INCOSE
TRANSPORTATION

International Council on Systems Engineering
A better world through a systems approach

Transportation Infrastructure Workshop

Dale Brown – Transportation WG + APTA SLE Subcommittee
Marcel Van De Ven – Infrastructure WG + Smart Cities WG
Tony Wu – President INCOSE Canada Chapter
William Hui – APTA SLE Subcommittee Chair

APTA
SLE Subcommittee

Rev 04

INCOSE International Symposium 2025 | Ottawa, Canada

Dale Brown

President, Chicagoland Chapter

Co-Chair Infrastructure

Chair Transportation WG

APTA – INCOSE Relationship Manager

APTA SLE Subcommittee Founder, Vice Chair

TechOps AD – Analytic Enabler WGs

NSI Advisory Services

AGENDA

Summary of the Event

- Collaboration & Outreach
- Dutch National Tunnel Standard and the use of MBSE
- INCOSE and APTA Work on the SLE Standard
- Workshop Scenarios

Results Summary

Draft Timeline

Going Forward

TIW Report to INCOSE

Who Showed Up

Stakeholders in the room:

~ 50 people

- Transit Agencies – TTC, TransLink, Metrolinx, OCTranspo
- Via Rail – National Rail Passenger Service Provider
- Transport Canada Policy Leaders
- Equipment Suppliers
- Services Suppliers
- Tool Suppliers
- Engineering Consultancies
- Educators

Suggest: Prototype for future events where the country chapter can lead off the main event with a workshop or other way to showcase the local INCOSE chapter and promote the flagship events.

Collaboration!

INCOSE INFRASTRUCTURE

Smart Cities Initiative

APTA SLE Subcommittee

INCOSE TRANSPORTATION

"If we want to succeed as a team, we need to put aside our own selfish, individual interests and start doing things my way."

INCOSE Canada

CANADA

WI IL IN INCOSE CHICAGOLAND

TRACCS
Transit Rail Association for Canadian Contractors, Maintainers, Operators and Standards

