Organizing for Success:

Improving our Engineering Team Architectures

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Problem Statement

- **Extensive work in SE community on improving system architecture maturity**
  - **Traditional Structured Analysis**
  - **UML, SysML**
  - **Architecture “frameworks” (DoDAF, MoDAF, FEAF)**
  - **Model-Based System Design**

- **Little work in improving “organization architectures”**
  - **Weak definitions and representations in SEMP**
  - **Poorly defined interfaces**
  - **Rarely “optimized” for problem set**

- **Can we architect our organizations like we architect our systems?**

Business Case

- **Success of a project is strongly influenced by the architecture (structure & composition) of that project's organization**
  - **Improved communication**
  - **Lower cost (less overhead, meetings, waste)**
  - **Lower project risk**
  - **Better project deliverables**

"Relationships among the elements are what give the organization its added value. The greatest leverage, risks, and dangers are at the interfaces."

- Eberhardt Rechtin, "System Architecting of Organizations: Why Eagles Can't Swim", p.166

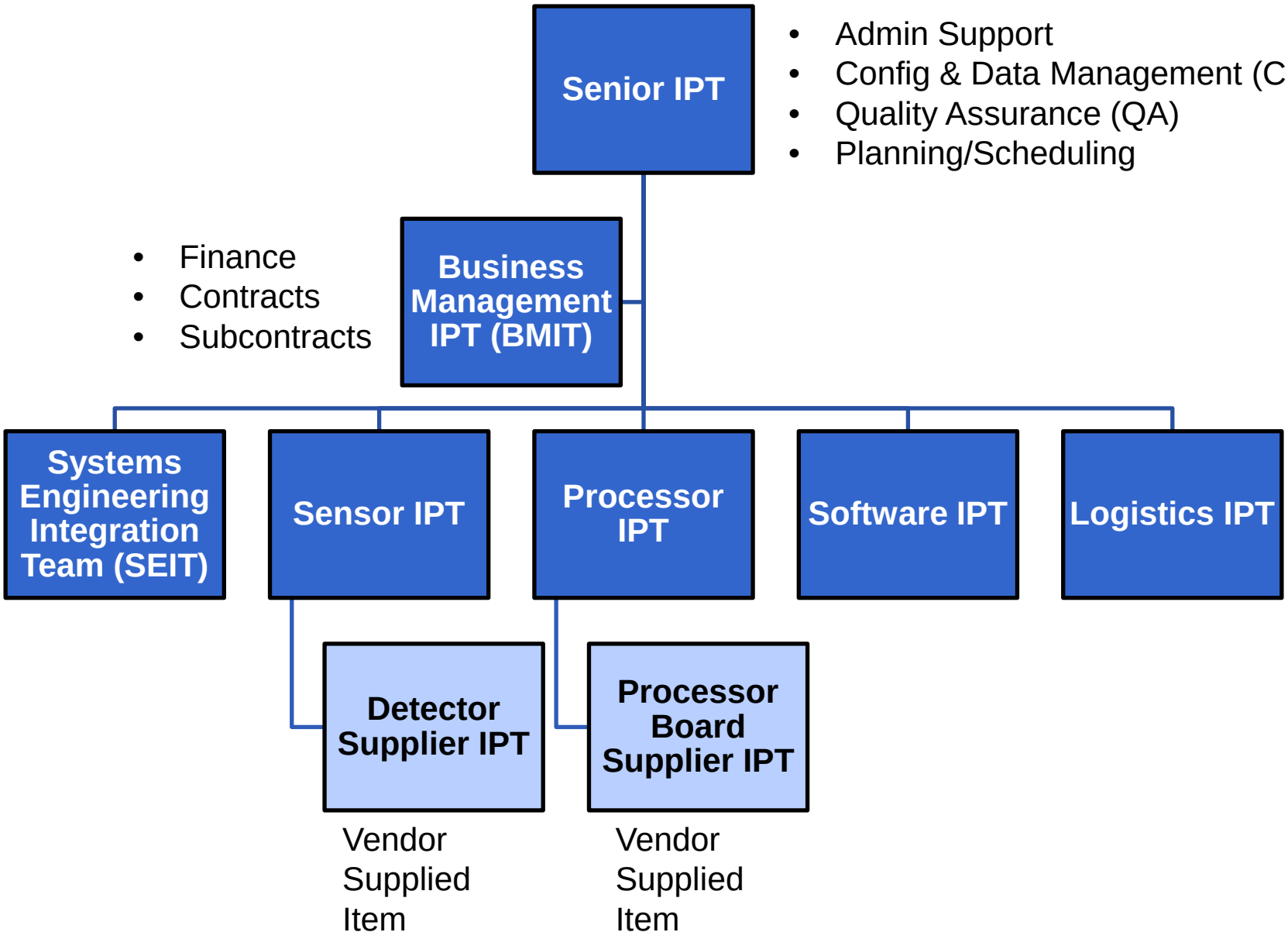
“Typical” SEMP

- **Defined in DI-MGMT-81024 (27 August 90)**
  - **Part I – Systems Engineering**
  - **Part II - Technical Program Planning and Control**
  - **Part III - Engineering Integration**

- **Extensive coverage of SE process and deliverables**
  - **System description, block diagram, schedule, WBS, risk process, TPMs, etc**
  - **Discussion of integration with “ilities” disciplines**

- **Scant discussion of organization architecture**
  - **Organization chart**
  - **Brief description of what each team will do**

“Generic” Organization Chart



Organization Chart Structures

- **Functional-Based**
  - **Strong correlation to organization's functional organization**
  - **Weak correlation to the product architecture**

- **IPT-Based**
  - **Strong correlation to the product architecture**
  - **Weak correlation to organization's functional organization**

- **Matrix Organization**
  - **Blends the IPT based and Functional based**
