Agile Systems Engineering – Fundamentals Learned from Analyzing Successful Mixed-Discipline Practices

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Abstract: This presentation will discuss six key findings from the INCOSE Agile Systems Engineering Life Cycle Model (ASELCM) project: a CURVE problem-space characterization framework, an asynchronous/concurrent Life Cycle Model Framework, a set of nine Sense-Respond-Evolve behavior principles, the encompassing ASELCM Pattern of three concurrent systems operating simultaneously, a general Agile SE Response Requirements framework, and the concept and mitigation of Information Debt. Case study examples will be referenced and discussed.

Presenter Bio: Rick Dove is CEO of Paradigm Shift International, specializing in agile systems research, engineering, and project management; and an adjunct professor at Stevens Institute of Technology teaching graduate courses in agile and self-organizing systems. He chairs the INCOSE working groups for Agile Systems and Systems Engineering, and for Systems Security Engineering, and is the leader of the INCOSE Agile Systems Engineering Life Cycle Model project. He is an INCOSE Fellow, and author of *Response Ability, the Language, Structure, and Culture of the Agile Enterprise*.

Agile Systems Engineering Life Cycle Model (ASELCM)

An INCOSE Project to…

- ❑ **Discover generic principles/patterns that are necessary for effective agile systems engineering of SW/FW/HW projects.**
- ❑ **Publish informative case studies.**
- ❑ **Build evidence-based generic agile-SE life cycle model to inform effective implementation.**

And …

- ❑ **Provide material for next INCOSE Handbook revision.**
- ❑ **Influence published standards.**

ASELCM Project Status

2015 Four On-Site Analytical Workshop

2016 Four Case Studies Written

2017 Key Findings Emerged

- **Life Cycle Model Framework**
- **General operational pattern**
- **General operational principles**
- **General problem-space characterization**
- **General response requirements**

2018 Activity and Focus:

- **Downloadable Findings working paper (updating continues)**
- **2-Day Tutorial: SE Problem Space and Solution Space (Tucson Chapter, April)**
- **INSIGHT Theme Issue Q2, 3 articles (done)**
- **INCOSE Webinar for Sept 2018 (in process)**
- **Additional verification/validation of findings (maybe, we have enough already)**
- **Preliminary draft of final project report**
- **Paper summarizing the findings for IS19 submission and/or Systems Journal**

Value Proposition for Agility

Faster, lower cost system development?

An appealing argument, but only a side effect (at best).

The value proposition for agility is Risk Management.

Sustainability of project/process/product at risk.

Assertions

Sustainable systems are living systems capable of responding effectively to their environment.

They are reactively resilient and proactively innovative.

They are complex adaptive systems of systems.

This is the essence of agility.

