28th Annual INCOSE international symposium
Washington, DC, USA
July 7 - 12, 2018

# Case Study: Agile Systems Engineering at Lockheed Martin Aeronautics Integrated Fighter Group

Rick Dove
Paradigm Shift International

Bill Schindel
ICTT System Sciences

*Ken Garlington*
*Lockheed Martin Corporation*

# Overview

**Integrated Fighter Group (IFG), in Fort Worth, Texas.**

- **F16 and F22 weapon system capability evolution (hardware/software).**
- **Faster changing threats need urgent/rapid defense response.**
- **Tailoring baseline of Scaled Agile Framework (SAFe®).**
- **1,200 people involved/trained: executives, managers, developers.**
- **Oct 2015 analyzed 2 years of transformation experience, updated 2017.**
- **Agile process facilitated by aircraft Open System Architecture: reusable cross-platform components, faster response to new needs.**
- **Process synchronizes internal tempo-based development intervals with external mixture of agile/waterfall subcontractor development.**

**Emphasis: agility as purpose & outcome of embedded *system of innovation.***

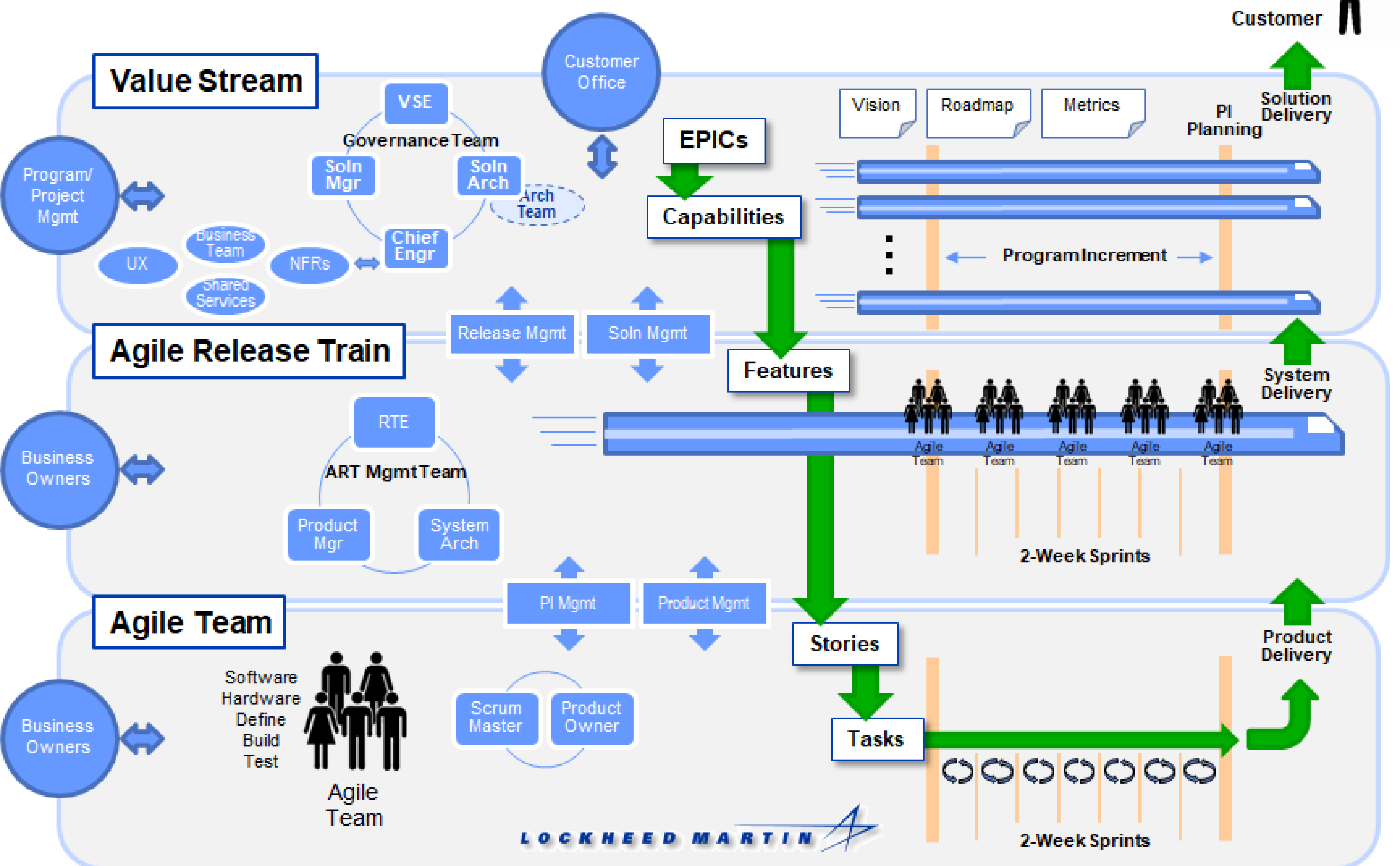
**Introducing concepts of:**

- **process instrumentation**
- **information debt**
- **preliminary systems integration lab**

# IFG-TS Operational Model

## Integrated Fighter Group – Tailored SAFe®

(SAFe and Scaled Agile Framework are registered trademarks of Scaled Agile, Inc.)