Jama software

Marcel Van De Ven

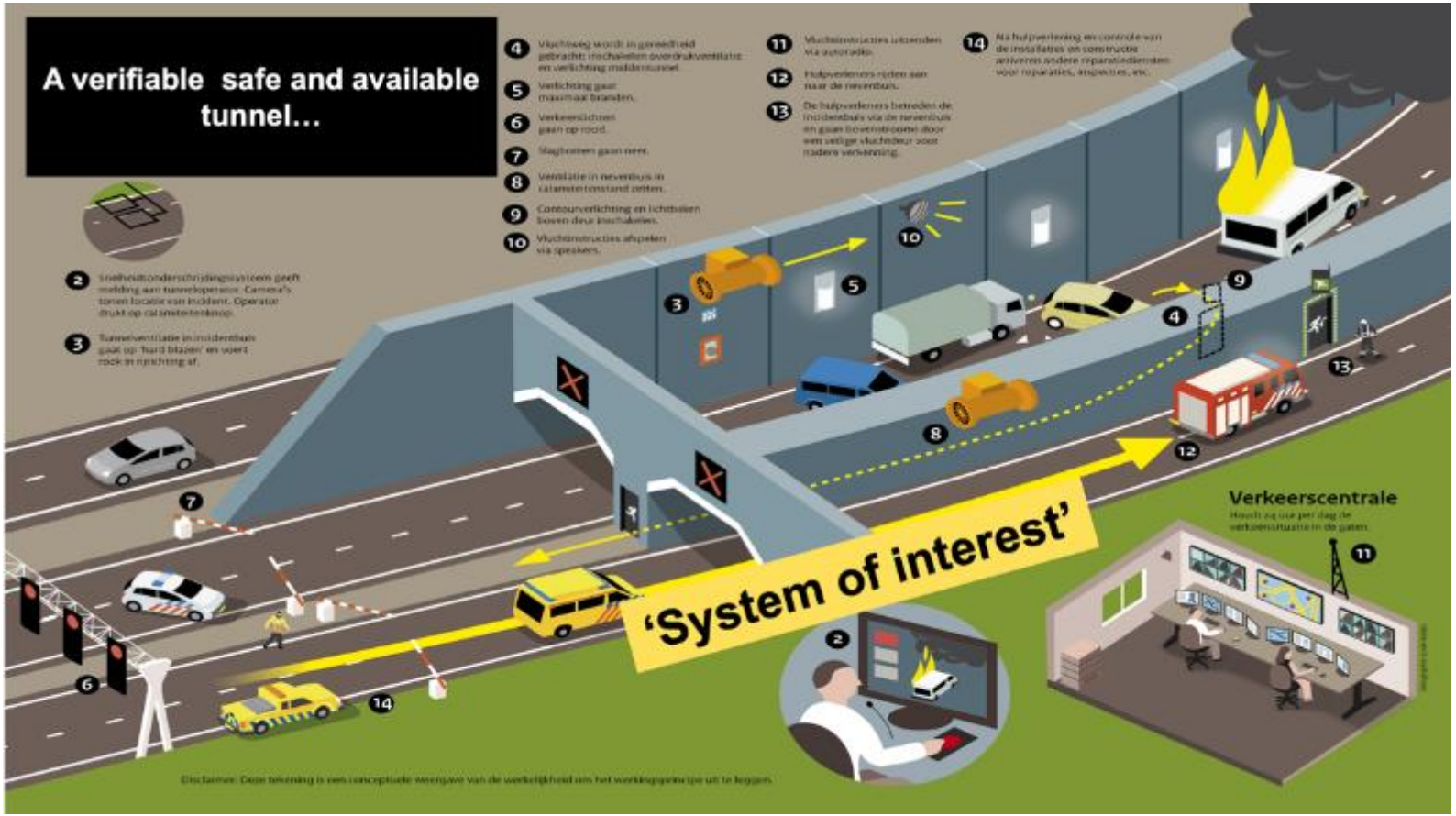
Co-Chair Smart Cities

Chair Infrastructure

Co Chair Transportation WG

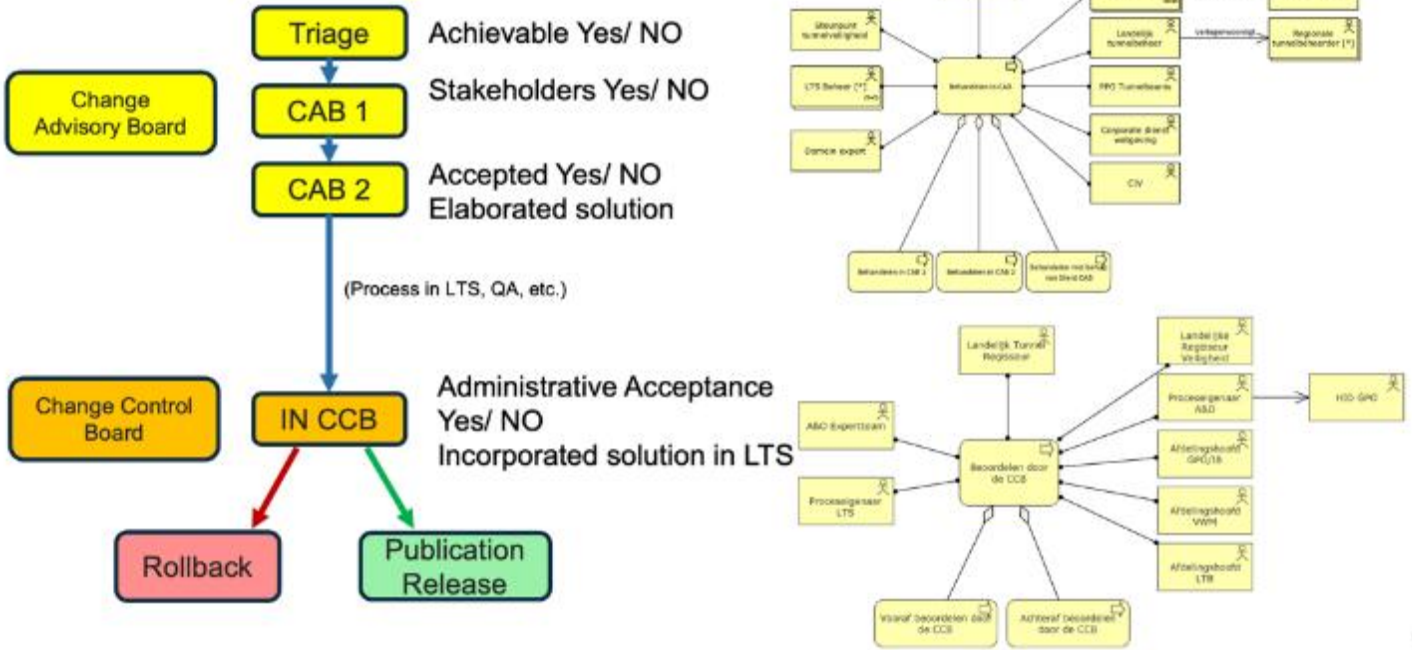
Heijmans

Use of safety standards and scenarios



Configuration & Change Management

Detail: Issues /Changes by Stakeholders



Tunneling Infrastructure vs. Train Systems

Comparing Train Transportation System – Tunnel System

Can we apply lessons learned from MBSE LTS to Train Transportation Systems?

• Investment ratio Civil – Technical installations for Tunnel:	Civil 85 % - Technical 15 %
• Operational costs ratio Civil – Technical installations for Tunnel:	Civil 15 % - Technical 85 %
• Both Systems have big impact on environment:	Multiple decades – century
• Test scenarios:	Train: Signalling + Safety cases – Tunnel operational safety
• Need for standardization Military options?!?!	Tunnel: Yes – Train: Yes? Unless
• Safety first!	
• Need for early detection of design failures!	

Take aways

1. Start with the model and meta model
2. Think in Events/ Processes
3. Incorporate business processes
4. Analyse
5. Use Configuration Management / Issue manegement
6. Stakeholders
7. Updates: How, when, why, what

INCOSE and APTA work on the standard

Words Matter...

The phrase “Systems Engineering” is ambiguous in the Infrastructure domain!

Most practitioners use it colloquially as the contraction of “Sub-Systems Engineering”

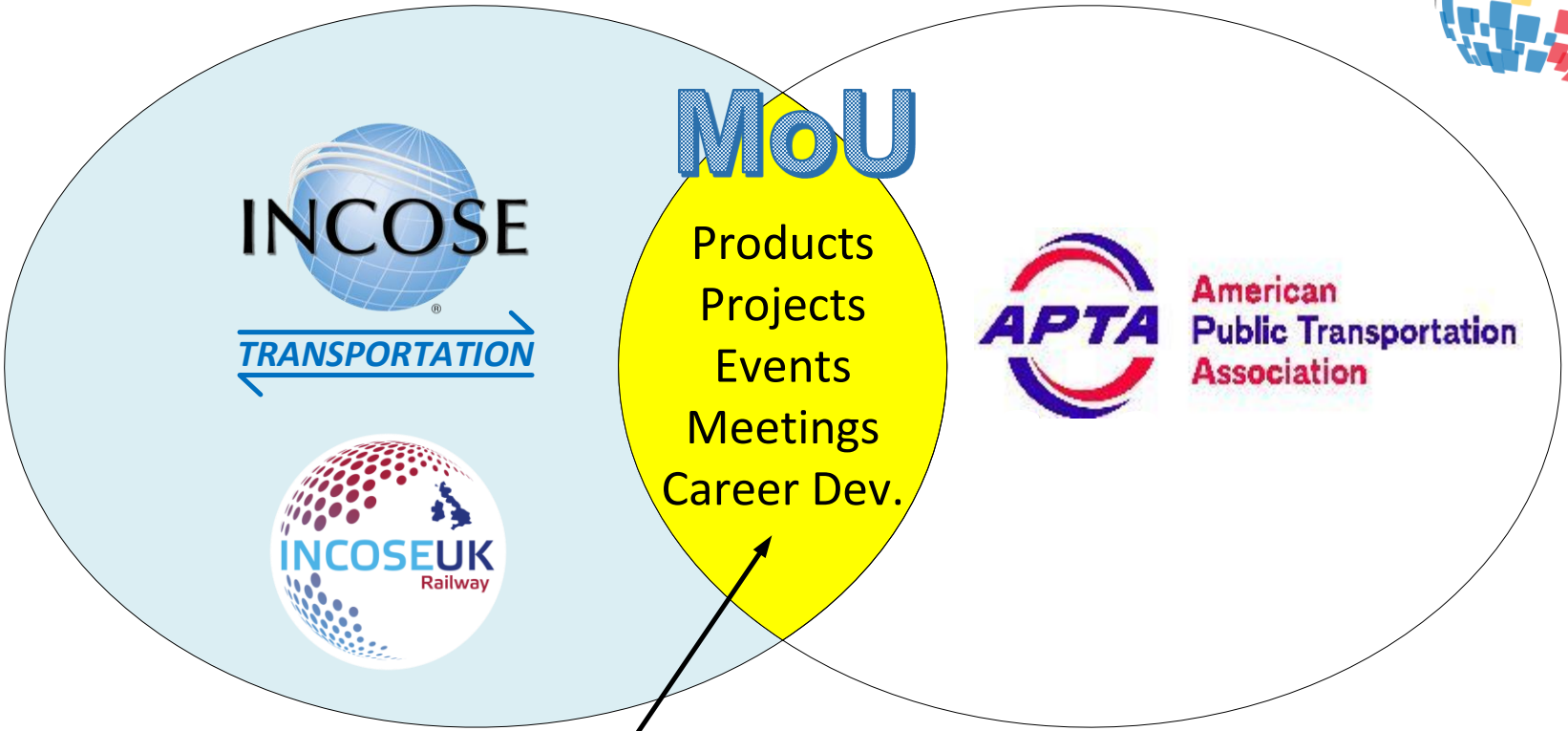
…meaning HVAC, Electrical, Drainage, IT, Comms, Train Control, Signaling ,etc.

We strive to drive ambiguity out of the Rail and Transit Industry

Synonyms helpful for clarification:

- Holistic Engineering
- Holistic Thinking
- Systems Thinking

We are using Systems Lifecycle Engineering to differentiate from Sub-Systems Engineering.



Areas of Strong Professional Collaboration

The promise of SE (SLE)

Rail & Transit: Global Forces & Mega Trends

Economic uncertainty & funding pressures

Pressures caused by a global pandemic, lengthy procurement paths, inefficient agency Processes, State of Good Repair urgency & decreased ridership are squeezing Capital Program Budgets & schedules.

Increased oversight and regulatory mandates

Compliance and safety regulations monitored by state and federal authorities mandate higher standards for quality, safety, reliability and resiliency – especially during and after the current global pandemic.

