

Welcome to the Webinar – if you have not dialed into the audio portion, please do so now. In the U.S., dial 1-855-747-8824, passcode **4348124177**. If you are outside the U.S., the webinar invitation includes a list of toll-free numbers for different countries. Please note that your phone is automatically on mute when you join to avoid disturbing other participants.

INCOSE Webinar Series

Wednesday 2nd August 2017– Webinar 102

**Feature-based Product Line
Engineering: PLE for the
Enterprise**



Dr Paul Clements



1

INCOSE is offering Webinars ...



- To provide a forum for experts in the field of Systems Engineering to present information on the “State of the Art”
- To explain how INCOSE works, and how to make the most out of INCOSE membership



2

INCOSE Systems Engineering Professional PDU Credit

Please note that you can claim 1PDU credit towards your Systems Engineering Professional re-certification by attending this webinar. INCOSE webinars may also apply to the PDU requirements of other organizations, depending on the subject matter

To qualify, you must have attended through at least 75% of the webinar for webinars that last less than one hour, or through 45 minutes of the webinar for webinars that last for 1 hour or longer.

Here is the link to details about certification renewal, including information on PDUs.

<http://www.incose.org/certification/CertProcess/CertRenew>



Choreography

1. Andy Pickard (your host) will introduce the Webinar and the speaker
2. Paul will speak for about 40 to 45 minutes
3. During his talk, participants can write questions using the Webex Q&A window
4. After Paul completes his talk, he will spend 10 minutes answering questions that Andy selects from those submitted by the audience
5. Andy Pickard will provide information about upcoming Webinars and then end this session
6. This Webinar is being recorded and will be made available on the INCOSE website to members and employees of CAB organizations





**Engineer
Your
Competitive
Advantage**

Feature-based Product Line Engineering: PLE for the Enterprise

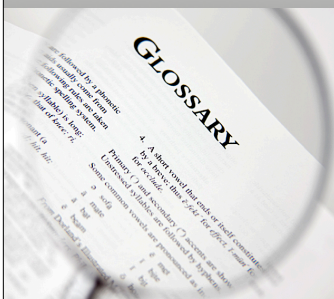
Paul Clements, PhD, VP of Customer Success, BigLever

INCOSE Webinar 102
02 August 2017

Product Line Engineering (PLE) Defined

Product Line:

a family of similar products or systems with variations
in features and functions



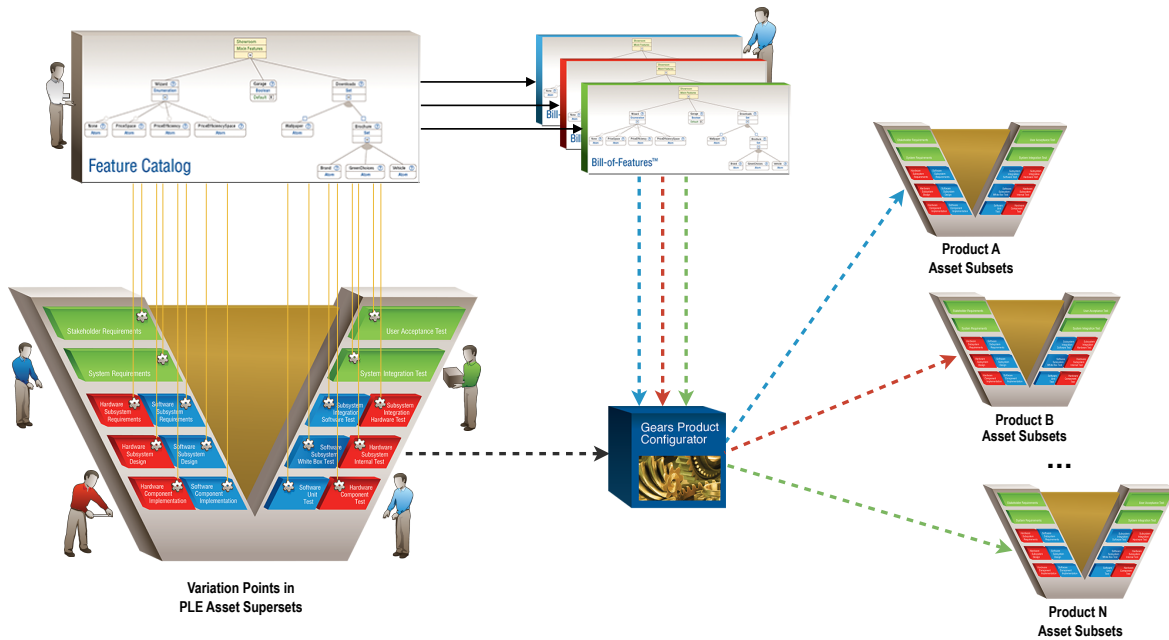
Product Line Engineering:

the engineering of a product line using
a shared set of engineering assets,
a managed set of features, and
an automated means of production...