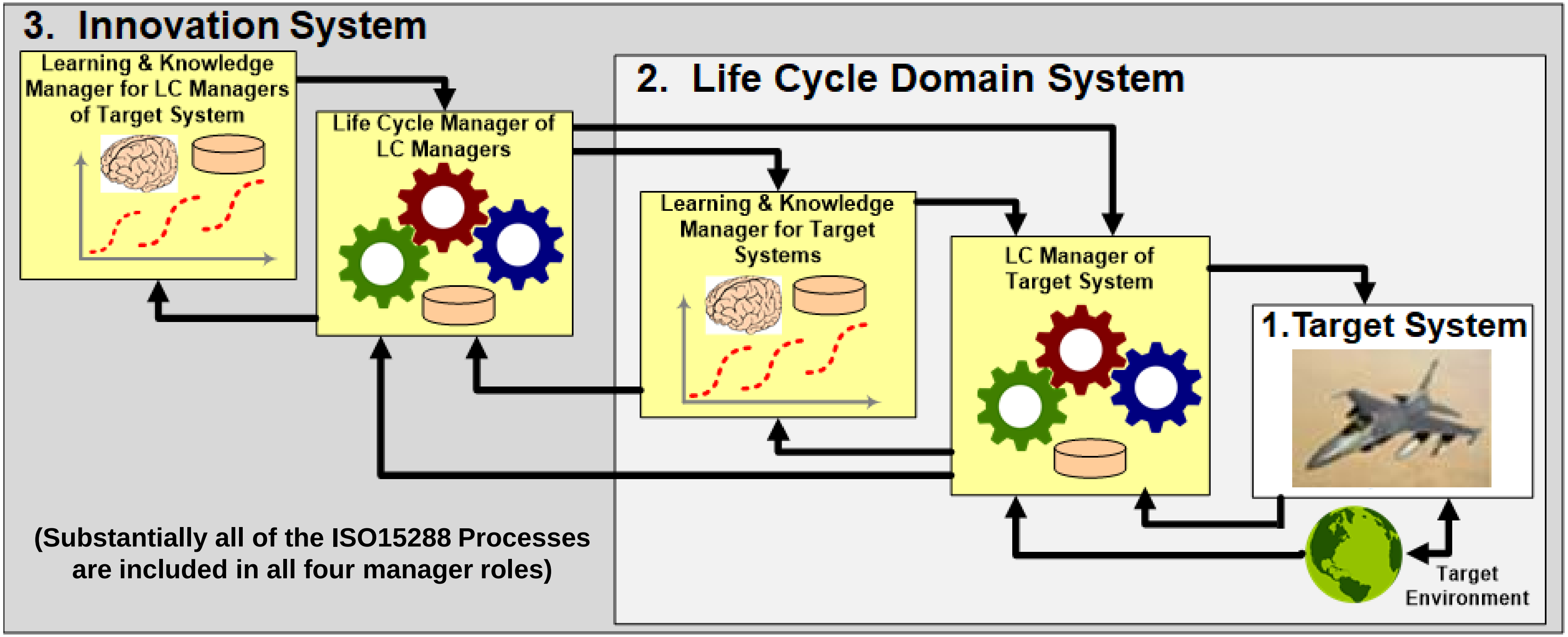



LOCKHEED MARTIN

# Agile SE Life Cycle Model (ASELCM) Pattern

## System Reference Boundaries

**(Logical/behavioral, not physical, boundaries)**



# Environment CURVE – Characterization

**Caprice**: Unknowable situations
CC1: Urgent pre-emptive customer needs, sometimes called Quick Reaction Notice events
CC2: Changes in business environment, e.g., congressional funding commitments or legal requirements
CC3: Project scope change

**Uncertainty:** Randomness with unknowable probabilities
CU1: Effectiveness of process tailoring
CU2: Contract/customer compatibility with agile approach
CU3: Management support/engagement in agile approach
CU4: Team-member engagement with agile approach

**Risk:** Randomness with knowable probabilities
CR1: Cultural incompatibility
CR2: Ability to keep and attract talent
CR3: External stakeholder schedules (e.g. certification)
CR4: Systems of Systems requirements changes

**Variation:** Knowable variables and ranges
CV1: Multiple-project resource conflicts (e.g. test facilities, key people)
CV2: Subcontractor development compatibility
CV3: System of Systems integration integrity
CV4: Requirements of differing importance levels

**Evolution:** Gradual Successive Development
CE1: OSA/OMS emphasis