Declining Engineering Design & Development productivity

Complexity and inefficiency in supplier development processes contribute to extended product development cycles and reduce innovation opportunities.

Subsystem suppliers (OEMs) are using the digital thread approach to thrive.

Advances in technologies and Digital Transformation

OEM Suppliers are pursuing digital transformation from both a regulatory compliance necessity and an internal efficiency (profit margin) standpoint.

Transit and Rail agencies must keep up with the digital transformation.

Powerful forces are reshaping the global Rail & Transit industry = funding reduction & greater agency risk exposure!

Expectation for Rail and Transit projects that SLE will:

Reduce Design and Development Time

Reduce Cost of Compliance (i.e., Quality, Safety, Security)

Improve quality while dealing with increasing complexity

Mitigate Risk across the project

Tools and Process Contributions to success

Correctly Specifying, Acquiring and Deploying a professional tool set for Requirements Management can bring substantial benefits

Reduce **development costs** by

57

Decrease **design and development cycle time** by

20

Lower **cost of quality** by

69

WARNING: Poor RM Processes and Tool Deployment can bring your project to a standstill!

Reality …so far

Rail and Transit Project Performance

Network Rail - Gospel Oak to Barking – Delays in Electrification Plans

- Plan to double the current capacity of passengers on the line
- Work began on the £130M upgrade in June 2016 with a target completion date of 27th Feb 2017
- Completed in May 2018 - **> 1-year delay**

" The heights of station platforms and bridges had apparently come as a surprise. Materials arrived late. The design work had errors in it... When the steelwork turned up, it didn't fit and had to be scrapped."

SNCF (French Railways)

The French train operator SNCF has discovered that 2,000 new trains it ordered at a cost of 15B Euros ($20.5bn; £12.1bn) are **too wide for many regional platforms**.

It is an embarrassing blunder that has, so far, **cost the rail operator over 50M Euros** ($68.4m; £40.6m) to fix

Context:

- Mega Rail and Transit Sector Train Control project
- Project is very late.
- Suppliers are very far over-budget ($100sM)
- >50k Requirements

- Very poor RFP requirements quality – non-compliance with ISO29148 (>80% fail rate)
- QA is 'missing-in-action' for engineering processes, including change control & defect tracking
- Excessive Design Statement constraints in System Requirements (ISO29148)
- Requirements Management (RM) practitioners were not competent with RM processes
- RM tool setup was inexpertly managed – Static Data disks between parties (loss of CM & chaos)
- SE and RM has now degenerated into bureaucratic 'tick-box exercise' – negative project value

Poor Requirements Management results can be exhibited though:

- ✓ ***Poor Requirements***
- ✓ ***Poor RM Tool setup***
- ✓ ***Both of the above***

False conclusion often used periodically:
"Deployment results of SE / RM proves that SE is too complex for the Rail & Transit Industry"

Actual Root Cause:
"Improper Deployment of SE has been wasteful and ruinous for many N.A. Rail & Transit Industry projects"

Rail and Transit Project Performance

- ✓ Lack of data collection & audit 'chain of custody'
- ✓ Inaccurate or missing survey data before design
- ✓ Scope changes not tracked & controlled
- ✓ Delays in design approvals & decision making
- ✓ Configuration Management is ad-hoc or missing
- ✓ Delays due to misalignments between owners & supp...
- ✓ Excessive Rework due to errors in requirements & designs
- ✓ Compliance delays – regulatory & statutory approvals
- ✓ Lack of communication & coordination amongst stakeholders

All point to poor or missing SLE process execution.

Summary:

- *Using outdated Engineering methods & tools*
- *Not deploying SE best practices such as RM*
- *Missing SE enabling processes, such as CM*

www.giapjournals.com report for Rail & Metro project failures

Rail and Transit Project Execution Reality

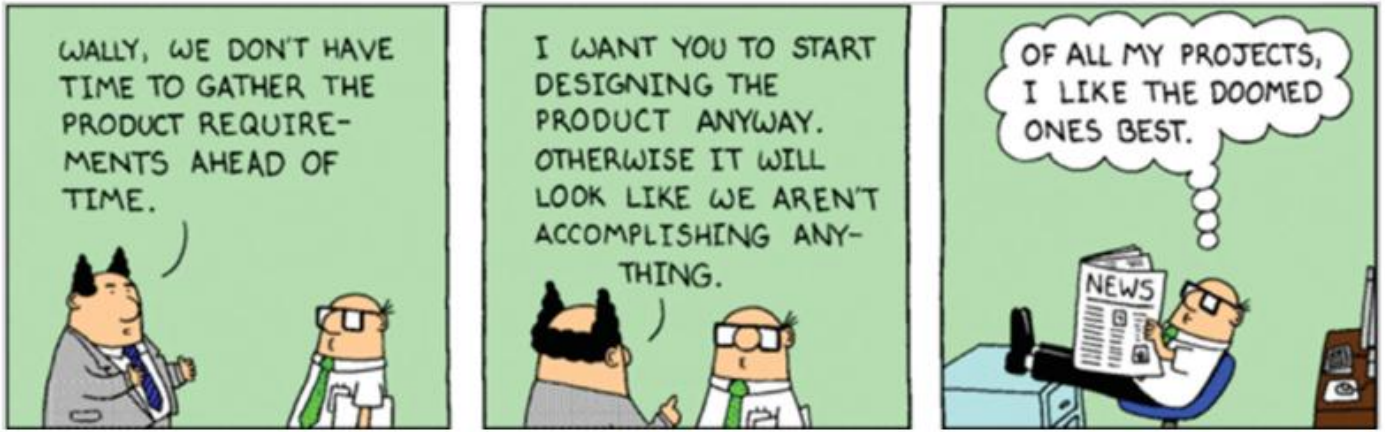


FIGURE 3.4 Importance of the concept stage. DILBERT © 1997 Scott Adams. Used with permission from UNIVERSAL

Sadly, Figure 3.4 from the INCOSE Handbook V4 represents the actual execution of many Rail & Transit Projects

- ✓ PMO pressure is very strong to show progress through project control gates
- ✓ Supplier is quite anxious to get paid "on schedule" in **conformance to cash flow projections**
- ✓ **Conformance to Systems Requirements is secondary to progress and cash flow**