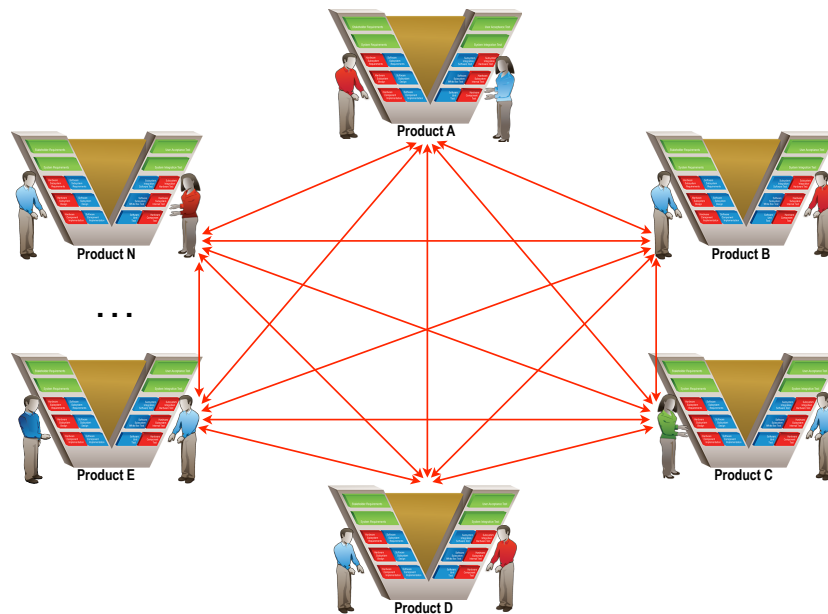


- taking advantage of the **commonality** shared across the family
- efficiently and systematically managing the **variation** among the systems

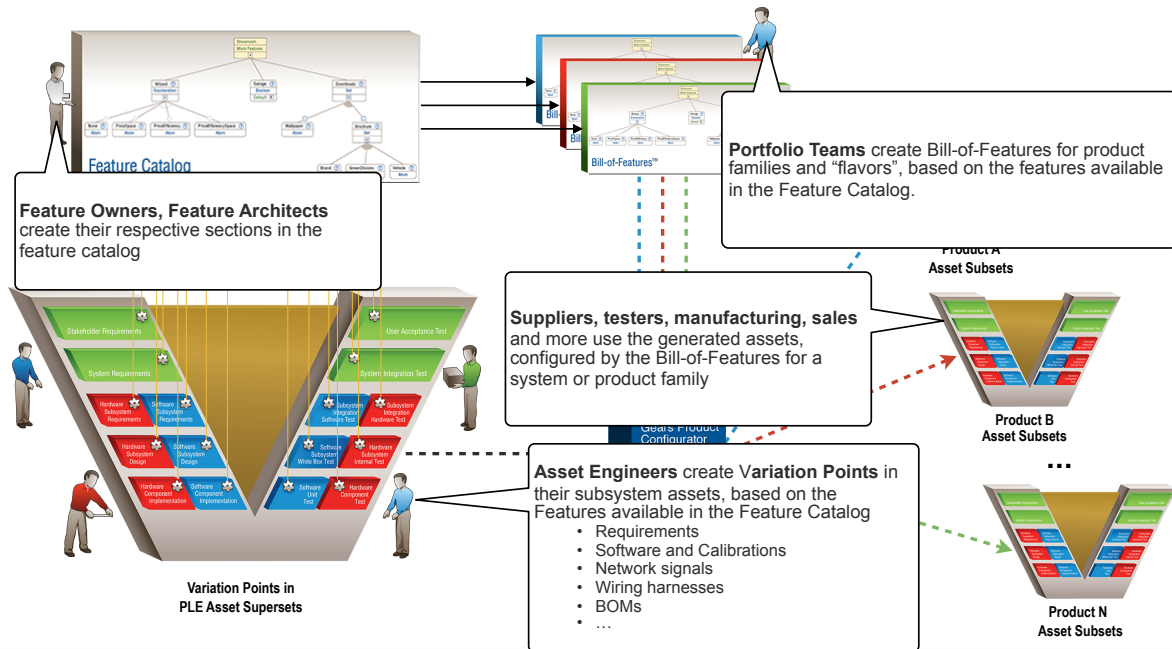
Feature-based PLE: The PLE Factory



PLE is a move away from product-centric duplication, branch & merge, clone-and-own, N^2 coordination



Roles and Responsibilities in Feature-based PLE



What's a Feature?