CE2: Customer mission needs
CE3: New compelling technology availability

# Proactive Response Requirements

**What must the process be creating or eliminating during its operational life?**

RC1: A safe environment for people to take prudent risks (CR2)<-Tied to CURVE
RC2: Risk identification and mitigation plans at project and functional level (CC2/3, CU4)
RC3: Loading plans with spare capacity for unknowns/inaccurate planning (CV1)
RC4: Architectural development horizon to accommodate variation (CC3, CV4, CE2)
RC5: Experience accumulation (CU1)

**What anticipated events will require a change in process infrastructure?**

RM1: Evolution of customer missions (CE2)
RM2: Cybersecurity and related standards (CC3, CU2, CR3)
RM3: DoD Open Missions approach (CE1)

**What performance will the process be improving during its operational life?**

RI1: System level optimization vs. local/functional optimization (CU1/4, CR1)
RI2: Responsiveness to customer needs (CC1)
RI3: Stakeholder, developer, and supplier alignment (CU2/3, CR1/3, CV2)
RI4: Customer acceptance rate from acceptance testing events (CC1)
RI5: Agility of existing integrated system (CU1, CE1)
RI6: Awareness of evolving process effectiveness (CU1)
RI7: Effectiveness of distributed knowledge exchange (CU1, CR2, CV2)