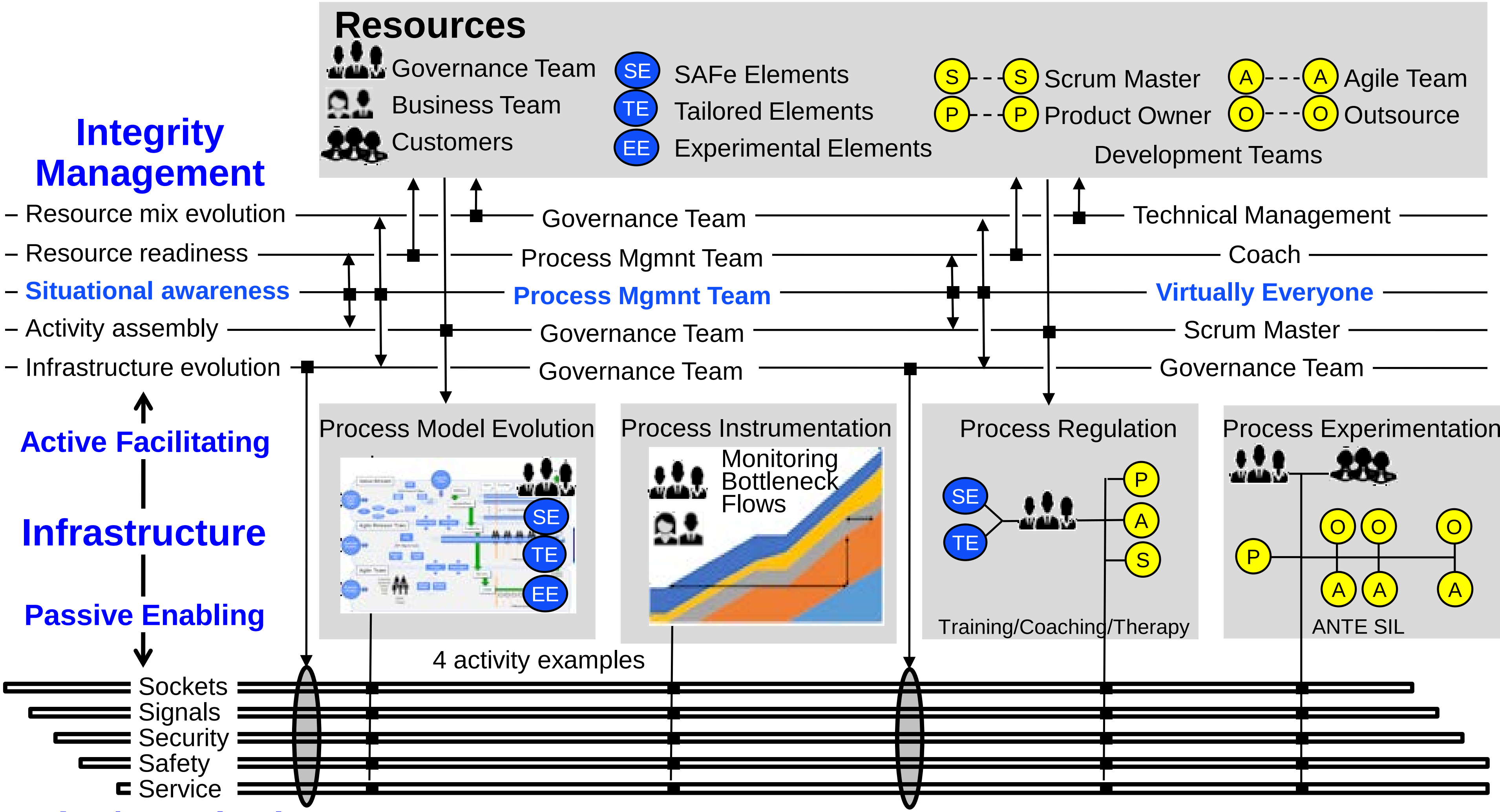
Sustaining Agility Requires …

- Proactive awareness of situations needing responses
- Effective options appropriate for responses
- Assembly of timely responses

Five Agility-Sustaining Responsibilities:

1. Resource Mix Evolution – Who (or what process) is responsible for capabilities of resources appropriate for needs?
2. Resource Readiness – Who (or what process) is responsible for conditions of rapidly deployable resources?
3. Situational Awareness: Who (or what process) is responsible for monitoring/evaluating/anticipating the operational environment?
4. Activity Assembly – Who (or what process) is responsible for assembling new response configurations as situations require?
5. Infrastructure Evolution – Who (or what process) is responsible for evolving the enabling infrastructures?

