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INCOSE Webinar Series

Wednesday 2nd August 2017– Webinar 102

Feature-based Product Line Engineering: PLE for the Enterprise

Dr Paul Clements

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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

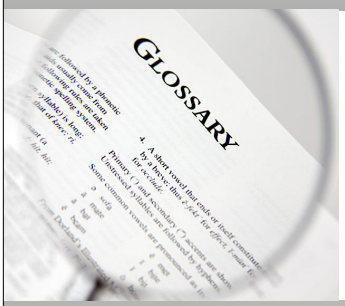
Feature-based Product Line Engineering: PLE for the Enterprise

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

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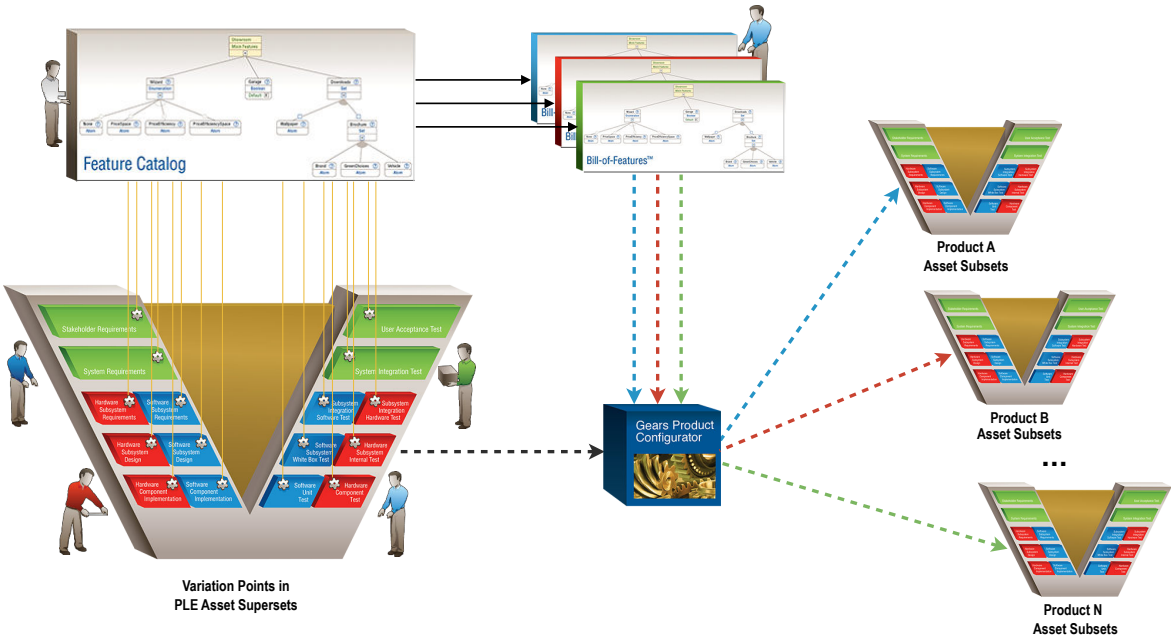
Feature-based PLE: The PLE Factory



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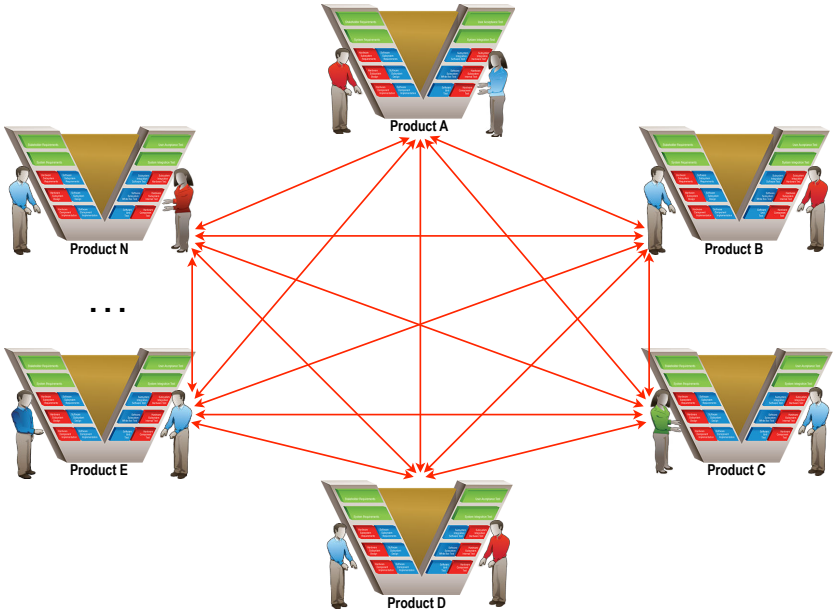
PLE is a move away from product-centric duplication, branch & merge, clone-and-own, N^2 coordination



