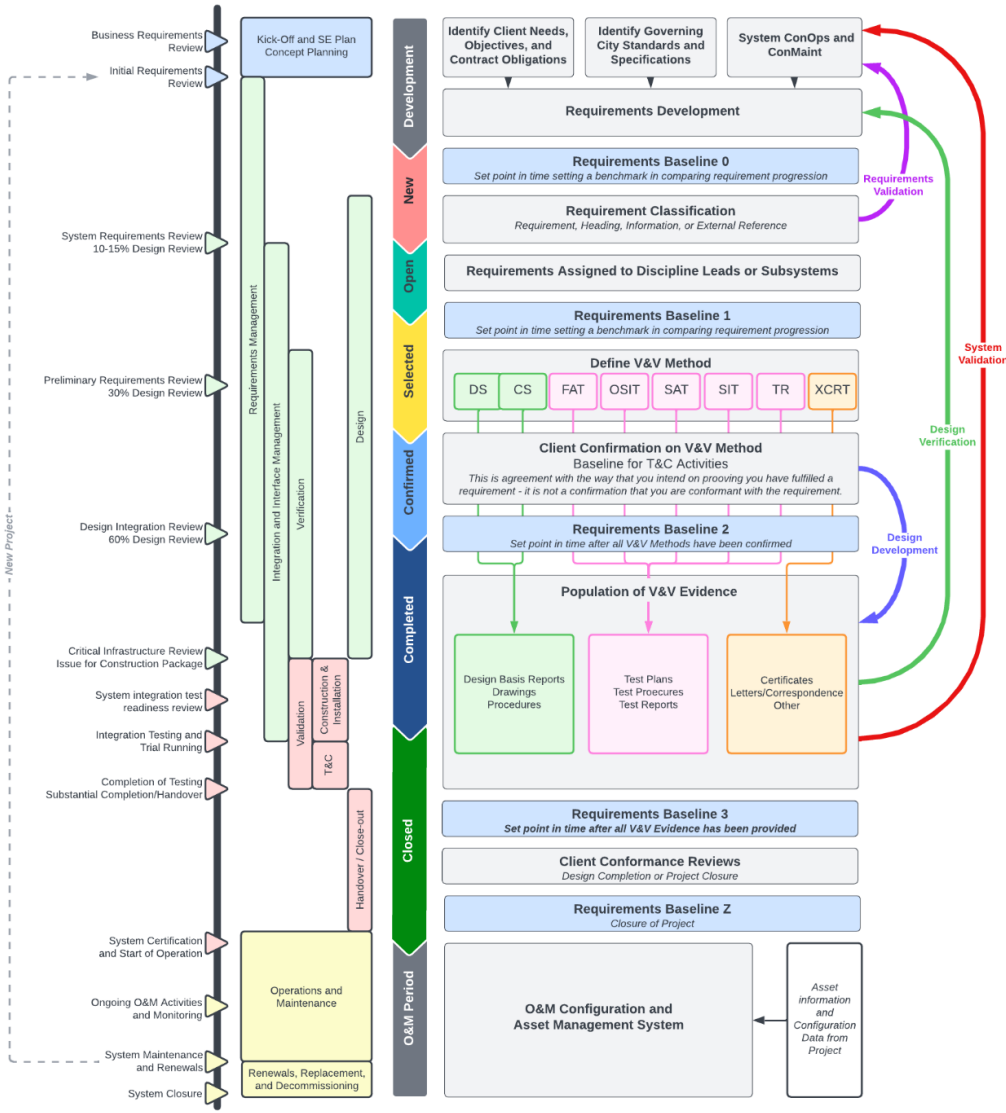
Verification and Validation… it's coming

ID	Requirement ID	Contents	Artifact Type	Requirement …	Objec…	Wor…	Section
		described in Section 3.1.11.5.					
111362	NCL.Sch15.42351	"Building Substructure" means the section of the Building Structure that is below ground level.	Context	CR 00442	4	4	0-1.0-3.0-2
111363	NCL.Sch15.42352	"Building Superstructure" means the section of the Building Structure that is above ground level.	Context	CR 00442	4	4	0-1.0-3.0-2
111364	NCL.Sch15.39898	"Canopy" means a structure on a Platform having a roof cover.	Context		4	4	0-1.0-3.0-2
111365	NCL.Sch15.39900	"Centre Platform" means a single Platform configuration for which the Platform serves both directions of travel.	Context		4	4	0-1.0-3.0-2
111366	NCL.Sch15.39899	"Centre Platform Station" means a Station with a Centre Platform.	Context		4	4	0-1.0-3.0-2
111367	NCL.Sch15.39901	"City Standards" means references, codes, standards, specifications, guidelines, policies, reports, publications, manuals, bulletins, and other such documents issued by the City of Toronto.	Context		4	4	0-1.0-3.0-2
111368	NCL.Sch15.39902	"Civil Structures" are the structural	Context	CR 00603	4	4	0-1.0-3.0-2