Rail and Transit Project Failure - Summary Points

Consistent theme: Poor/Missing Requirements = Failure

Decades of Real Project evidence is available on a global scale

Hidden project costs appear years later = Accountability Fade

Frequent sub-optimal short-term Schedule & Budget -based decisions

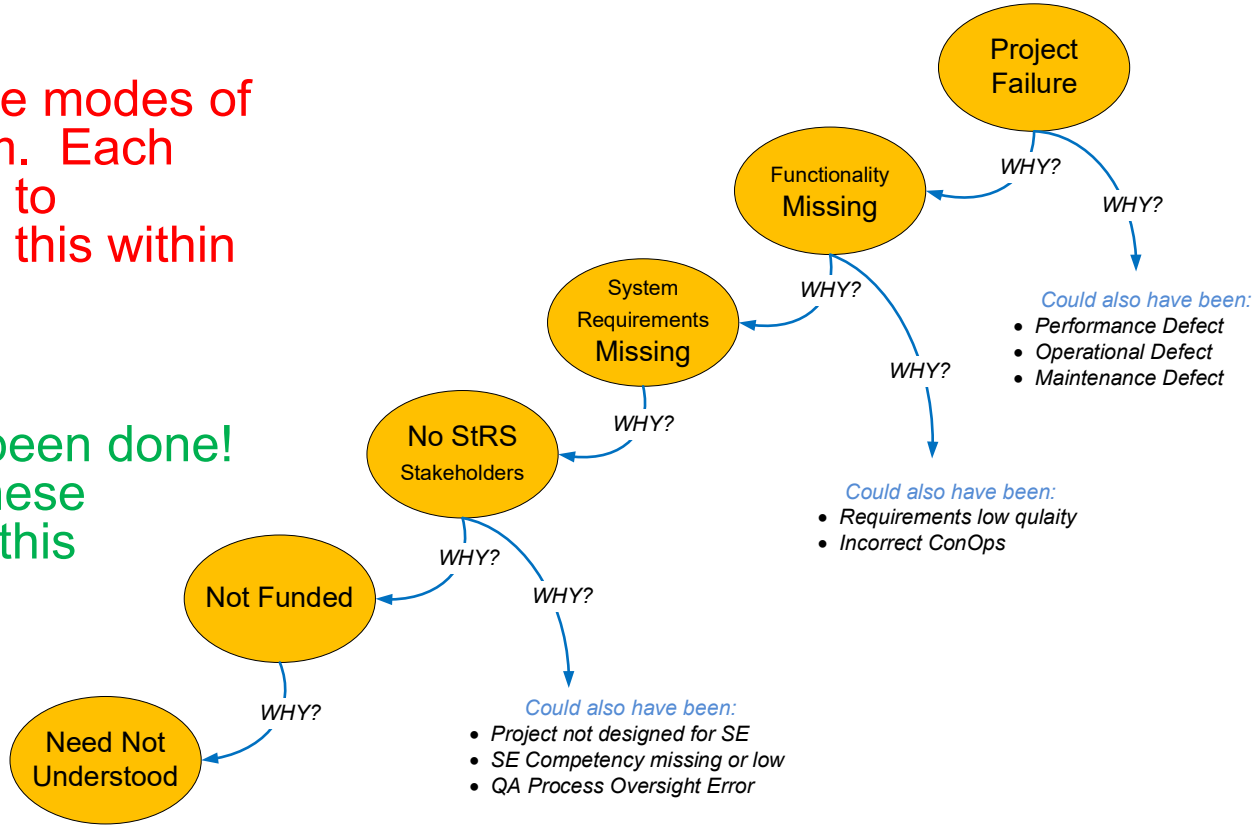
ROOT CAUSE: the short timeline for typical project reward structures.

"… project was doing well when I left – I wonder what went wrong"

Multi-Why Analysis - getting to root causes

- **Bad News**: Projects have modes of failures – like any system. Each failure must be analyzed to discover what is causing this within our industry.

- **Good News:** This has been done! We reference some of these project failure studies in this presentation.



System Lifecycle Engineering mandated

Just referencing ISO15288 in an RFP is **not** working…

We are not learning the lessons (money flowing, not broken, don't fix)
- Short term rewards and thinking don't care about future cost savings

It requires a massive cultural change (i.e., purchase vs. acquisition)
- Complex subsystems are treated as purchase items, not an integration process
- Not doing our homework and no funding to do it. "shovel-ready" pressures

Integration Team Missing ….property owner inherits
- Prime & Subs are done/paid 90%….
- Responsibility for failed interfaces is…? *(Hint: Property Owner by default)*
- Clarify roles, accountability chain, responsibility agreement

Early Lifecycle Activities

TABLE 3.1 Generic life cycle stages, their purposes, and decision gate options

Life cycle stages	Purpose	Decision gates
Concept	Define problem space 1. Exploratory research 2. Concept selection Characterize solution space Identify stakeholders' needs Explore ideas and technologies Refine stakeholders' needs Explore feasible concepts Propose viable solutions	Decision options • Proceed with next stage • Proceed and respond to action items • Continue this stage • Return to preceding stage • Put a hold on project activity • Terminate project
Development	Define/refine system requirements Create solution description—architecture and design Implement initial system Integrate, verify, and validate system	
Production	Produce systems Inspect and verify	
Utilization	Operate system to satisfy users' needs	
Support	Provide sustained system capability	
Retirement	Store, archive, or dispose of the system	

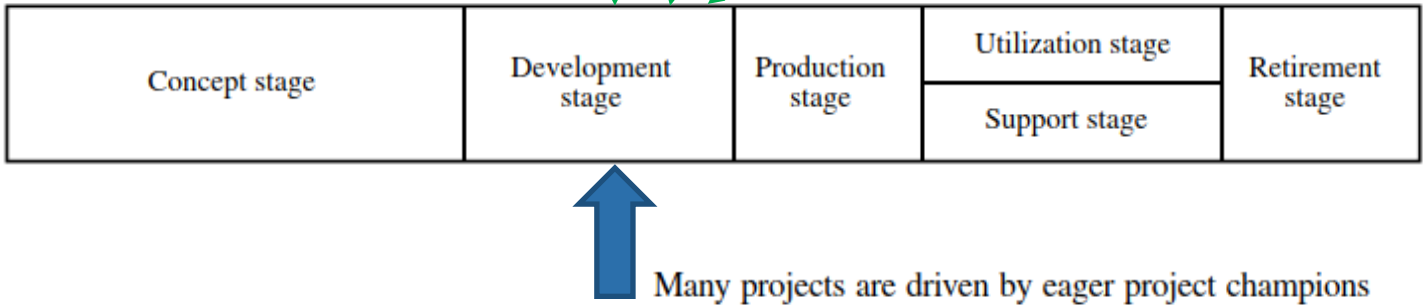
Early Activities represent a majority of the overall project activities!

…but they are pre-design & low $$, so less interesting to designers and the PMO.

Payment Milestones Apply Pressure

$$ CDR 30%
$$ PDR 60%
$$ FDR 90%

Generic life cycle (ISO/IEC/IEEE 15288:2015)



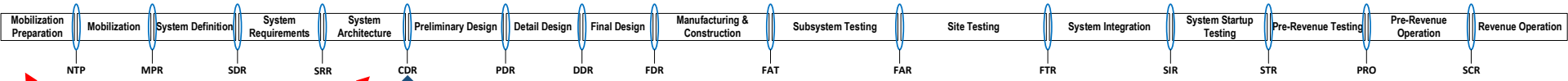
INCOSE SE Handbook Excerpt Section 3.3.1

Many projects are driven by eager project champions who want "to get on with it." They succumb to the temptation to cut short the concept stage, and they use exaggerated projections to support starting development without adequate understanding of the challenges involved, as comically illustrated in Figure 3.4. Many commissions reviewing failed systems after the fact have identified insufficient or superficial study in the concept stage as a root cause of failure.

More Early Lifecycle Observations

Phase 0	Phase 1	Phase 2			Phase 3	Phase 4	Phase 5
Long Range Planning 20 year Needs (Program/Programmatic)	Project Profile, Master Plan, Concept of Operations, User Requirements	Concept Design	Prelim Design	Final Design	Construction & Implementation	Operations & Maintenance	Rehab, Retire, Replace (End of Life)

Basic Rail and Transit Asset Lifecycle



Typical Rail and Transit Project Lifecycle

Compressed to 3-6 months

Many Infrastructure Projects effectively start here!