**What modifications might need made during operational life?**

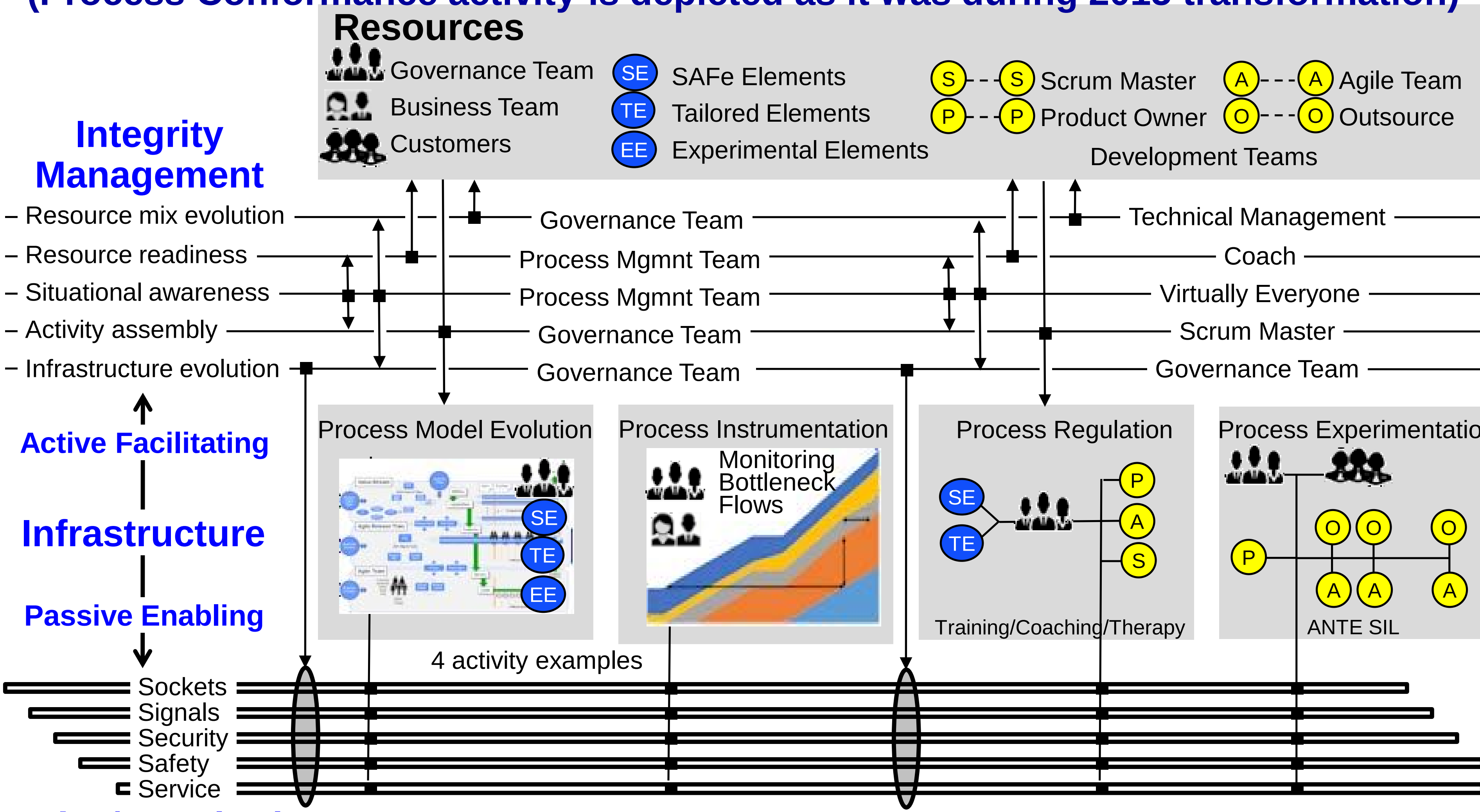
RA1: Personnel that make up a team (CV1, CR2, CV4)
RA2: Test infrastructure to maintain throughput (CV1)
RA3: Modification in project-specific details of the operational model (CU1)
RA4: Addition of subcontractor with new technology and/or process expertise (CE3)
RA5: Reallocation of work between prime contractor and other entities (CC1, CV1)