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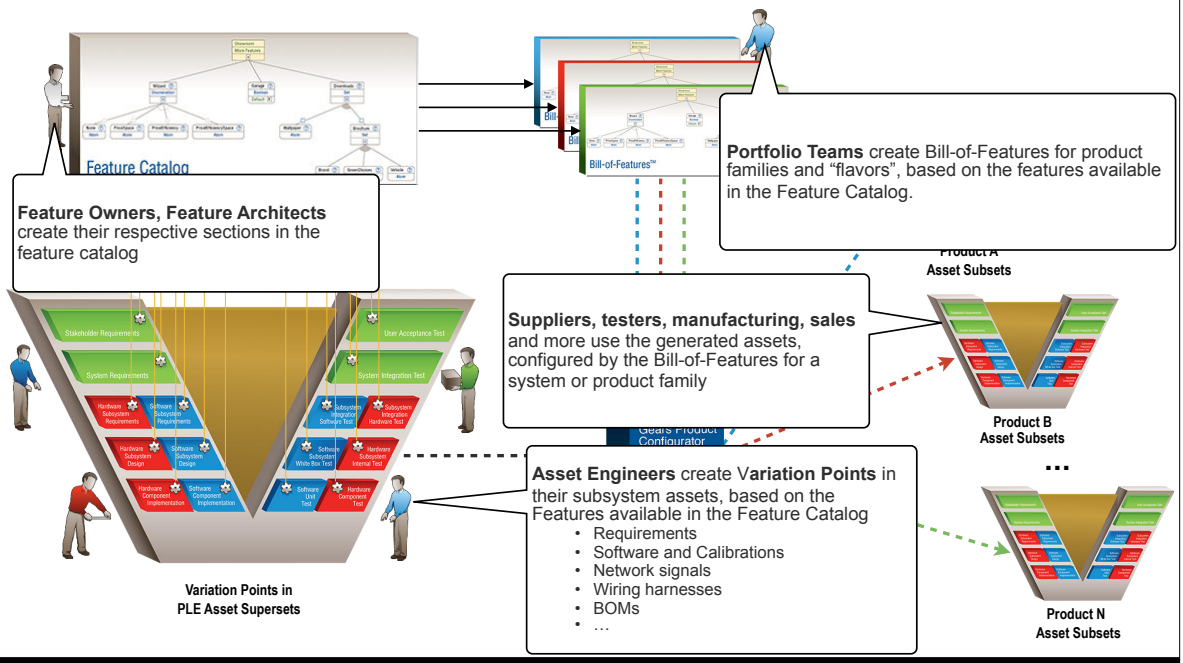
Roles and Responsibilities in Feature-based PLE



Feature Owners, Feature Architects create their respective sections in the feature catalog

Portfolio Teams create Bill-of-Features for product families and "flavors", based on the features available in the Feature Catalog.

Suppliers, testers, manufacturing, sales and more use the generated assets, configured by the Bill-of-Features for a system or product family

Asset Engineers create **Variation Points** in their subsystem assets, based on the Features available in the Feature Catalog

- Requirements
- Software and Calibrations
- Network signals
- Wiring harnesses
- BOMs
- …

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What's a Feature?

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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.

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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.

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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.

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A Feature Ontology for Feature-based PLE

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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.

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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

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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…

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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

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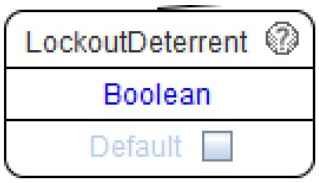
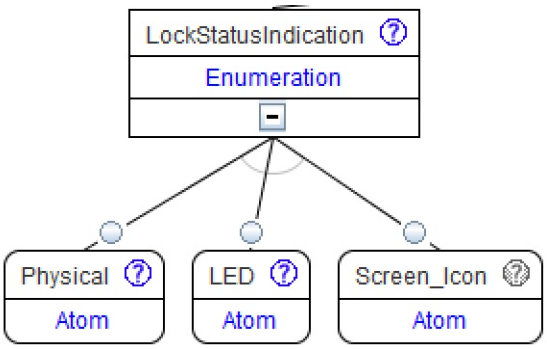
Two examples