- **Typical Rail and Transit Project Startup Characteristics:**
  - Project Teams are mobilized on the basis of: "*same as last project - so not a big deal – minimal effort*"
  - Dozens of process planning documents are usually due at NTP + 30, 60 ...negative ROI on this shelfware
  - System Requirements & Architecture are not adequately budgeted and soon get left behind…
  - RM tool, CM tool, Document Control all “assumed” to be operational a few days after NTP – never true yet

Almost Guaranteed to fail…years ago

Phase 0	Phase 1	Phase 2			Phase 3	Phase 4	Phase 5
Long Range Planning 20 year Needs (Program/Programmatic)	Project Profile, Master Plan, Concept of Operations, User Requirements	Concept Design	Prelim Design	Final Design	Construction & Implementation	Operations & Maintenance	Rehab, Retire, Replace (End of Life)

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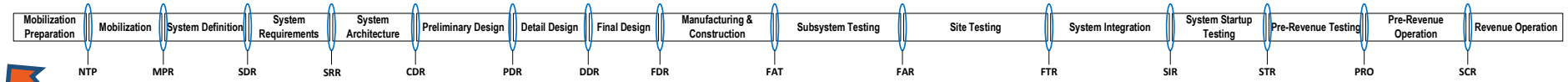


Typical Rail and Transit Project Lifecycle

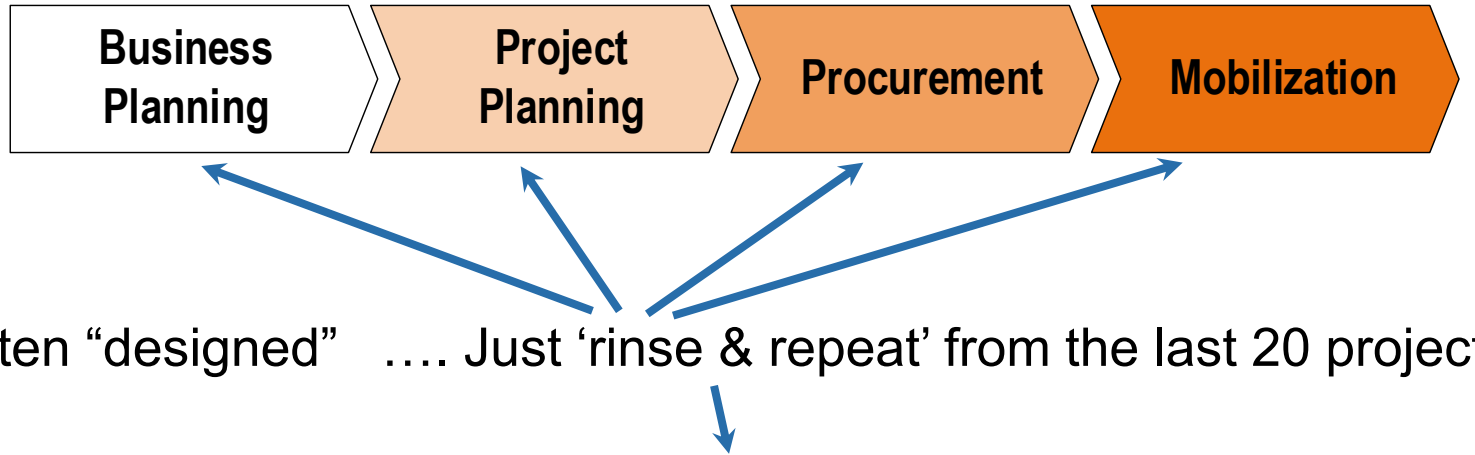
Projects are doomed to failure …years before NTP!

POSIT:

- Project failure is locked in during early concept and planning stages – years before NTP!
- Gates not enforced rigorously (includes pre-NTP gates)

The Early System Lifecycle – what is it?

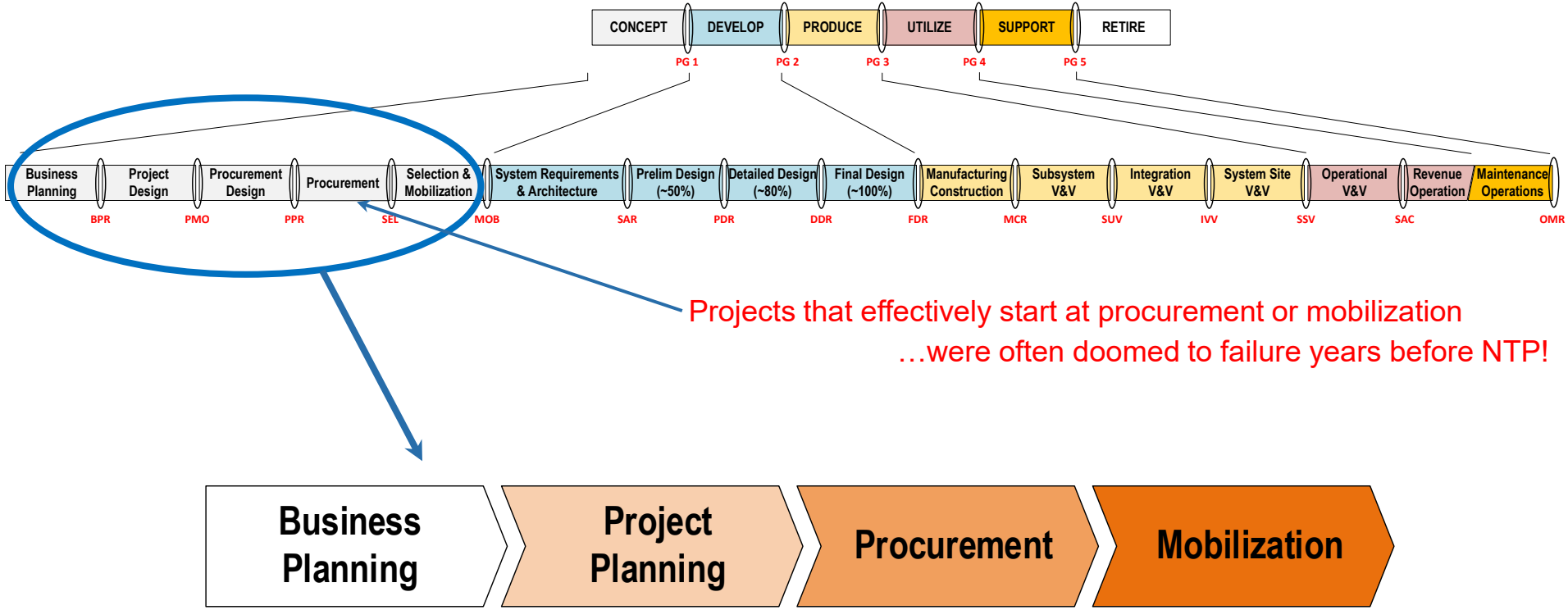
SLE Standard work is initially focusing on early lifecycle activities



Not often “designed” …. Just ‘rinse & repeat’ from the last 20 projects…

…statement based on observations within the community members of the TWG working on US and Canadian projects over the last few decades

The Early System Lifecycle – initial focus



Initial Framework

Curated for Transit & Rail

ISO/IEC/IEEE 15288:2015

AGREEMENT PROCESS CLASS (2)

- Acquisition
- Supply

ORGANIZATIONAL PROJECT ENABLING PROCESS CLASS (6)