Features

- “A distinguishing characteristic that sets products in a product line apart from each other” [3]
 - Usually, but not always, visible to customer or end user
- What constitutes a “distinguishing characteristic?”
 - Products are differentiated by differences in all of the places where the digital engineering representations of any two products differ from each other.
 - Requirements objects, model elements from design specs, test cases, lines of software, mechanical parts in a Bill of Materials, paragraphs or sections in a user's manual, slides in training courseware, and much more

[3] Kang, K.; Cohen, S.; Hess, J.; Novak, W.; & Peterson, A. “Feature-Oriented Domain Analysis (FODA) Feasibility Study” (CMU/SEI-90-TR-021, ADA235785). Pittsburgh, PA: Software Engineering Institute, Carnegie Mellon University, 1990.

Features

- In a product line comprising thousands to tens of thousands of instances there may easily be millions of these differences.
- While these are undeniably “distinguishing characteristics,” albeit tiny ones, and undeniably important to manage correctly, they cannot be features: No organization could create and manage a bank of millions of features.
- More precisely, there cannot be a one-to-one correspondence between a feature and a variation in an engineering artifact.

Features

- “A distinguishing characteristic that sets products in a product line apart from each other” [3]
 - This can range from large scale customer facing capabilities — like autonomous driving on an automobile — to fine grained implementation details like algorithm tradeoffs in range detection
- Engineering realization of distinguishing characteristics
 - Products are differentiated by differences in all of the places where the digital engineering representations of any two products differ from each other.
 - Requirements objects, model elements from design specs, test cases, lines of software, mechanical parts in a Bill of Materials, paragraphs or sections in a user’s manual, slides in training courseware, and much more

[3] Kang, K.; Cohen, S.; Hess, J.; Novak, W.; & Peterson, A. “Feature-Oriented Domain Analysis (FODA) Feasibility Study” (CMU/SEI-90-TR-021, ADA235785). Pittsburgh, PA: Software Engineering Institute, Carnegie Mellon, 1990.

A Feature Ontology for Feature-based PLE

Ontology

- An ontology is an “explicit formal specification of the terms in a domain and relations among them” [1], in order to “share common understanding of the structure of information among people or software agents” [2].

- [1] Gruber, T.R. (1993). A Translation Approach to Portable Ontology Specification. *Knowledge Acquisition* 5: 199-220.
[2] Noy, Natalya F, and McGuinness, Deborah L., “Ontology Development 101: A Guide to Creating Your First Ontology,” Stanford University, Stanford University, Stanford, CA, 94305, http://protege.stanford.edu/publications/ontology_development/ontology101-noy-mcguinness.html, downloaded 09 November 2016.

Feature-based PLE Feature Ontology

- Based on abstraction **levels**, where each level comprises:
 - Data structure modeling the **features** at that level
 - Multiple **feature profiles**: Chosen instances of the feature model
 - Abstraction of the choices provided to the next higher level in the ontology
- Must reduce complexity from ranging from 1,000,000 options and variants down to 10 options and variants
- The levels together serve the diverse feature management roles and responsibilities across an enterprise
 - Implementors, designers, architects, chief engineers, product management, product marketing, portfolio management, manufacturing, service, IoT operations, sales, corporate strategy