▲ Ontario Line requirements managed in DOORS NG



◄ Auto-generated report representing types of requirements by project phase (General, Design, Construction, Installation, T&C)



▲ V&V process flow chart

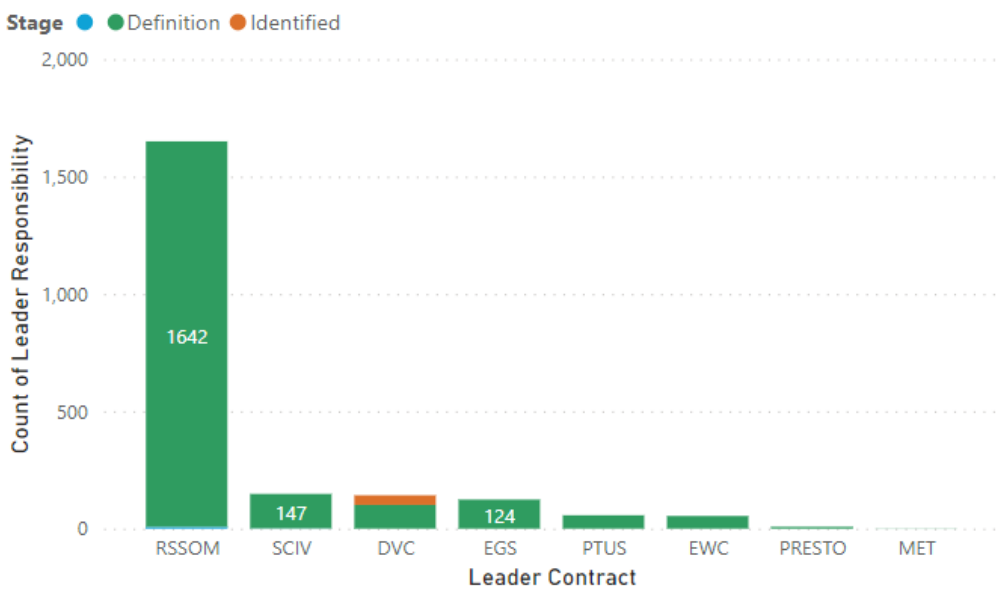
Effective reports shared using DOORS and Power BI

ONE TEAM
ONTARIO LINE TECHNICAL ADVISOR

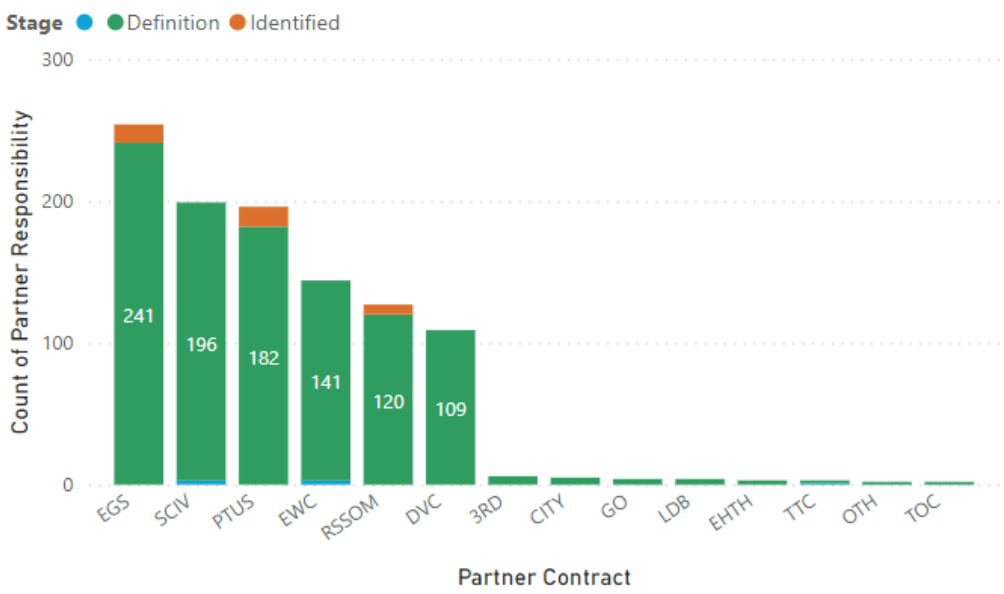
Stage and Phase Status

Confidential & Proprietary: This report is for internal deliberative purposes only

Leader Contract - Stage Status



Partner Contract - Stage Status



Leader Contract - Phase Status

Phase	DVC	EGS	EWC	MET	PRESTO	PTUS	RSSOM	SCIV	Total
		1							
Construction & Installation	17	14	5		2	4	194	7	**2**
Design	69	60	28		3	35	588	95	**8**
General	46	42	19	1	3	16	778	43	**9**
Testing & Commissioning	10	7	2			2	90	3	**1**
Total	**142**	**124**	**54**	**1**	**8**	**57**	**1650**	**148**	**21**

Partner Contract - Phase Status

Phase	3RD	CITY	DVC	EGS	EHTH	EWC	GO	LDB	OTH	PTUS	RSSOM
			1								
Construction & Installation			31	58		24				52	23
Design	3	11	73	156	3	118	14	4	6	128	226
General	7	3	113	216		96	5			177	96
Testing & Commissioning	1		16	30		12				23	9
Total	**11**	**14**	**234**	**460**	**3**	**250**	**19**	**4**	**6**	**380**	**354**

Final Thoughts

PDH Questions

What percentage of project failures are linked to Requirements Management?