Lockheed Martin IFG, Tailored SAFe-Like Process



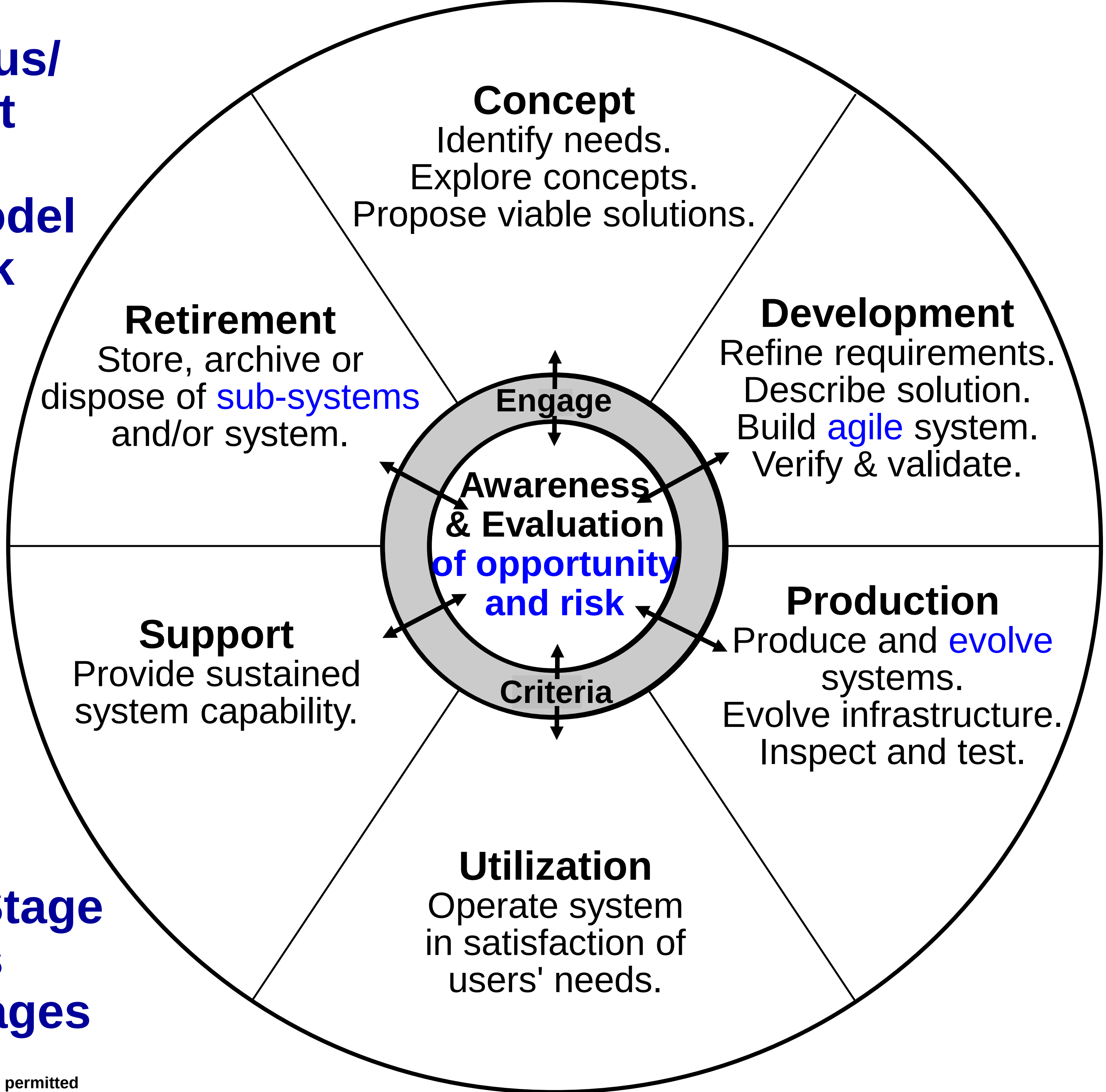
Rules/Standards

Details in IS18 paper at: www.parshift.com/s/ASELCM-04LMC.pdf

Sockets: Roles, Teams, Meeting formats, ANTE/Simulation frameworks
Signals: Flow, Info debt, Process conformance, Experiment results, Contract performance
Security: Executive commitment, Governance, Cultural consistency
Safety: Information radiators, No-penalty measurement, Flow monitoring/mitigation, Real-time status information, 2-3 PI look-ahead
Service (ConOps): Operational model, Cadence, Customer/User involvement, Experimental learning, Systems 1-2-3 AAPs