Level 0

Asset Variation Points

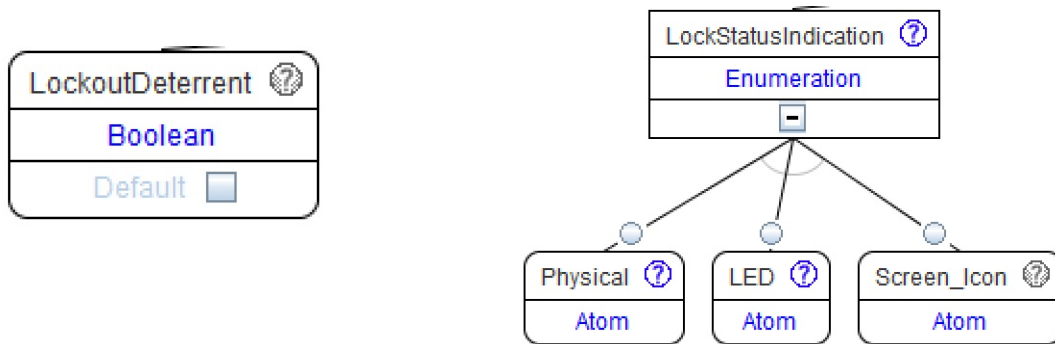
- Purpose and roles
 - Asset engineers create feature-based variation points to implement differentiating characteristics
- Data structure for the feature model
 - Each variation point is either *optional* or comes in multiple *variants*
- Feature profiles
 - Variation point behaviors result in different possible asset instantiations
- Abstraction provided to the next higher level
 - None. Feature abstractions must be discovered.
 - Why, why, why...

Level 1

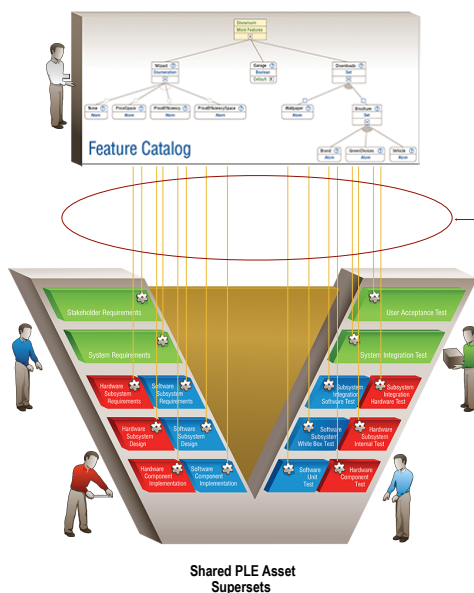
Primitive Standalone Features

- Purpose and roles
 - Feature engineers create feature abstractions for root-cause variation
 - Can be derived bottom-up or top-down
 - Typical responsible for driving variations in multiple assets
- Data structure for the feature model
 - Each feature has a name and a type, such as boolean, enumeration, set, record, integer, ...
- Feature profiles
 - Defined according to the possible instantiations of the feature type
- Abstraction provided to the next higher level
 - The feature names, types, and profile instantiations are directly provided

Two examples



Primitive Feature Abstraction Layer over Variation Points

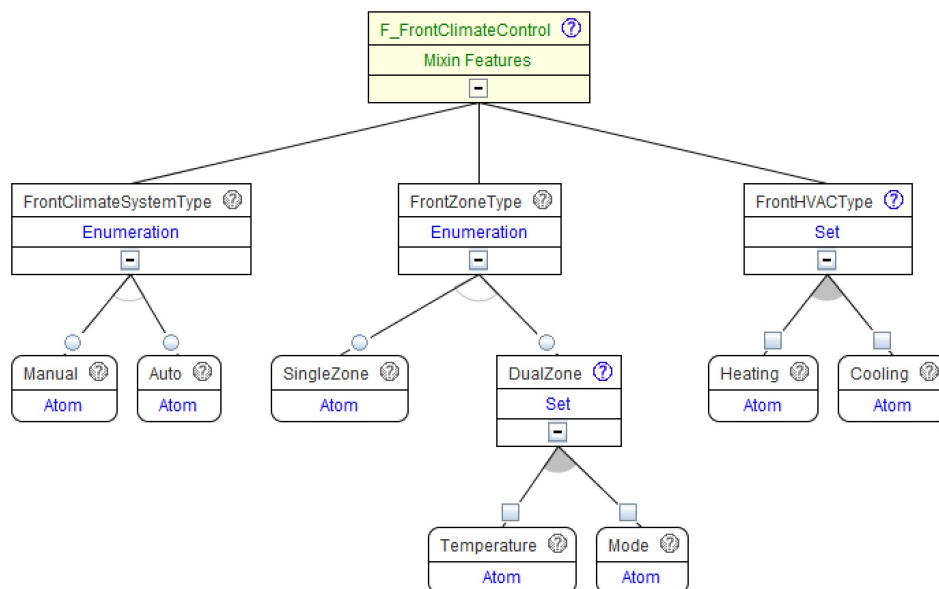


- Automated mapping from primitive features to variation point configurations
- $2^{1,000,000} : 2^{10,000}$ combinatoric reduction
- Roles
 - Engineering Subsystem Leadership
 - Asset Engineers