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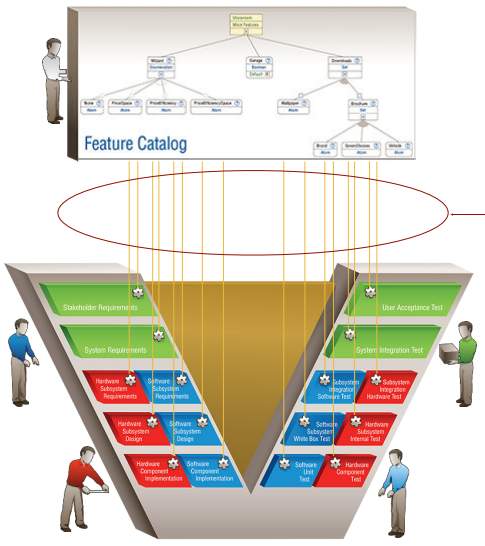
Primitive Feature Abstraction Layer over Variation Points



Shared PLE Asset Supersets

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

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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

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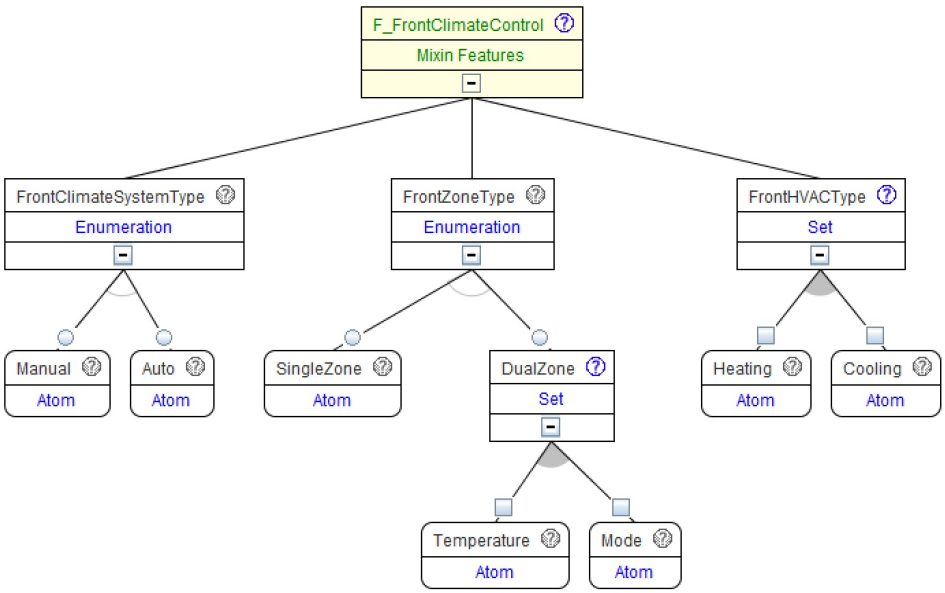
Example



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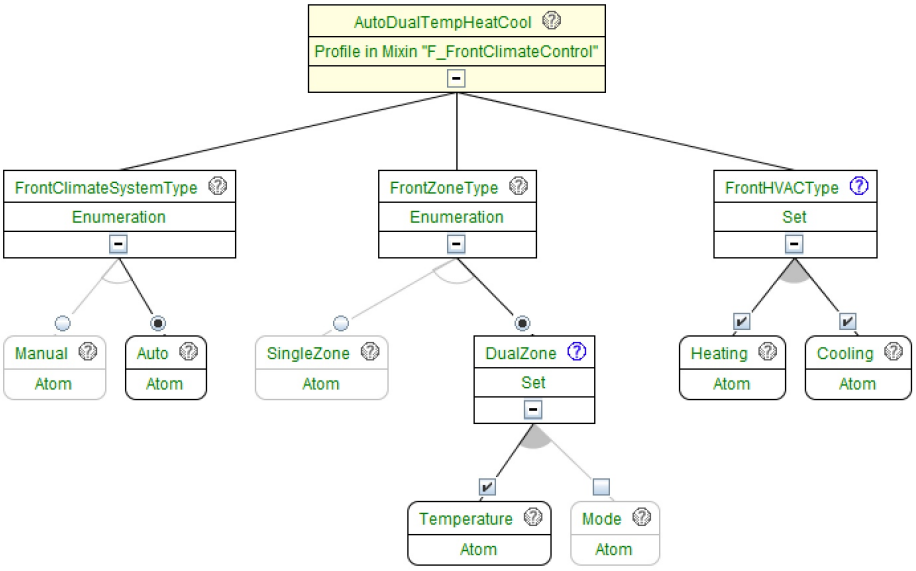
Example profile