  - **"Functional" (Engineering Discipline) Leads & IPT leads**
  - **Most complex structure**

Organization Chart Weaknesses

- **Incomplete representation of team dynamics**
  - **Only represents flow of delegation/reporting**
- **Does not capture interfaces between teams**
  - **Often not captured in SEMP text**
  - **Workflows not represented**
- **Some critical teams may not be represented at all!**
  - **CDM, Subcontracts, QA**
  - **Customer**
  - **Enterprise Organization**
  - **Other project teams**

An Organization Chart is NOT an Architecture!

Reviews and Interviews

- **Detailed review of dozens of SEMPS**
  - **LM and others**
  - **Multiple product lines, sizes**

- **Interviews with practitioners and team leads**
  - **General agreement on poor interface definition**

- **Often defer to the Senior IPT for conflict resolution and interface definition “on the fly”**

N2 Chart Notation

- NxN in size, where “N” is the number of functions (or “Nodes”)
- Each function name along the diagonal
- Other cells identify the interface(s) between two functions; clockwise order
- If no interface, enter a “-” or a “X”
- Essentially a Data Flow Diagram (DFD) in matrix form

Outputs are shown in rows, inputs are shown in columns!

Input

Function 1	F1→F2	F1→F3	X	F1→FN
F1←F2	Function 2	X	X	F2→FN
F1←F3	F2←F3	Function 3	X	F3→FN
X	X	X	…	X
F1←FN	F2←FN	F3←FN	X	Function “N”

Output

Output

Input

N2 Analysis (1 of 3)

- Function 5 is “disconnected” from the other functions in the “System”
  - No Inputs or Outputs
- Is the function required? Can it be combined?
- Or have inputs and outputs been left off?

Function 1	S13, S14	S1, S2	X	X
S15, S16	Function 2	S3, S4	X	X
S12	S10, S11	Function 3	S8, S9	X
X	X	S5, S6, S7	Function 4	X
X	X	X	X	Function 5

N2 Analysis (2 of 3)

- Function 3 is a “critical function”
  - Sends/receives data to/from most other functions
- Could be a system bottleneck
- May be a candidate for re-partitioning into multiple functions

Function 1	S13, S14	S1, S2	X	X
S15, S16	Function 2	S3, S4	X	X
S12	S10, S11	Function 3	S8, S9	X
X	X	S5, S6, S7	Function 4	X
X	X	X	X	Function 5

N2 Analysis (3 of 3)