# Reactive Response Requirements

| What can go wrong that will need a systemic detection and response? | What elastic-capacity will be needed on resources/output/activity/other? |
|---|---|
| RW1: Leadership and stakeholder churn that change vision and expectations (CC2, CC3, CU3)<br>RW2: Non detection of variances (CU4. CV1, CV3)<br>RW3: Insufficient identification and management of opportunities and risks (CR1, CR4) | RE1: System test capacity (CV1)<br>RE2: Development capacity band to avoid disruption when work is more than expected in volume or difficulty (CC1, CC3, CV3, CV4) |
| **What process variables will need accommodation?** | **What types of resource relationship configurations will need changed during operation?** |
| RV1: Tailored process self-improvement and policing (CU1, CU4)<br>RV2: Alignment and coordination of PI Planning (CC1, CC3, CU1, CV4)<br>RV3: Organizational acceptance and adoption of tailored process (CU3, CU4, CR1) | RR1: Team-personnel assignments among multiple weapon systems (CC1, CR2, CV1)<br>RR2: Work reassignments to match team capacities (CU1, CR2, CV1 )<br>RR3: Priorities for requirements (CC3, CV1, CV4)<br>RR4: Acquisition procedures/policies/contract for situational and objectives reality (CC1, CU2, CE2, CE3) |

# Agile Architecture Pattern for IFG-TS

## (Process Conformance activity is depicted as it was during 2015 transformation)




## Rules/Standards

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

# Process Model Evolution

**Examples:**

- **Tested capability-based work breakdown structure for one aircraft platform with a wait-and-see on others (now adopted)**
- **12-week program increments (now variable at 12-14 weeks),**
- **Long-term teams (now adopted partially)**
- **Weighted-shortest-job-first (SAFe concept inappropriate for IFG)**
- **“Preliminary” systems integration laboratory (discussed later).**

**Process evolution continues:**

- **Additional process changes (unsharable)**
- **Contracting approaches that support evolving process agility**
- **Favorable evolution in team-member engagement with the approach**

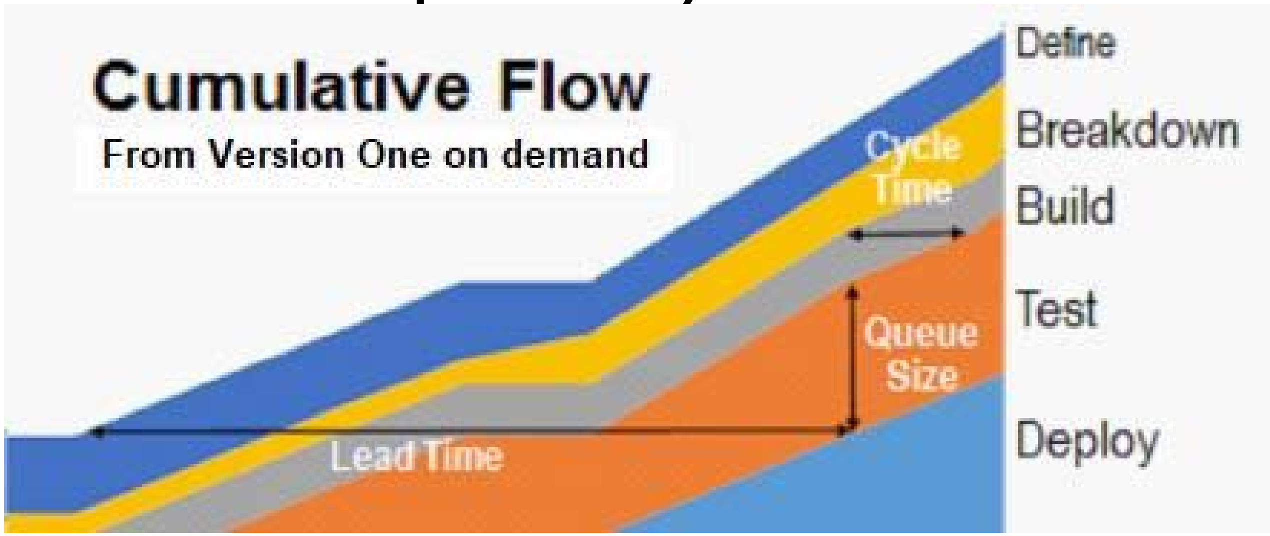
# Process Instrumentation

**Workflow management critical to avoid schedule-threat bottlenecks.**

**Instrumentation provides awareness and bottleneck prediction.**

**Examples:**

- **Test facility bottlenecks mitigated by managing queue size.**
- **Team loading bottlenecks mitigated be assigning tasks to less-loaded teams (rather than most-expert teams).**