Asynchronous/ Concurrent Agile SE Life Cycle Model Framework

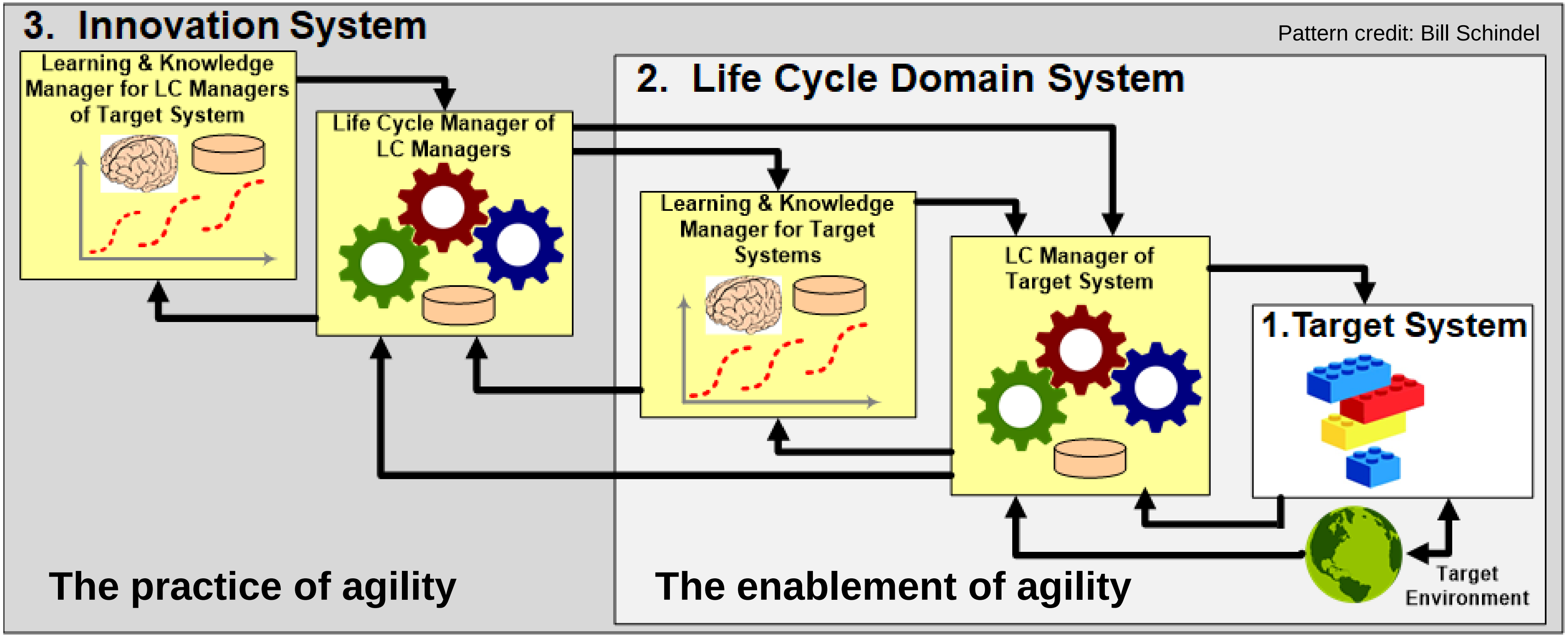
Consistent with Systems and Software Engineering — Life Cycle Management — Part 1: Guidelines for Life Cycle Management. ISO/IEC TS 24748-1:2016



Central Awareness Stage Engages All Other Stages

General Operational Pattern

Systems 1, 2, 3 Logical/Behavioral Boundaries



- **System-1 is the target system under development.**
- **System-2 includes the basic systems engineering development and maintenance processes, and their operational domain that produces System-1.**
- **System-3 is the process improvement system, called the system of innovation that learns, configures, and matures System-2.**

General Operational Principles

Sensing (observing, orienting)
- **External awareness (proactive alertness)**
- **Internal awareness (proactive alertness)**
- **Sense making (risk & opportunity analysis, trade space analysis, …)**

Responding (deciding, acting)
- **Decision making (timely, informed)**
- **Action making (invoke/configure process activity for the situation)**
- **Action evaluation (validation & verification)**

Evolving (improving above with more knowledge and better capability)
- **Experimentation (variations on process ConOps)**
- **Evaluation (internal and external judgement)**
- **Memory (evolving culture, response capabilities, and ConOps)**

General Problem-Space Characterization

CURVE

Internal and external environmental forces that impact project/process/product as systems

Capriciousness: Unknowable situations.
Unanticipated system-environment change.

Uncertainty: Randomness with unknowable probabilities.
Kinetic and potential forces present in the system

Risk: Randomness with knowable probabilities.
Relevance of current system-dynamics understanding.

Variation: Knowable variables and associated variance ranges.
Temporal excursions on existing behavior attractor.

Evolution: Gradual successive developments.
Experimentation and natural selection at work.

