Model-based Guidance of an Emergent Product Line

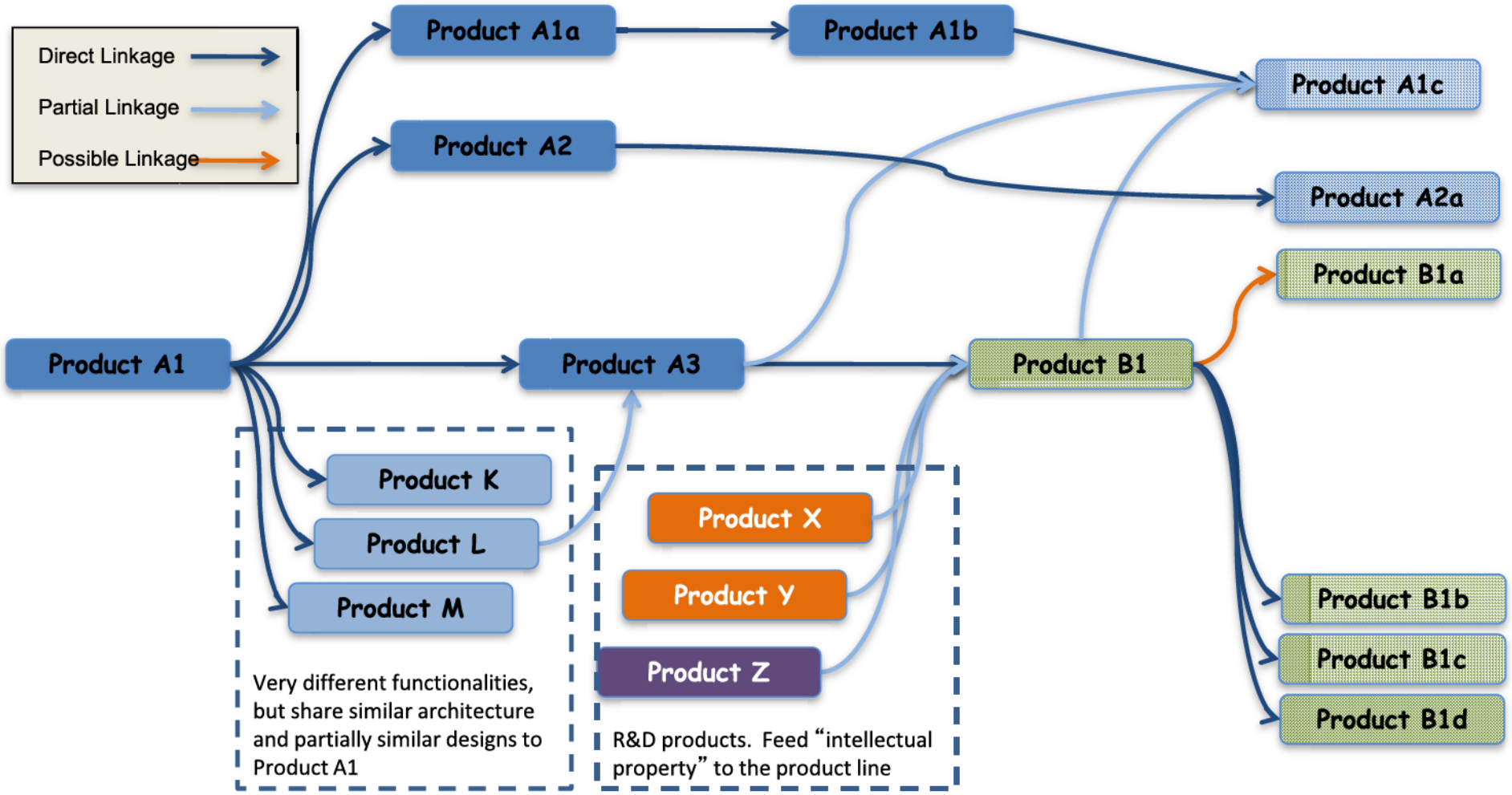
Ken Peters
Jet Propulsion Laboratory,
California Institute of Technology
Ken.Peters@jpl.nasa.gov
(with thanks to Milton Lavin)