A. 20%

B. 95%

C. 48%

D. 60%

Approximately how many requirements have been developed across all contracts?

A. 8,000

B. 21,000

C. 48,000

D. 26,000

In which city is the Ontario Line?

A. Ottowa

B. Toronto

C. Montreal

D. Calgary

Bonus question – Can you name the hockey teams in each of these cities?

A. Ottowa

B. Toronto

C. Montreal

D. Calgary

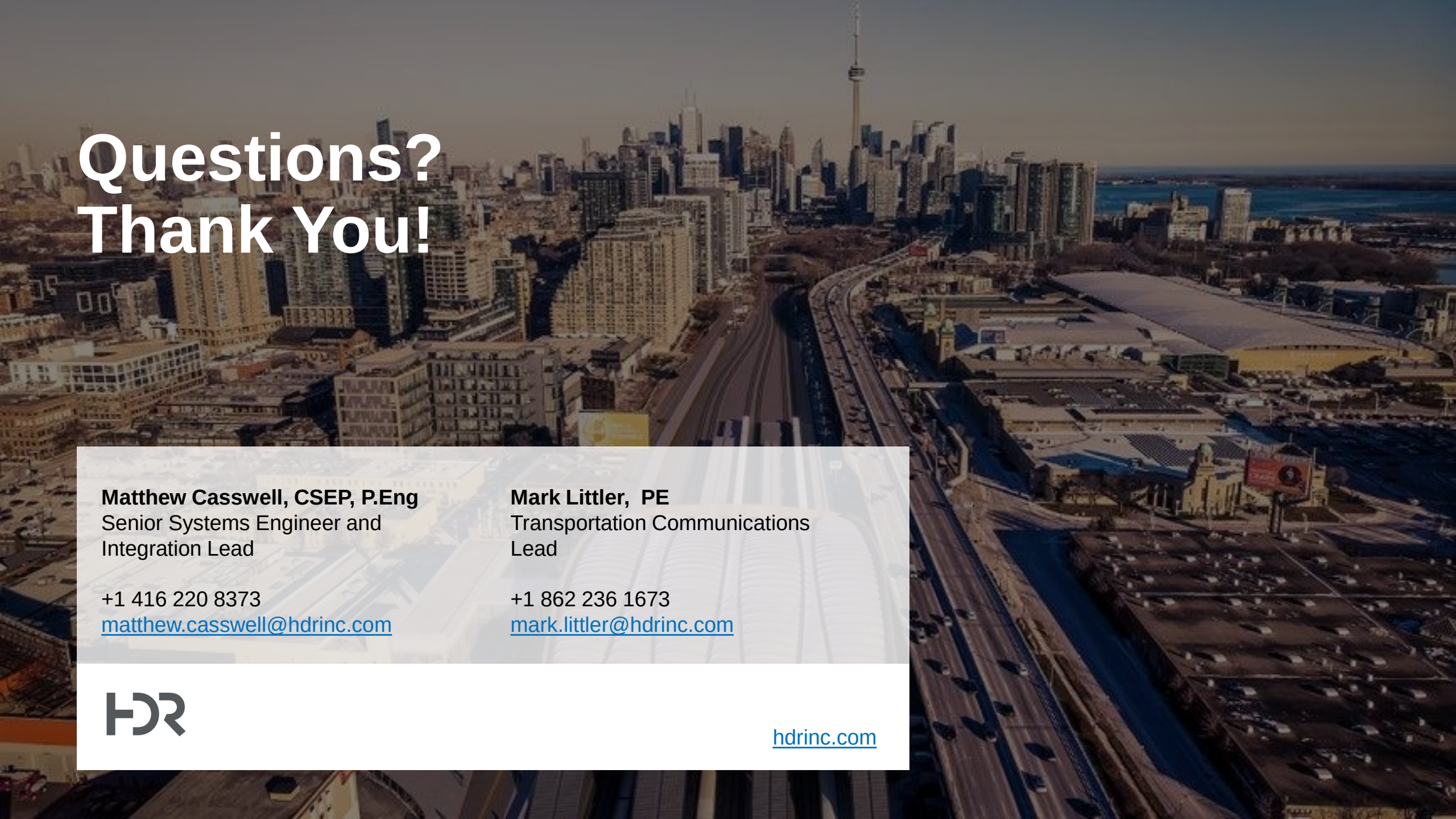
Bonus question answers

A. Ottowa - Senators

B. Toronto – Maple Leafs

C. Montreal - Canadiens

D. Calgary - Flames



Questions?
Thank You!

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