General Response Requirements

	Domain	Response Requirements
Proactive	Creation (and Elimination)	What will the process be creating or eliminating in the course of its operational activity? • Opportunity and risk awareness/knowledge • Acculturated memory • Response actions/options • Decisions to act
	Improvement	What performance will the process be expected to improve during operational life cycle? • Awareness/Sensing • Effectiveness of response actions/options • Memory in acculturation, inventoried response options, and ConOps
	Migration	What major events coming down the road will require a change in the process infrastructure? • New fundamentally-different types of opportunities and risks
	Modification (Add/Sub Capability)	What modifications in resources-employed might need made as the system is used? • Response action appropriate for specific response need • Personnel appropriate and available for a response action
Reactive	Correction	What can go wrong that will need a systemic detection and response? • Insufficient/inadequate awareness • Wrong decisions • Ineffective response actions/options
	Variation	What process variables will need accommodation? • Effectiveness of response actions/options • Effectiveness of response evaluation
	Expansion (and Contraction) of Capacity	What elastic-capacity ranges will be needed on resources/output/activity/other? • Capacity to handle 1-? critical response actions simultaneously
	Reconfigu-ration	What types of resource relationship configurations will need changed during operation? • Elements of a response action • Response managers/engineers

Concept and Mitigation of Information Debt

Information Debt expresses the difference between the information currently available and the information needed to deliver and support the life cycle.

As an explicit concept this helps us address the perceived tension between Agile Software Development methods and traditional Systems Engineering methods.

Does the Agile Manifesto mean that the project will end with remaining information debt, leaving us with a “working system” but a shortage of needed information?

Early stage systems engineering reduces information debt and can be generated without an equivalent surge in systems engineering expense.

This is accomplished by discovering and maintaining system pattern assets, then applying them in the early project stage as IP assets to rapidly reduce info debt.

Fig 1. Scenarios 3 illustrates the worrisome case

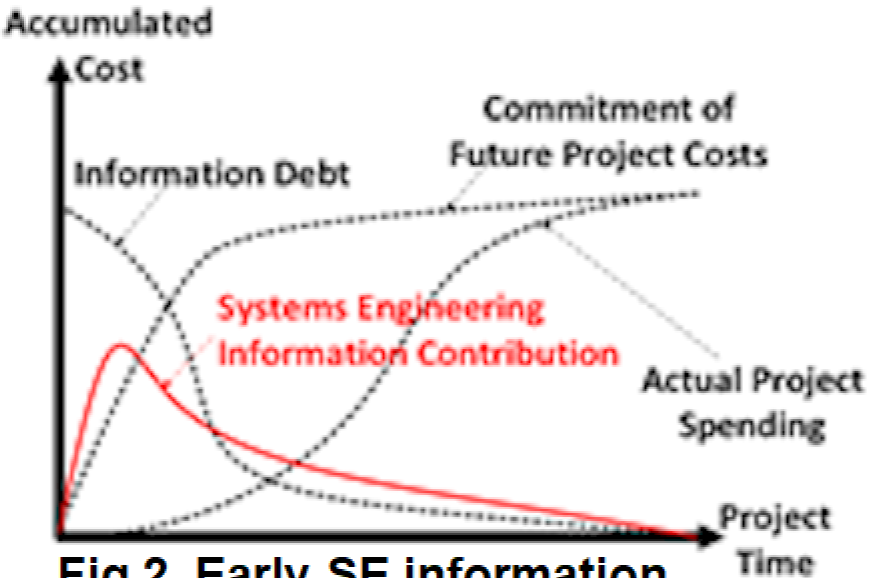


Fig 2. Early SE information reduces information debt

Lockheed Martin IFG-TS Example

(www.parshift.com/s/ASELCM-04LMC.pdf)

The Lockheed Martin Aeronautics Integrated Fighter Group (IFG), in Fort Worth, Texas, was motivated to move to an agile system engineering (SE) development methodology by the need to meet urgent defense needs for faster-changing threat situations.

IFG has and is tailoring a baseline Scaled Agile Framework (SAFe®) systems engineering process for a portfolio of mixed hardware/software aircraft weapon system extensions, involving some 1,200 people in the process from executives, through managers, to developers.