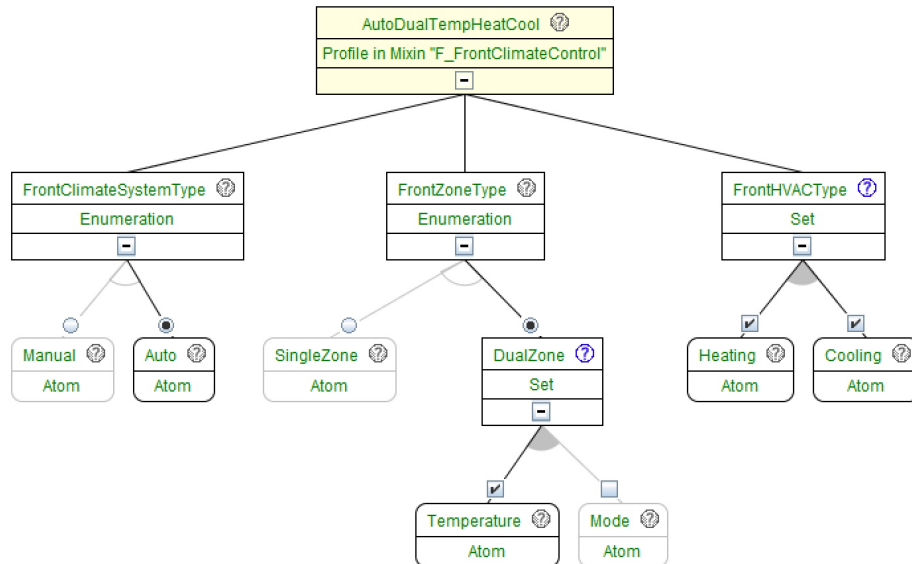
Level 2 Component Feature Model

- Purpose and roles
 - Feature and component architects modularize primitive features into component feature models
- Data structure for the feature model
 - Aggregation of primitive features based on modularity grouping criteria
- Feature profiles
 - A named list of desired profiles are defined according to possible instantiations of the feature model
- Abstraction provided to the next higher level
 - Component Feature — component feature model is encapsulated with named feature profiles and the bundle is given an abstract feature name

Example



Example profile



Level 3 Subsystem Feature Model

- Purpose and roles
 - Feature and subsystem architects modularize component feature models into subsystem feature models
- Data structure for the feature model
 - Aggregation of component features
- Feature profiles
 - A named list of desired profiles are defined according to possible instantiations of the feature model
- Abstraction provided to the next higher level
 - Subsystem Feature — subsystem feature model is encapsulated with named feature profiles and the bundle is given an abstract feature name

Example

| Products | | | |
|-----------------------------|-----------------------------------|-----------------------|----------------------------------|
| | ▼ PowerDoorLocks | ▼ RearEnclosureUnlock | ▼ FuelFillerDoorUnlock |
| Basic | Basic | KeyCylinder | \$omitted\$ |
| Basic_Plus | Basic_plus_KeyFob | KeyCylinder | \$omitted\$ |
| Intermediate_Low | Intermediate | KeyCylinder | \$omitted\$ |
| Intermediate_Low_Plus_Speed | Intermediate_plus_AutoSpeed | KeyFob | FuelDoorUnlockInteriorButtonOnly |
| Intermediate_Plus | Intermediate_plus_AutoGearNeutral | KeyFob | FuelDoorUnlockInteriorButtonOnly |
| Premium | Premium_with_KeyCylinder | InteriorButton_KeyFob | FuelDoorUnlockButtonOnKeyFob |
| Premium_Plus | Premium_with_DigitalKeypad_5 | InteriorButton_KeyFob | FuelDoorUnlockButtonOnKeyFob |