- Functions 1, 2 and 3 are “tightly coupled”
  - AKA “fully coupled” for function groups that have both inputs and outputs to all other functions
- May be a good candidate for consolidating into a single function to reduce I/O or interactions

Function 1	S13, S14	S1, S2	X	X
S15, S16	Function 2	S3, S4	X	X
S12	S10, S11	Function 3	S8, S9	X
X	X	S5, S6, S7	Function 4	X
X	X	X	X	Function 5

Using N2 to Optimize Architectures

One part of N2 Chart analysis is looking for "clustering" to see relationships between adjacent functions…these functions may be candidates for consolidation into subsystems or larger functions to reduce system complexity Can swap functions in the N2 chart to make these clusters appear…

No pattern here…

F1	-	1	-
-	F2	-	2
3	-	F3	-
4	5		F4

Swap Functions 2 & 3…

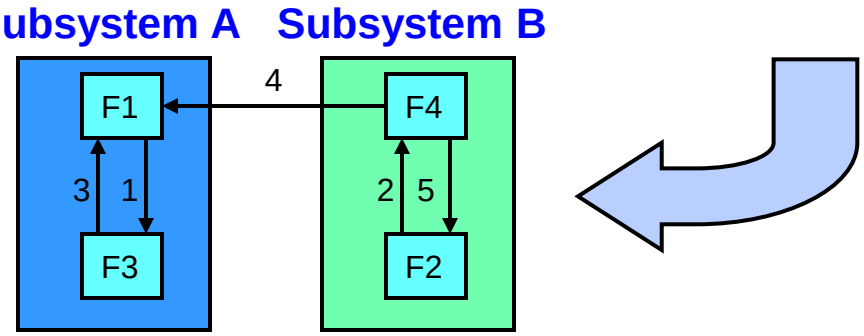
F1	1	-	-
3	F3	-	-
-	-	F2	2
4	-	5	F4

And a Pattern Emerges…

F1	1	-	-
3	F3	-	-
-	-	F2	2
4	-	5	F4

Functions F1 & F3 are "tightly coupled", as are F2 and F4…

Architecture Heuristic: High internal complexity, low external complexity…



Organization Architectures

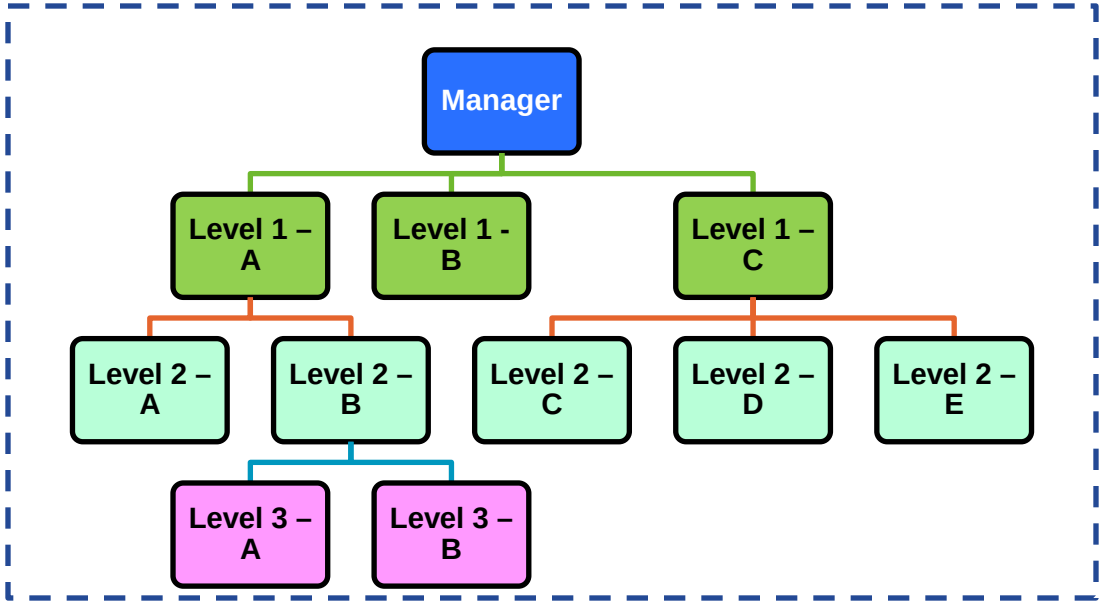
- **Organizations are systems too!**
  - **Can be represented like any other system**
- **Model internal IPTs and functions**
- **Model external entities as functions as well**
  - **Customer**
  - **Enterprise**
- **Easily represent structure and flow of information**
- **Like all architectures, use to communicate to all stakeholders**
  - **Leverage existing approaches to optimize**