The process is referred to here as IFG Tailored SAFe (IFG-TS)

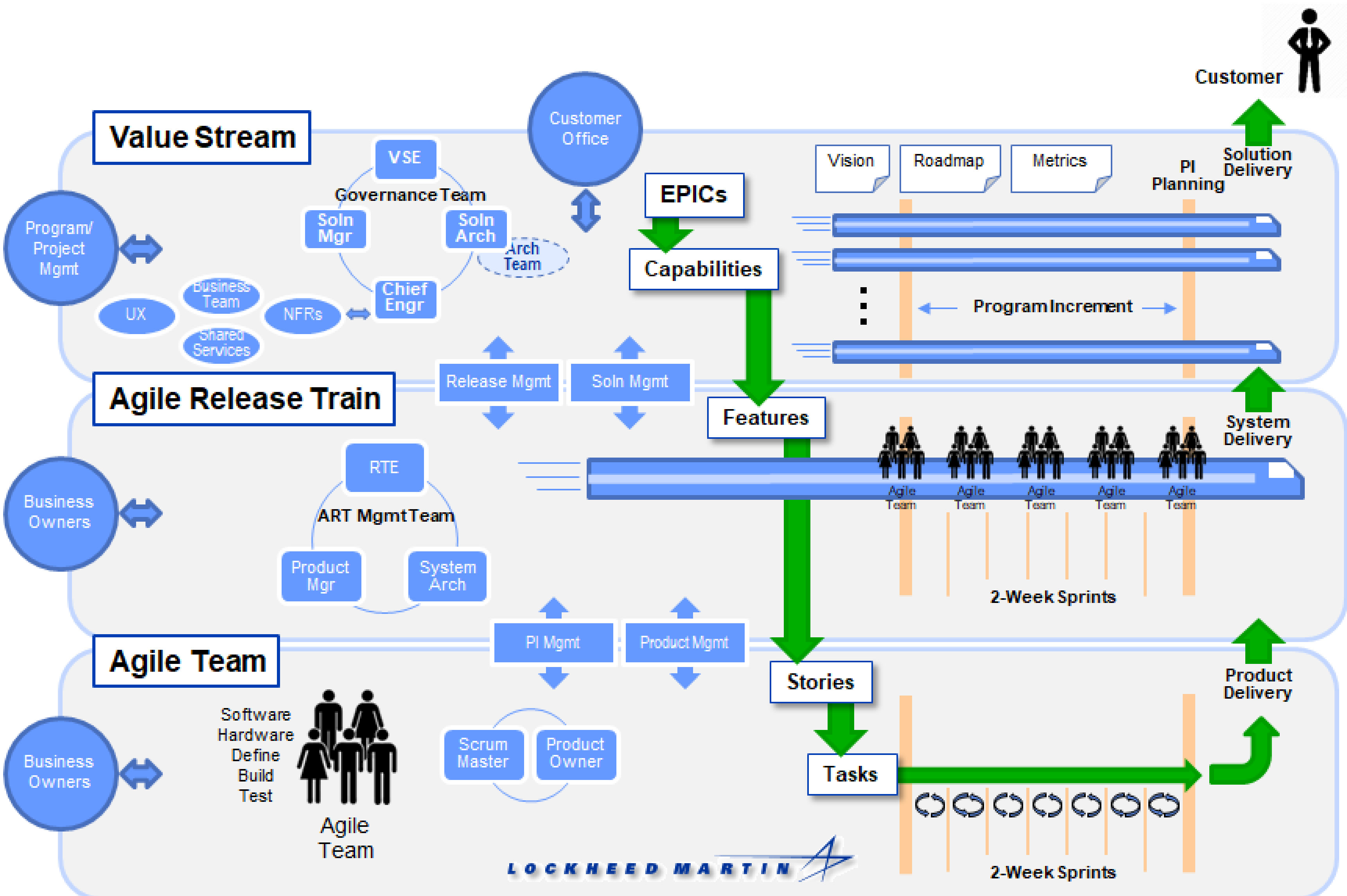
Notably, the SE process is facilitated by a transformation to an Open System Architecture aircraft-system infrastructure, enabling reusable cross platform component technologies and facilitating faster response to new system needs.