**Automated cumulative process-flow metrics, with queue size predicting cycle time in a test facility.**

**See Don Reinertsen. 2009. *The Principles of Product Development Flow.***

# Process Regulation

Emphasis on training, coaching, and therapy for process conformance.

1200 people at IFG had been trained on SAFe and IFG-TS.

Training started at the executive level and worked its way down the chain.

Initially an “external” dedicated transformation team of 4 full-timers and 2-to-6 part-timers managed process configuration and conformance.

With time process ownership transitioned to the “internal” Engineering and Technology group, and the transformation team was eliminated.

Coaching was important in the first few years, with little necessary now as the concepts have been assimilated and acculturated.

Explicit training continues for new team members, with emergence of peer-peer informal knowledge distribution and coaching.

# Process Experimentation

A “preliminary” system integration lab (SIL) is of particular note .

In 2015 IFG was in early experimentation with a preliminary SIL concept, called the Agile Non-Target Environment (ANTE).

The ANTE is conceptually similar to a Live, Virtual, Constructive (LVC) environment, used to compose early integrated systems.

ANTE systems consist of real devices, simulated devices, IFG software work-in-process, and operators.

ANTE also employs lower-fidelity open-market devices with similar capability but lower performance than what is eventually expected.

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

By mid-2017 ANTE was declared a successful experiment based on customer feedback that values:

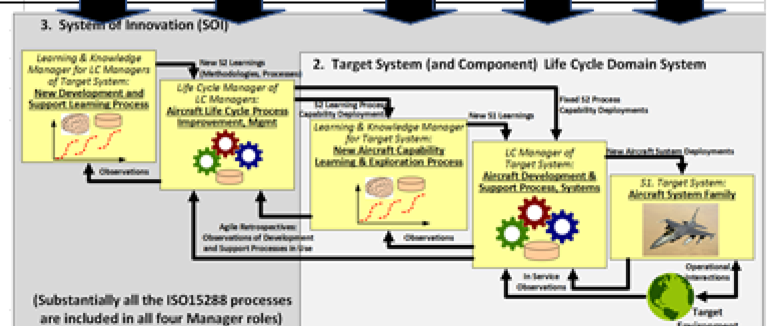
- Early and incremental demonstration of working concepts
- Advanced exposure to difficulties in need of attention

# Response Requirement Fulfillment Examples

| RSA Req (Figure 5) | Lockheed Martin Case Study Example |
|---|---|
| RA3 | Working with customer on evolution of acceptable agile methods, including contract issues |
| RC2 | Higher level of attention to general LMC competitive capabilities |
| RA4 | Subcontractor performance monitoring and adaptation |
| RC2 | CONOPS of evolving LMC Aircraft Operations & Maintenance |
| RC5 | Accumulation of agile methods |
| R16 | Evolving customer appreciation and assimilation, with contract accommodation evolution |
| RA3 | Variation of configuration of cadence increment time length |
| RC1 | Training class on SAFe framework and LMC Aircraft Operations and Maintenance |
| RA3 | Selection of Scrum versus Kanban at the team level |
| RV1 | Training, coaching, and therapy for processes |
| RE1 | Adjust cycles to accommodate shared facility resources |
| RE2 | Loading of flow across enterprise to manage bottlenecks |