“Organizations are Purposeful Systems”

- Eberhardt Rechtin, “System Architecting: Creating & Building Complex Systems”, page 270

Organization Chart → N2 Chart

External organizations not shown:
- Customer
- Vendors
- Local Organization
- Corporate Organization
- Outside Standards
- Home Life
- etc

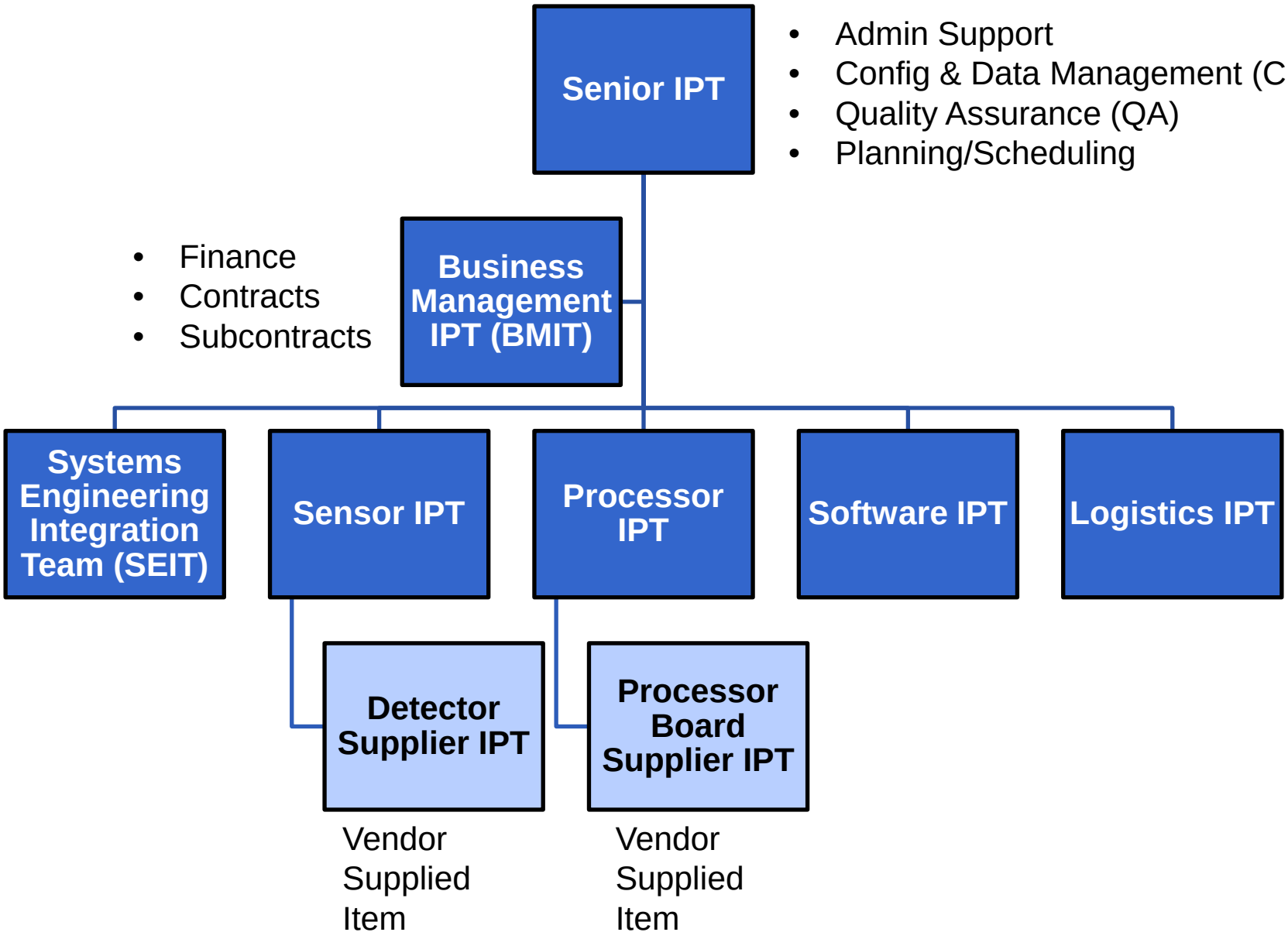


M	1	1	1	-	-	-	-	-	-	-
1	L1A	-	-	1	1	-	-	-	-	-
1	-	L1B	-	-	-	-	-	-	-	-
1	-	-	L1C	-	-	1	1	1	-	-
-	1	-	-	L2A	-	-	-	-	-	-
-	1	-	-	-	L2B	-	-	-	1	1
-	-	-	1	-	-	L2C	-	-	-	-
-	-	-	1	-	-	-	L2D		-	-
-	-	-	1	-	-	-	-	L2E	-	-
-	-	-	-	-	1	-	-	-	L3A	-
-	-	-	-	-	1	-	-	-	-	L3B

"Reporting To"
"Status Reporting"

"Delegation"
"Information Flowdown"

“Morphing” the Org Chart



Using N2 Charts for Organizations

Customer										
	Senior IPT									
		BMIT								
			QA Team							
				SEIT						
					Sensor IPT					
						Processor IPT				
							Software IPT			
								Logistics IPT		
									CDM Team	
										Enterprise

Using N2 Charts for Organizations

Requirements Flow Scenario

Customer	SOW	-	Sys Spec Sys ICD	-	-	-	-	-	-	-
Tech Status	**Senior IPT**	-	-	-	-	-	-	-	-	-
-	-	**BMIT**	-	-	-	-	-	-	Risk Reports	-
-	-	-	**QA Team**	-	-	-	-	-	-	Defect Trends
-	TPM/KPP Status	Technical Risks	Spec Peer Reviews	**SEIT**	Sensor Spec/ICD	Proc Spec/ICD	SRS, SIRS	Logistics Req'ts	Spec Delivery	Req'ts Metrics
-	-	-	-	Sensor Risks	**Sensor IPT**	-	Sensor Algos	-	Deliver-able Sim	-