The process synchronizes internal tempo-based development intervals with an external mixture of agile/waterfall subcontractor development processes.

This example is as-presented by IFG,
it is instructive but not necessarily comprehensive.

(www.parshift.com/s/ASELCM-04LMC.pdf)

IFG-TS Process Operational Model



Slide credit: Ken Garlington, Lockheed

IFG-TS CURVE Example

Selected examples as presented by them
(Tag at front is for later traceback)

Caprice

CC1: Urgent pre-emptive customer needs (eg, Quick Reaction Notice events)

CC3: Project scope change

Uncertainty

CU1: Effectiveness of process

CU4: Team-member engagement with agile approach

Risk

CR1: Cultural incompatibility

CR2: Ability to keep and attract talent

Variation

CV1: Multiple-project resource conflicts (e.g. test facilities, key people)

CV4: Requirements of differing importance levels

Evolution

CE1: Open System Architecture (OSA) and Open Mission System (OMS)

CE2: Customer mission needs

IFG-TS Selected Proactive RSA Example

Domain	Proactive Response Requirements must deal with…
Creation (and Elimination)	What artifacts must the system be creating/eliminating in the course of its operational activity? **RC3: Loading plans with spare capacity for unknowns/inaccurate planning (CV1)** ←Trace to CURVE element **RC5: Experience accumulation (CU1)**
Improve-ment	What performance characteristics will the system be expected to improve during op life cycle? **RI3: Stakeholder, developer, and supplier alignment (CR1)** **RI5: Agility of existing integrated system (CU1, CE1)** **RI7: Effectiveness of distributed knowledge exchange (CU1, CR2)**
Migration	What major events coming down the road will require a change in the system infrastructure? **RM1: Evolution of customer missions (CE2)** **RM2: Cybersecurity and related standards (CC3)**
Modification (Add/Sub Capability)	What modifications in resources-employed might need made as the system is used? **RA1: Personnel that make up a team (CV1, CR2, CV4)** **RA5 Reallocation of work between prime contractor and other entities (CC1, CV1)**

IFG-TS Selected Reactive RSA Example

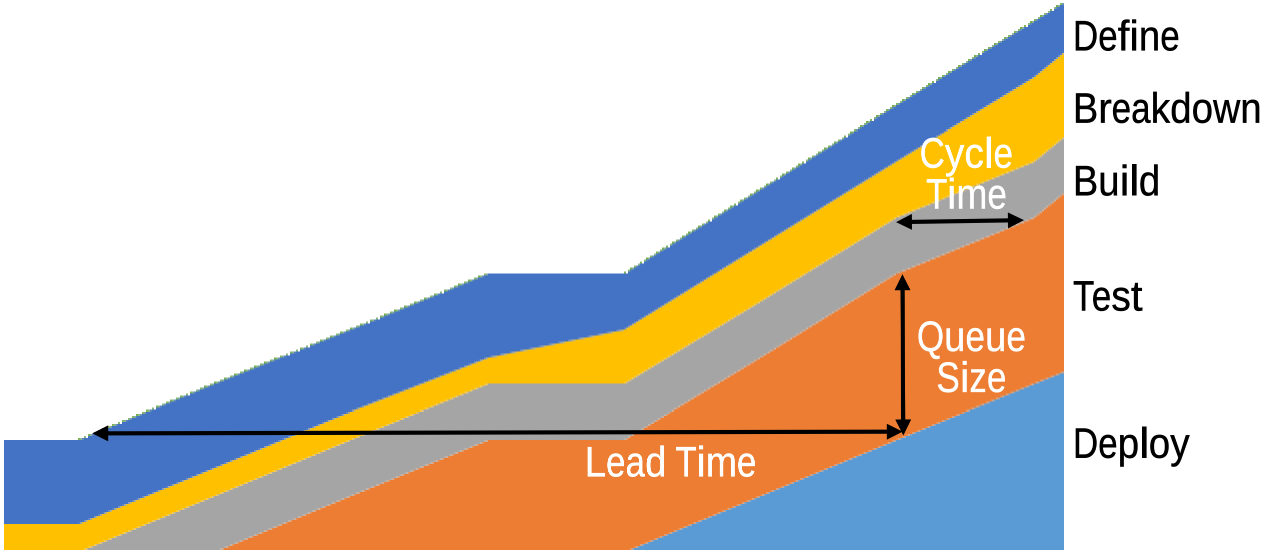
Domain	Reactive Response Requirements must deal with…
Correction	What can go wrong that will need an automatic systemic detection and response? **RW2: Non detection of variances (CU4, CV1)** **RW3: Insufficient identification and management of opportunities and risks (CR1)** ←Trace to CURVE element
Variation	What system/process variables will range across what values and need accommodation? **RV1: Process self-improvement and policing (CU1, CU4)** **RV3: Organizational acceptance and adoption of process (CU4, CR1)**
Expansion (and Contraction of Capacity)	What are "quantity-based" elastic-capacity range needs on resources/output/activity/other? **RE1: System test capacity (CV1)** **RE2: Development capacity band to avoid disruption when work is more than expected in volume or difficulty (CC1, CC3, CV4)**
Reconfig-uration	What types of resource relationship configurations will need changed during operation? **RR3: Priorities for requirements (CC3, CV1, CV4)** **RR4: Acquisition procedures/policies/ contract for situational and objectives reality (CC1, CE2)**