# Readable In the Paper – Visual Concept Here

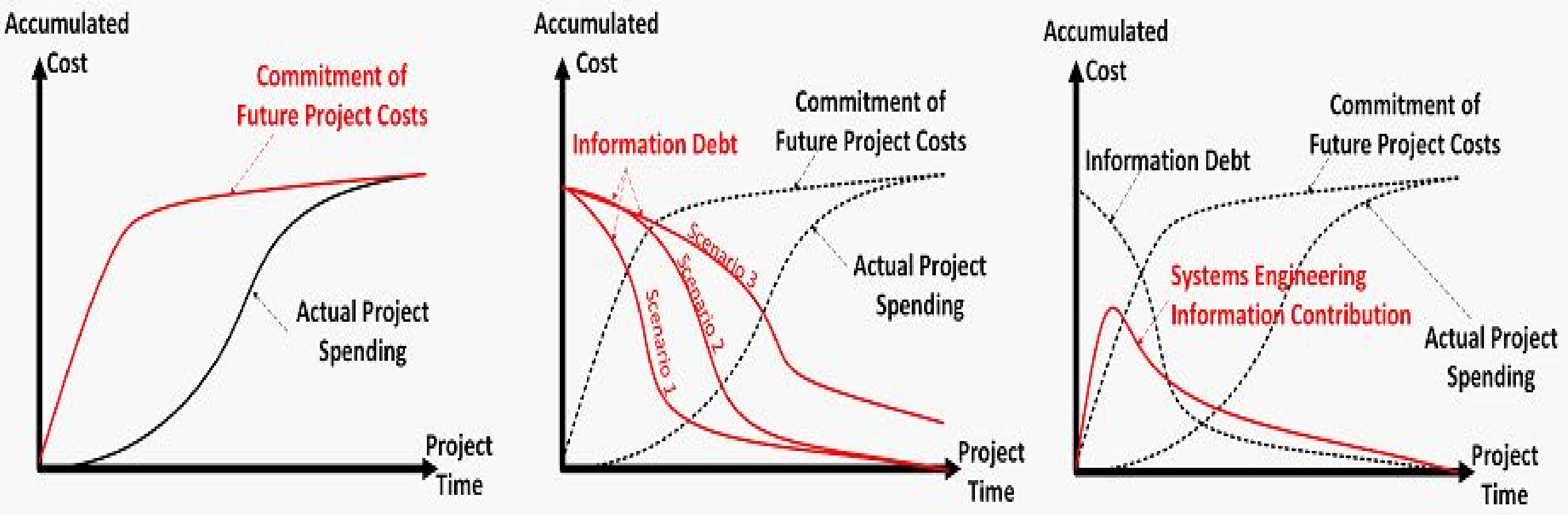
| | S3L | S3M | S2L | S2M | S1 |
|---|---|---|---|---|---|
| RC1: A safe environment for people to take prudent risks (CR2) | >> | > | | * | |
| RC2: Risk identification and mitigation plans at project and functional level (CC2, CC3, CU4) | >> | > | | * | |
| RC3: Loading plans with spare capacity for unknowns/inaccurate planning (CV1) | >> | > | * | * | |
| RC4: Architectural planning/development horizon to accommodate variation (CC3, CV4, CE2) | | | >> | > | * |
| RC5: Experience accumulation (CU1) | >> | | >> | | |
| RI1: System level development productivity vs. local/functional optimization (CU1, CR1, CU4) | >> | > | | * | |
| RI2: Responsiveness to customer needs (CC1) | >> | > | | * | |
| RI3: Stakeholder, developer, and supplier alignment (CU2, CU3, CR1, CR3, CV2) | >> | > | | * | |
| RI4: Customer acceptance rate at initial operational test (CC1) | >> | > | | * | |
| RI5: Agility of existing integrated system (CU1, CE1) | | | >> | > | * |
| RI6: Awareness of evolving process effectiveness (CU1) | | > | * | * | |
| RI7: Effectiveness of distributed knowledge exchange (CU1, CR2, CV2) | >> | > | * | * | |
| RM1: Evolution of customer missions (CE2) | | | >> | > | * |
| RM2: Cybersecurity and related standards (CC3, CU2, CR3) | | | >> | > | * |
| RM3: DoD Open Missions approach (CE1) | | | >> | > | * |
| RA1: Personnel that make up a team (CV1, CR2, CV4) | >> | > | * | * | |
| RA2: Test infrastructure to maintain throughput (CV1) | >> | > | * | * | |
| RA3: Modification in project-specific operating model (CU1) | >> | > | * | * | |
| RA4: Addition of subcontractor with new technology expertise (CE3) | >> | > | * | * | |
| RA5: Reallocation of work between prime contractor and other entities (CC1, CV1) | >> | > | * | * | |