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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

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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

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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

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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

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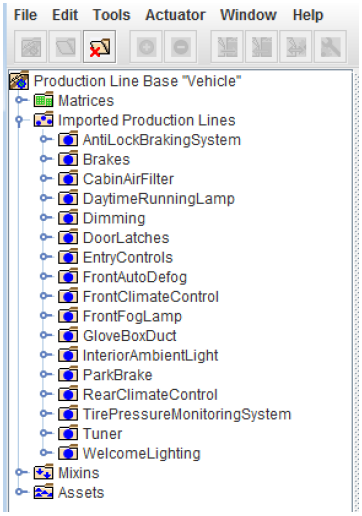
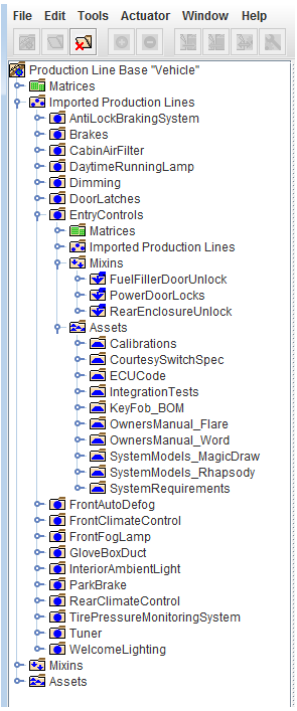
Hierarchies of production lines





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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

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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	$2^{1,000,000}$

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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

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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.

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Thank you for participating!

Questions?

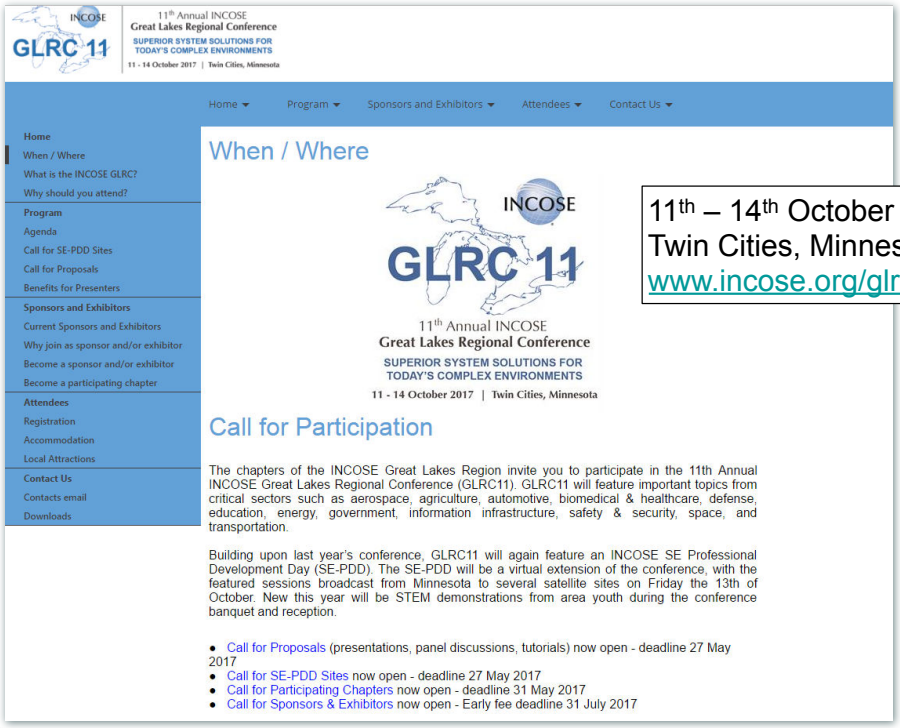
Upcoming Webinars (tentative schedule)

Who	What	When
Ian Presland	INCOSE Certification Program Competency Areas Update	August 23rd 2017 at 11am EDT
Rick Dove	Agile Systems and Processes 106 – Risk Management and Mitigation	September 20th 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 added around two weeks before the webinar is scheduled to take place.

INCOSE GLRC11 – Twin Cities, Minnesota



11th – 14th October 2017
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