An Active Awareness Example at IFG

Managed Workflow: Process instrumentation for cumulative work flow awareness and pending-bottleneck predictive capability is provided at IFG by VersionOne (www.versionone.com) ***agile*****-process management software. The IFG-TS team considers effectively managed work flow as the critical factor in avoiding bottlenecks that threaten schedule.**

The Figure depicts the measurement of queue size as the predictor of test facility cycle time, a frequent bottleneck that can be mitigated by managing queue size.

Queue size for tasks awaiting attention by development (build) teams can also guide team loading to favor task assignment to less-loaded teams. See Reinertsen (2009) for the concepts and math behind flow management.



Reinertsen, D. G. 2009. ***The Principles of Product Development Flow: Second Generation Lean Product Development*****. Celeritas Publishing, Redondo Beach, CA, USA.**

Another Active Awareness Example at IFG

Facilitated Experimentation: Process experimentation with a "preliminary" system integration lab (SIL), which they call the Agile Non-Target Environment (ANTE).

The ANTE is conceptually similar to a Live, Virtual, Constructive (LVC) environment, and is used to compose integrated systems consisting of real devices, simulated devices, IFG software work-in-process, and operators.

When useful for integration testing, the ANTE also employs lower-fidelity open-market devices with similar capability but lower performance than what is eventually expected from subcontractors.

Subcontractors are required to provide device simulations to IFG ANTE specs.

In contrast, the target system testing environment includes both traditional SIL and test-aircraft platforms employed at the end of program increments.

ANTE was declared (mid-2017) a successful concept based on customer feedback that values the early and incremental demonstration of working concepts and advanced exposure to difficulties in need of attention.

Information Debt Reduction Examples at IFG

IFG's OSA architectural platform with catalogs of reusable previously developed components increased rapid response flexibility by lowering the cost of early stage Information Debt reduction.

Reusable modules included previously documented information.

IFG also looks ahead a few increments (of multiple sprints) to develop necessary system architecture and infrastructure additions and modifications – deferring development commitment to these architecture/infrastructure evolutions until sufficient past experience can guide future needs.

IFG recognizes a future need to reduce life-cycle information debt by providing sufficient documentation for stand-alone third-party system maintenance and upgrade as:

- **depot maintenance is expected to move in that stand-alone direction,**
- **the undocumented implicit knowledge of engineers who did original development is no longer available with attrition,**
- **supporting third party maintenance is a disruption to resource availability.**

Emerging Operational Principles

All ASELCM case studies enable and facilitate (with different methods):

- **Project situational sensing and response.**
- **Team-members' engagement sensing and response.**
- **Development-issue sensing and response.**
- **Integration-issue sensing and response.**
- **Assimilated shared-culture and evolution.**
- **Process and procedure evolution.**
- **Product evolution.**

Three Categories of Fundamental Principles Emerge:

- **Sense/Monitor – awareness is the driver of agility**
- **Respond/Mitigate – action is the expression of agility**
- **Evolve – applied learning is the sustainer of agility**

Agility Operational Principles

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References and Additional Info

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