| | | |
|---|---|---|
| >> | Learner | >> |
| > | Manager | > |
| * | Performer | * |

| | S3L | S3M | S2L | S2M | S1 |
|---|---|---|---|---|---|
| RW1: Leadership and stakeholder churn that change vision and expectations (CC2, CC3, CU3) | >> | > | | * | |
| RW2: Non detection of variances (CU4. CV1, CV3) | >> | > | | * | |
| RW3: Insufficient identification and management of opportunities and risks (CR1, CR4) | >> | > | | * | |
| : | : | : | | | |
| RR3: Priorities for requirements (CC3, CV1, CV4) | >> | > | | * | |
| RR4: Acquisition procedures/policies/contract for situational and objectives reality (CC1, CU2 | >> | > | | * | |

# On Information Debt




(a) When Project Costs Are Committed versus Incurred

(b) Information Debt is Reduced Over the Course of Project

(c) Systems Engineering Information Is Generated to Reduce Information Debt

**Future costs of a project become committed early by SE decisions. One of the traditional arguments for early stage SE investment.**

**Will project end with outstanding information debt: a "working system" but an interest penalty caused by shortage of needed information?**

**SE information must be generated (e.g., reqs, architectures, risk assessments, etc.) early enough in the project.**

# ASELCM Project References


**Case Study:** Agile Systems Engineering Process Features Collective Culture, Consciousness, and Conscience at SSC Pacific Unmanned Systems Group. Dove, R., W. Schindel, C. Scrapper. 2016. Proceedings International Symposium. International Council on Systems Engineering. Edinburgh, Scotland, 18-21 July. www.parshift.com/s/ASELCM-01SSCPac.pdf

**Case Study:** Agile SE Process for Centralized SoS Sustainment at Northrop Grumman. Dove, R., W. Schindel. 2017. Proceedings International Symposium. International Council on Systems Engineering. Adelaide, Australia, 17-20 July.
www.parshift.com/s/ASELCM-03NGC.pdf

**Case Study:** Agile Hardware/Firmware/Software Product Line Engineering at Rockwell Collins. Dove, R., W. Schindel, R. Hartney. 2017. Proceedings 11th Annual IEEE International Systems Conference. Montreal, Quebec, Canada, 24-27 April.
www.parshift.com/s/ASELCM-02RC.pdf

**Case Study:** Agile Systems Engineering at Lockheed Martin Aeronautics Integrated Fighter Group. Dove, R., W. Schindel, K. Garlington. 2018. Proceedings International Symposium. International Council on Systems Engineering. Washington, DC, US, 7-12 July. www.parshift.com/s/ASELCM-04LMC.pdf

Introduction to the Agile Systems Engineering Life Cycle MBSE Pattern. Schindel, W., R. Dove. 2016. Proceedings International Symposium. International Council on Systems Engineering. Edinburgh, Scotland, 18-21 July.
www.parshift.com/s/160718IS16-IntroToTheAgileSystemsEngineeringLifeCycleMBSEPattern.pdf

Agility in Systems Engineering – Findings from Recent Studies. Dove, R., Schindel, Bill. 2018. Working paper, 4-April-2018.
www.parshift.com/s/ASELCM170415-AgilityInSE-Findings.pdf