-	-	-	Proc Spec Defects	Processor Risks	-	**Processor IPT**	Processing Algos	-	-	-
-	-	-	-	Software Risks	Unit Test Results	Unit Test Results	**Software IPT**	-	-	Software Metrics
--	-	-	-	Logistics Analyses	-	-	-	**Logistics IPT**	Logistics CDRLs	-
Req'ts CDRLs	-	-	-	-	-	-	-	-	**CDM Team**	Metrics
-	-	-	-	DOORS scripts	Sensor Library	Algo Repository	S/W Tool Set	-	-	**Enterprise**

Other Possible Scenarios

- Integration Flows
- Verification & Validation
- Hardware/Software Deliveries
  - Internal (S/W test builds, fixtures, cables, etc)
  - External (“formal” H/W and S/W deliveries)
- Simulation, Algorithm development
- Status Reporting
- Technical Review Prep and Execution
- Defect Tracking

- “Big Ticket” items
  - Don’t sweat the small stuff!

Status & Path Forward

- **Successfully piloted on one project at LM**
- **Currently “socializing” the concept/approach with other projects now**
- **Select other pilots (small IR&D projects)**
  - **Develop N2 chart as part of team activity**
- **Integrate N2 chart into SEMP**
  - **One more “component” in “living SEMP” approach**

Summary

- **Organizations are “purposeful systems”**
  - **And demand architecture analysis & representation**
- **Clear business case**
  - **Direct benefit to project success**
- **N2 Charts proven technique for system architectures**
  - **Good applicability to organization architectures**
- **Integration into our project SEMPs improves their value**
  - **Increases SEMP utility to all stakeholders**