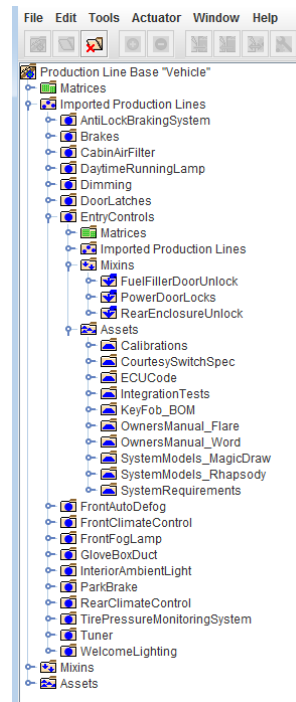
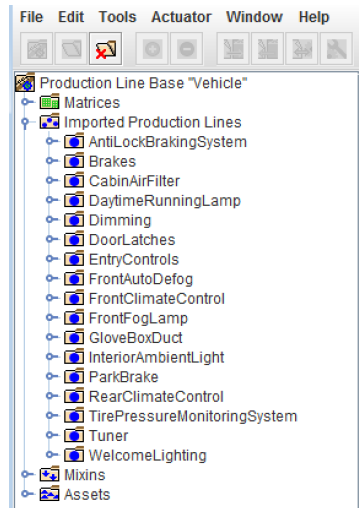
Level 4 System Feature Model

- Purpose and roles
 - Feature catalog and system architects modularize subsystem feature models into system feature models
- Data structure for the feature model
 - List structured aggregation of component and subsystem features
- Feature profiles
 - A named list of desired profiles are defined according to possible instantiations of the feature model
- Abstraction provided to the next higher level
 - System Feature — system feature model is encapsulated with named feature profiles and the bundle is given an abstract feature name

Example

| Products | RegionOfSale | PropulsionType | EntryControls | FrontClimateC |
|----------|-------------------|----------------|----------------------------|---------------------------------|
| Product1 | .USA.UnitedStates | BAS | EntryControls/Premium_Plus | FrontClimateControl/AutoSingleZ |
| Product2 | .USA.UnitedStates | BAS | EntryControls/Premium_Plus | FrontClimateControl/AutoSingleZ |
| Product3 | .USA.UnitedStates | BAS | EntryControls/Premium_Plus | FrontClimateControl/AutoSingleZ |
| Product4 | .USA.UnitedStates | BAS | EntryControls/Premium_Plus | FrontClimateControl/AutoSingleZ |

Hierarchies of production lines










Level 5++ Feature Bundle Overlay

- Purpose and roles
 - Product marketing portfolio designers overlay marketing feature bundles onto system-of-system feature models
 - System-of-system feature models with feature bundle overlays are used by upstream and downstream operations, such as portfolio planning, manufacturing, sales, IoT, service, and more
- Data structure for the feature model
 - Overlay on a subset of the system-of-system feature model that constrains desired marketing feature combinations
- Feature profiles
 - A named list of desired bundle profiles are defined according to possible instantiations of the overlay model
- Abstraction provided to the next higher level
 - Bundle combines multiple system, subsystem, and component members into one

Feature Ontology Abstractions Levels

| Level | Abstraction | Purpose and Roles | Complexity Potential |
|-------|------------------------------|--|----------------------|
| - | Feature Bundle Overlay | Product marketing portfolio designers overlay marketing feature bundles onto system-of-system feature models | 2^{10} |
| 4 | System Feature Model | Feature catalog and system architects modularize subsystem feature models into system feature models | 2^{100} |
| 3 | Subsystem Feature Model | Feature and subsystem architects modularize component feature models into subsystem feature models | 2^{250} |
| 2 | Component Feature Model | Feature and component architects modularize primitive features into component feature models | $2^{1,000}$ |
| 1 | Primitive Standalone Feature | Feature engineers create feature abstractions for root-cause functional and non-functional variation | $2^{10,000}$ |
| 0 | Asset Variation Points | Asset engineers create feature-based variation points to implement differentiating characteristics | $2^{1,000,000}$ |




| | | | | | |
|---|---|---|---|---|---|
|  |  |  |  |  |  |
| World's #1 Defense Contractor | World's #4 Defense contractor | World's #3 Automotive Manufacturer | World's #2 Data Storage Provider | World leader Online Vacation Property Rentals | Leading Aviation Supplier |
| AEGIS Weapon System | Live Training Transformation: US Army, Air Force, Marines | Largest, most complex product line comprising over 10,000,000 instances per year | High-end server storage systems | E-commerce websites hosted in over 200 countries worldwide | Whole-aircraft avionics product line |
| High cost of old approach threatened loss of entire contract | Innovative low-cost solution essential to win/keep major contract | Vehicles taking too long to engineer: expensive, error-prone processes | Unable to accommodate rapid market growth | Broad site variation around the world; needed to go live ASAP | High cost of product certification |