- Project Portfolio Management
- Infrastructure Management
- Lifecycle Model Management
- Human Resource Management
- Quality Management
- Knowledge Management

TECHNICAL MANAGEMENT PROCESS CLASS (8)

- Project Planning
- Project Assessment & Control
- Decision Management
- Risk Management
- Configuration Management
- Information Management
- Quality Assurance
- Measurement

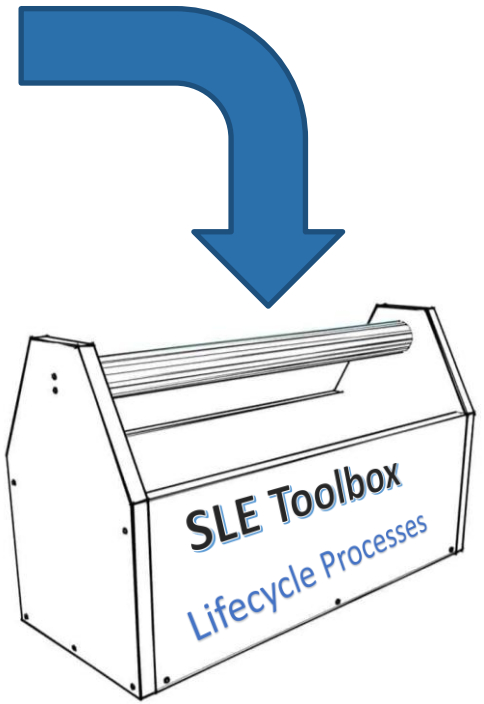
Foundational / Cross-Cutting

30 Lifecycle Processes

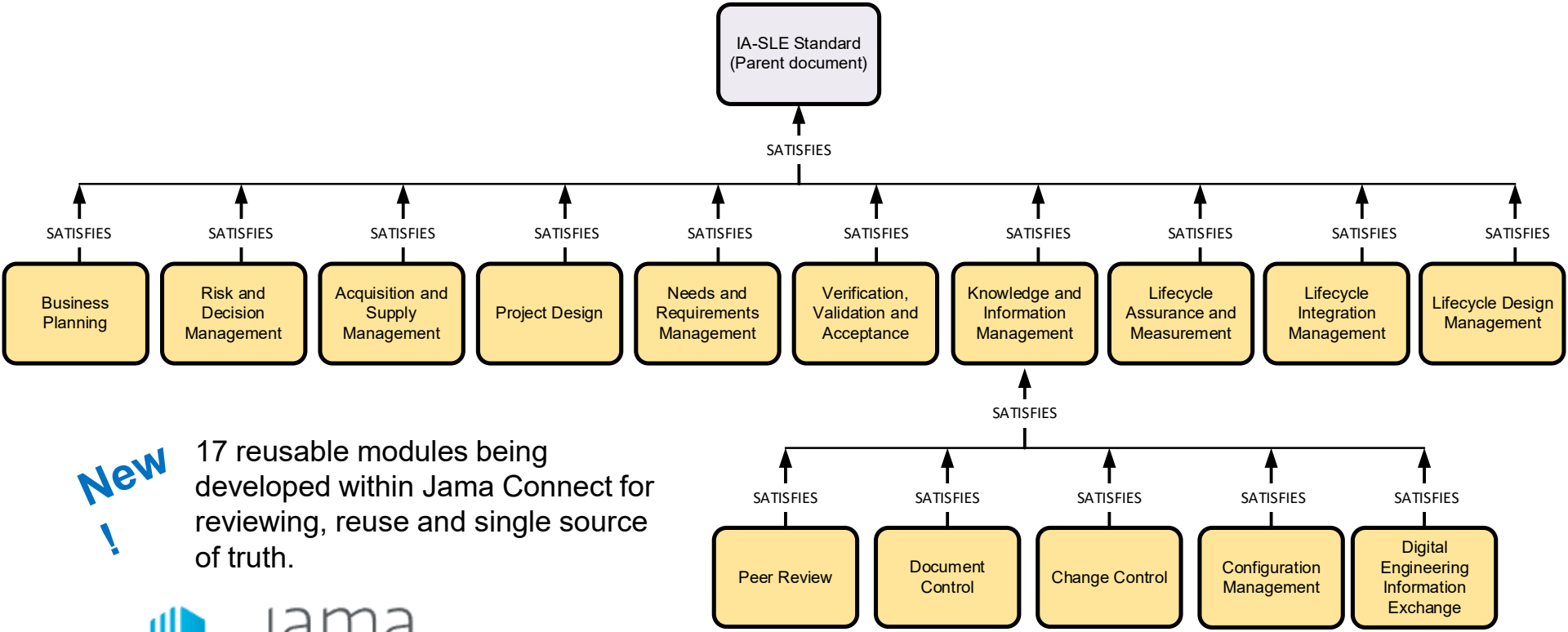
TECHNICAL PROCESS CLASS (14)

- Business/ Mission Analysis
- Stakeholder Needs & Requirements Definition
- System Requirements Definition
- Architectural Definition
- Design Definition
- Systems Analysis
- Implementation
- Integration
- Verification
- Transition
- Validation
- Operation
- Maintenance
- Disposal

Technical



IA-SLE Process Asset Library (PAL)