Feature-based Product Line Engineering Results with BigLever

| | | | | | |
|--|--|--|--|------------------------------------|--|
| Over 100 ship deployments: \$47 million saved annually | Over 300 training range deployments: \$750 million saved over 12 years | Hundreds to thousands of man/years annually; tens to hundreds of millions of dollars annually for one asset type alone | 2x-5x improvements in scalability, productivity, time-to-market, and product quality | First product went live in 60 days | 8:1 improvement in time to produce certification documents |
|--|--|--|--|------------------------------------|--|

Copyright © 2017 BigLever Software, Inc.
 31



Feature-Based PLE: Achieving Standards-Level Maturity

- ISO standard in progress:

ISO/IEC 26580, "Methods and Tools for the Feature-Based Approach to Software and Systems Product Line Engineering"
- With involvement and support from INCOSE Product Line Engineering International Working Group
- Will include a feature ontology similar to the one presented here.

Copyright © 2016 BigLever Software, Inc.
 32



www.biglever.com

Thank you for participating!

Questions?

Upcoming Webinars (tentative schedule)

| Who | What | When |
|--------------|--|---|
| Ian Presland | INCOSE Certification Program Competency Areas Update | August 23 rd 2017 at 11am EDT |
| Rick Dove | Agile Systems and Processes 106 – Risk Management and Mitigation | September 20 th 2017 at 11am EDT |

Invitations will be emailed in advance and informational updates will be placed on www.incose.org
Go to <http://www.incose.org/ProductsPublications/webinars> for more info on the webinar series, including a way to view the last Webinar and soon – this one!

Information on the webinars is now being posted in INCOSE Connect, in the INCOSE Library area, at <https://connect.incose.org/Library/Webinars/Pages/INCOSE-Webinars.aspx>. Joining instructions will be added around two weeks before the webinar is scheduled to take place.



35

INCOSE GLRC11 – Twin Cities, Minnesota

11th Annual INCOSE Great Lakes Regional Conference
SUPERIOR SYSTEM SOLUTIONS FOR TODAY'S COMPLEX ENVIRONMENTS
11 - 14 October 2017 | Twin Cities, Minnesota

Home ▾ Program ▾ Sponsors and Exhibitors ▾ Attendees ▾ Contact Us ▾

Home
When / Where
What is the INCOSE GLRC?
Why should you attend?
Program
Agenda
Call for SE-PDD Sites
Call for Proposals
Benefits for Presenters
Sponsors and Exhibitors
Current Sponsors and Exhibitors
Why join as sponsor and/or exhibitor
Become a sponsor and/or exhibitor
Become a participating chapter
Attendees
Registration
Accommodation
Local Attractions
Contact Us
Contacts email
Downloads

When / Where

11th – 14th October 2017
Twin Cities, Minnesota
www.incose.org/glrc11

Call for Participation

The chapters of the INCOSE Great Lakes Region invite you to participate in the 11th Annual INCOSE Great Lakes Regional Conference (GLRC11). GLRC11 will feature important topics from critical sectors such as aerospace, agriculture, automotive, biomedical & healthcare, defense, education, energy, government, information infrastructure, safety & security, space, and transportation.

Building upon last year's conference, GLRC11 will again feature an INCOSE SE Professional Development Day (SE-PDD). The SE-PDD will be a virtual extension of the conference, with the featured sessions broadcast from Minnesota to several satellite sites on Friday the 13th of October. New this year will be STEM demonstrations from area youth during the conference banquet and reception.

- [Call for Proposals](#) (presentations, panel discussions, tutorials) now open - deadline 27 May 2017
- [Call for SE-PDD Sites](#) now open - deadline 27 May 2017
- [Call for Participating Chapters](#) now open - deadline 31 May 2017
- [Call for Sponsors & Exhibitors](#) now open - Early fee deadline 31 July 2017



INCOSE Systems Engineering Professional PDU Credit

Please note that you can claim 1PDU credit towards your Systems Engineering Professional re-certification by attending this webinar. The webinars may also apply to the PDU requirements of other organizations, depending on the subject matter

To qualify, you must have attended through at least 75% of the webinar for webinars that last less than one hour, or through 45 minutes of the webinar for webinars that last for 1 hour or longer.

You can also claim credit for previous webinars you have attended; please contact info@incose.org if you wish to know which webinars you attended and if you met the qualification requirements