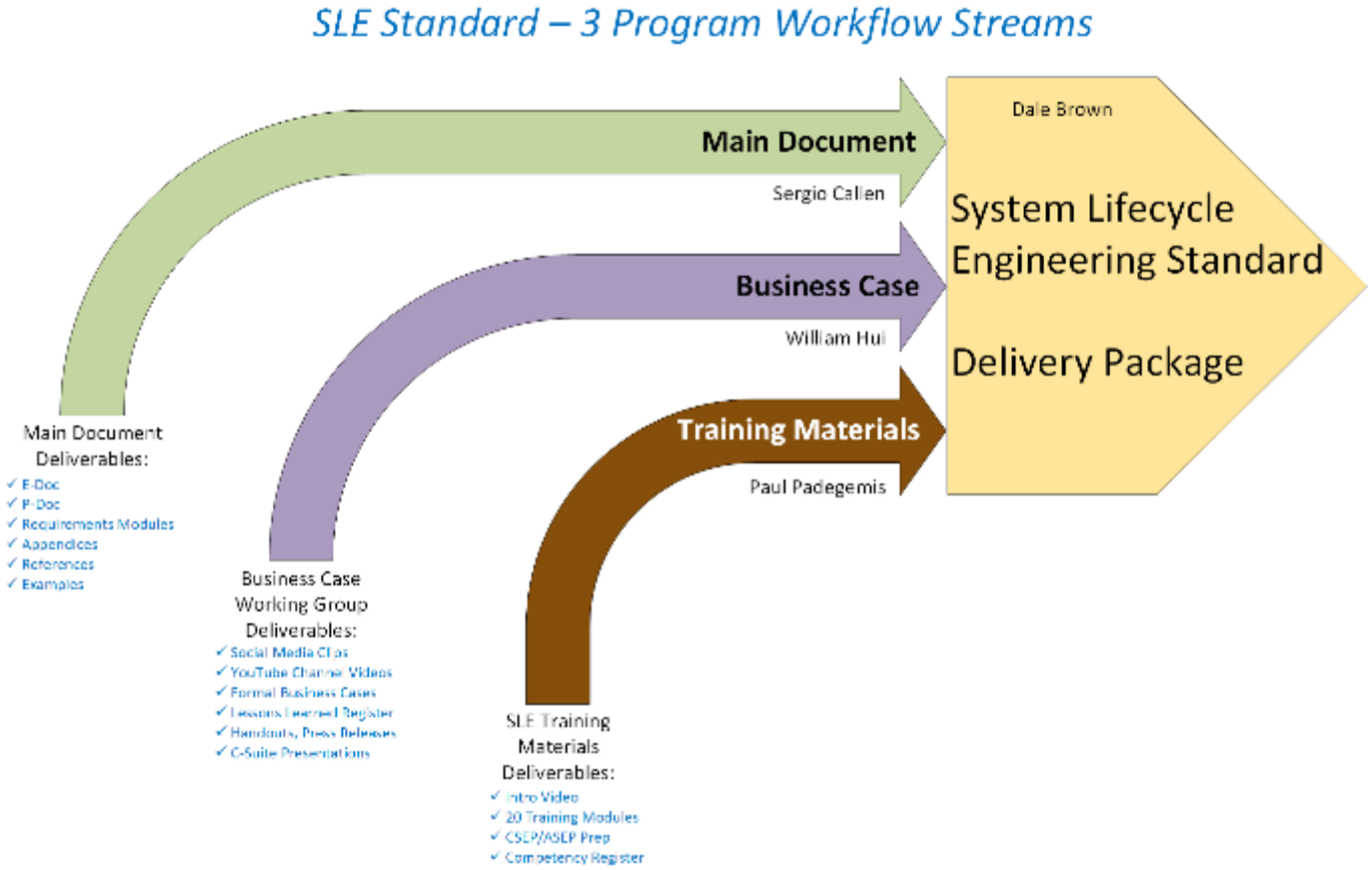


New !

17 reusable modules being developed within Jama Connect for reviewing, reuse and single source of truth.

jama connect™

Delivery Team for the SLE Standard package



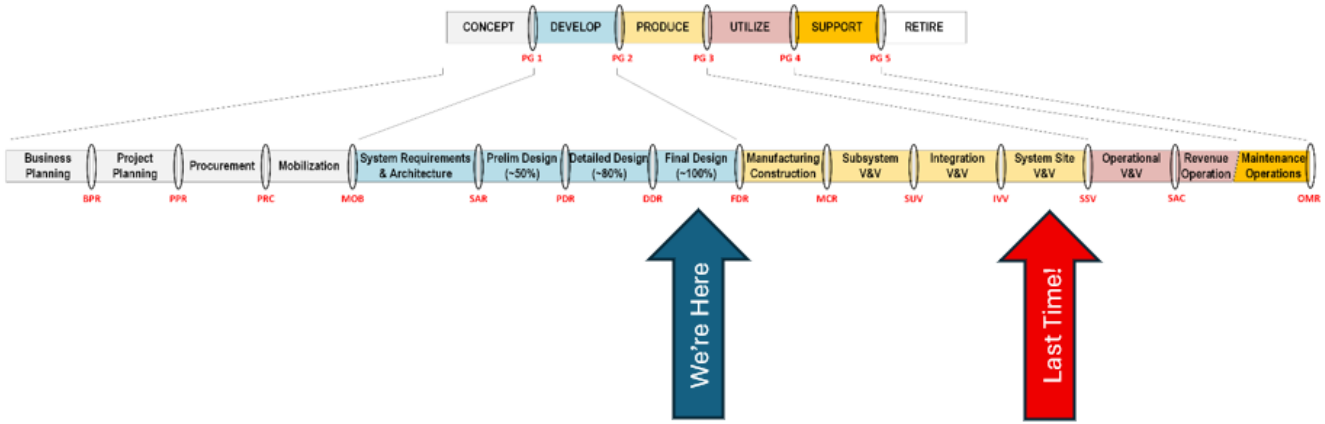

TRANSPORTATION
INFRASTRUCTURE
WORKSHOP
Calling all transit, transportation, infrastructure, and smart city professionals!
PRESENTED BY:
INCOSE
INCOSE Canada
INCOSE Working Groups
(Transportation • Infrastructure • Smart Cities)
CANADA
APTA
American
Public Transportation
Association
Systems Lifecycle Engineering
Subcommittee

Scenarios

SCENARIO 1 – Agency Viewpoint – No Requirements at Final Design

Your agency has contracted with a well-known signaling supplier to upgrade the aging train control system on your Commuter Rail network. As you approach Final Design Review (FDR) and approval for construction, a significant payment milestone for the supplier, you find that the set of applicable system requirements has not yet been finalized and agreed upon. You wonder: How did we get past Concept and Preliminary Design Reviews (CDR & PDR) without systems requirements? The agency will be taking a significant risk by approving a design without having established requirements. This seems to happen on most projects you've worked on recently. (Last project, you were in Test and Commissioning when this realization happened - see Red Arrow below)

If you could go back in time, how could you avoid this situation?



Tony Wu

President, Canada Chapter

Mott MacDonald

Our Findings from the workshop

Four Discussion Area Classifications

1. Competency & Education
2. Requirements & Standards
3. Integration & Interface Management
4. Design Review & Quality Assurance

(Note: Objectives are time-bound in accordance with the time-line)

1. Competency & Education

Mission:

Build and enhance Systems Engineering skills, knowledge, and awareness across engineering, management, legal, HR, and contract teams to elevate competency in the transportation infrastructure sector.

Goals:

A. Close the competency gap for systems engineering practitioners and project managers.
B. Increase understanding and support for systems engineering among technical and non-technical stakeholders, including legal and contracts teams.
C. Promote accessible education and standards adoption in systems lifecycle engineering.

Objectives:

1. Develop targeted training modules and workshops for project supervisors and managers without engineering backgrounds along with technical stakeholders without systems engineering background.
2. Create awareness campaigns or briefing documents to educate legal and contracts teams on systems engineering benefits and principles.
3. Produce simplified guides or cheat sheets on key systems engineering standards tailored for targeted stakeholders mentioned in mission statement (maybe make this a defined term)

2. Requirements & Standards

Mission:

Establish clear, pragmatic, and risk-based requirements and standards that improve project outcomes and compliance across transportation infrastructure projects.

Goals:

A. Standardize approaches to writing and tailoring requirements in RFPs and project documentation.
B. Encourage risk-based decision-making frameworks that are widely understood and consistently applied.

Objectives:

A. Develop templates and guidelines to make RFP requirements more specific and rationale-backed.
B. Formulate a common framework for risk-based decision making accessible to diverse stakeholders.

3. Integration & Interface Management

Mission:

Define and implement effective systems integration and interface management practices to ensure seamless collaboration, accountability, and coordination among all disciplines and contractors.

Goals:

A. Provide a clear definition and scope of systems integration responsibilities supported by a RACI matrix.
B. Identify and address integration pinch points through improved interface management.
C. Strengthen contractor and construction discipline involvement in integration activities.
D. Improve integration and interface management execution during design stages

Objectives:

1. Develop and disseminate a clear systems integration definition and responsibility matrix.
2. Produce tools or workshops focused on identifying and mitigating common interface conflicts (e.g., fire/life safety, signaling).
3. Establish protocols for contractor participation and designate a chief integration lead role.

4. Design Review & Quality Assurance

Mission:

Streamline the design review process to enhance efficiency, stakeholder participation, and quality assurance in transportation infrastructure engineering projects.

Goals:

A. Clarify roles and processes involved in design reviews, ensuring necessary stakeholders, including QA, are engaged early and appropriately.
B. Define clear design coordination gates and milestones to regulate review progress.
C. Reduce delays and improve the timeliness of design review cycles.

Objectives:

1. Document and communicate a standardized design review framework and participant roles.
2. Establish specific design coordination gates guideline with assigned approval criteria.

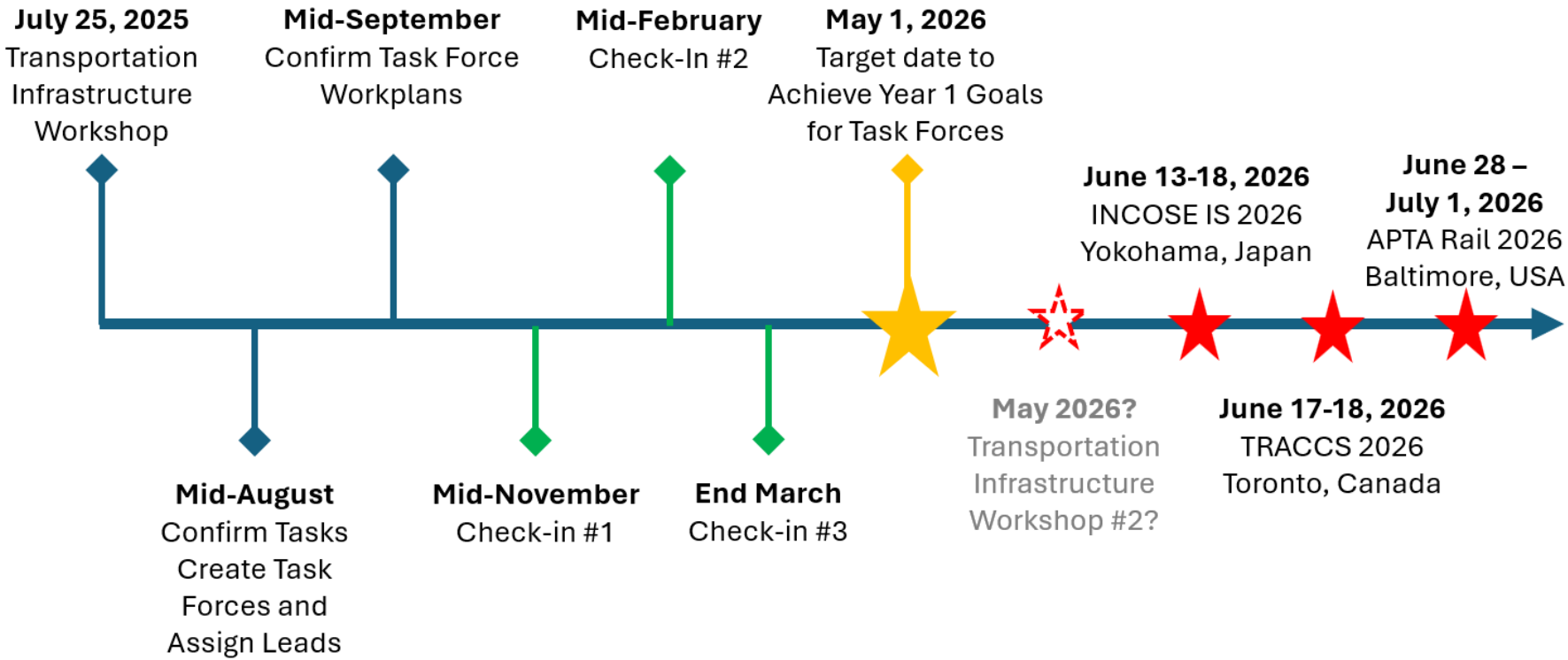
William Hui

Chair: APTA Systems Lifecycle Engineering Subcommittee

TransLink

Task Force Timeline

Saved to this PC



SLE Events on the Horizon

INCOSE– International Symposium 2025

3rd APTAtech SLE Tutorial & Workshop

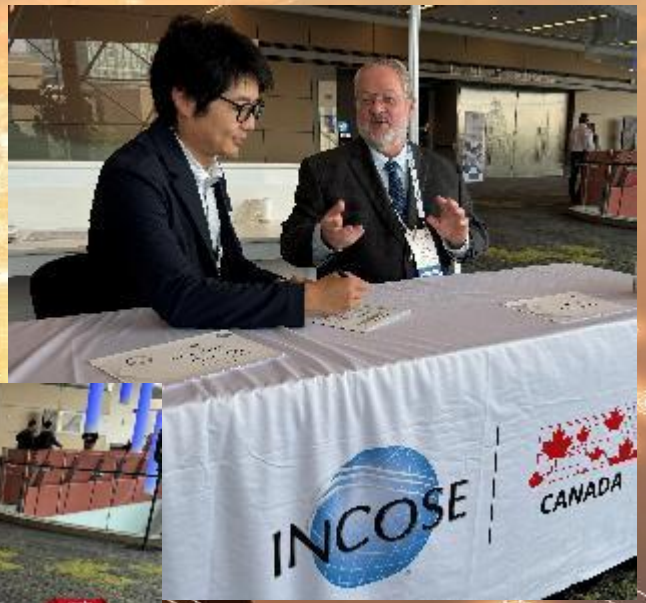
Sunday, Aug 03, 2025

2:15 PM - 5:15 PM EDT

Workshop: Engineering Assurance - Transforming Transit Program Delivery

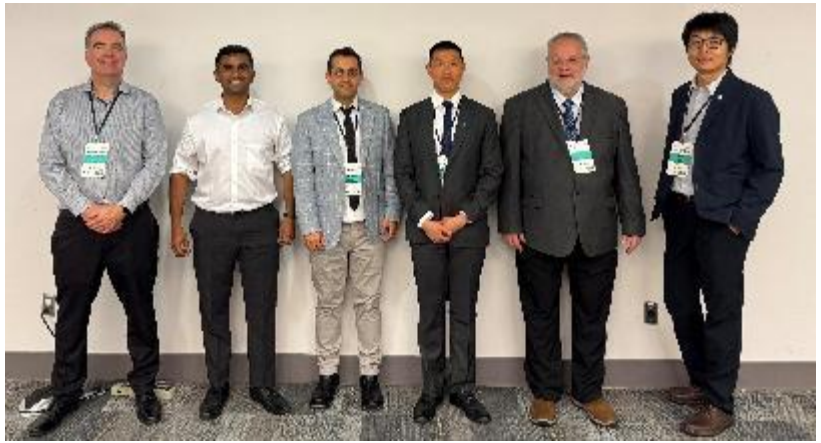
Many rail and transit projects suffer from excessive, overly prescriptive contract requirements, adding cost and complexity while overlooking critical risks. This **3-hour workshop** explores lessons from past projects and practical strategies to streamline requirements approaches, prioritize essential requirements, establish metrics, and thereby improve project delivery. Participants will learn to integrate various aspects of Systems Lifecycle Engineering with established civil and architectural practices, reducing inefficiencies. The workshop includes several breakout sessions to enhance learning and introduces the **INCOSE-APTA Systems Lifecycle Engineering Standard**, providing actionable insights to improve project delivery performance.

Going Forward



Team Canada and Chicagoland: Embracing the Future together!

INCOSE Canada | CANADA + WI IL IN INCOSE CHICAGOLAND =



Thank You!

35th Annual INCOSE international symposium

hybrid event

Ottawa, Canada
July 26 - 31, 2025