Background

- Product lines commonly grow from a successful initial product, rather than being planned in advance
- First couple of core products developed by one team, but later branches are assigned to different teams
  - Typical as result of expansion and personnel changes
- Management oversees proposals and products with an eye on inheritance, but technical details often coordinated by hallway discussions
- Separate products typically have separate artifacts/ documentation stored separately
  - Since products are focused on their own concerns and deliveries
  - In some cases storage is not easily accessible by other teams
- Example: Electra line of software-defined radios:
  - MRO, MTO, M3, MSL, MAVEN, TGO, CoNNeCT/SCaN Testbed, …
  - See next page for schematic diagram of product "line"

Product "Line" – Based on a True Story

- Very typical "bush" calls for organized product line view, without stifling growth



Product "Line" Notes

- This sort of product "bush" is typical
  - Particularly when a product line is developed via inheritance of point solutions, rather than planned with an overarching scope
  - Even when an initial overarching scope exists, it is often overtaken by events (changes in schedule, funding, or even project existence)
- Products may share different amounts of hardware and/or software
  - In some cases, similar hardware platforms support very different software
  - In others, very similar software runs on different hardware platforms
- Diagram does not show updates to individual products
  - Adds another nest of arrows between products
  - Updates have included new capabilities, which may then be ported to other products
  - Updates have included fixes during development (hardware and software) which may need to be applied to other products in development or released

Goals

- Produce simple techniques to infuse product line methods into developing product lines
  - Key point: Low barrier to entry. Want simple techniques with common tools, rather than new complex tools that developers would need to learn
  - Using the Electra family of programmable telecommunications systems as a test bed
- Facilitate transition from current "clone-and-own" practices
  - Move away from "silos" of knowledge
- Develop strategies to ease infusion
  - Want small, busy teams to be able to get benefits
- Define product line documentation to better support NASA's assurance activities
  - Consistency (at least within each line) makes assurance easier

Value To NASA

- Make it easier to propose/cost/build new products
  - Important across NASA to effectively manage and utilize inheritance
  - NASA is building more and more software defined radios, so facilitating the transition of Electra and JPL's SCaN Testbed radio to a recognized product line can help reduce development time and manage risk
- Improve quality and safety of new and old products
  - In general, take advantage of knowledge, testing, and lessons from other products in the line
  - Help each specific Electra project identify/access heritage information relevant to it
- Increase testability and "assurability" of new and old products
  - Central point to find documentation across products
  - Product line model to clarify variation points for attention
  - Possibility of component certification process
- Develop an Electra product-line reference architecture model with defined variation points
  - Tailored for JPL project needs & upcoming Electra project needs
  - Accommodates different needs of distinct user groups: project formulation, preliminary design, detailed designers and implementers, testers

Collaboration / Infusion: Projects

- Current missions using radios from the Electra line. These are all active customers as well as data contributors, and infusion targets:
  - Mars Reconnaissance Orbiter (MRO)
  - Mars Science Laboratory (MSL)
  - Mars Atmosphere and Volatile Evolution (MAVEN)
  - Mars Trace Gas Orbiter (TGO)
  - JPL Space Telecommunications Radio System (STRS) radio for Space Communications and Navigation (SCaN) Testbed on ISS
- JPL Core Flight Software group
  - Newly formed group whose purpose is to transition JPL's core avionics software to a product-line model. We have met and are meeting with them to begin infusion and cooperation.
- Interested in collaborating or disseminating beyond JPL

Collaboration / Infusion: Researchers

- Past collaboration with Prof. Robyn Lutz, Iowa State University
  - Member of our research team from inception to mid-2012
  - Lead author of book chapter "Managing Requirements Knowledge"
- Past & current collaboration with Dr. Martin Feather (SARP visualization task)
  - Explore use of advanced visualization techniques for product line data
- Future collaboration opportunities with other SARP tasks:
  - Dr. Leila Meshkat, Command Process Modeling task: Bayesian knowledge networks applied to product line decisions
  - Dr. Allen Nikora, Clear & Consistent Textual requirements: Product line requirement analysis and generation
  - Dr. Allen Nikora, Model-based techniques in Fault Management: Early fault analysis of products based on product-line model

Advancements Summary

- Product line issue-tracking methodology applicable to JIRA tool and possibly other tools
  - Paper not yet accepted to conference, now aiming for ISSRE Oct 2013 Pasadena CA
- Began "hyperlinked PowerPoint" Electra product-line architecture
  - Brings together several concepts developed during this task
  - Have demonstrated initial proof of concept to stakeholders, received very positive feedback
  - Lower barrier to entry than AADL, though there is still some AADL interest also
- Book chapter "Mining Requirements Knowledge from Operational Experience" published
  - In edited book "Managing Requirements Knowledge" from Springer/Computer Science Editorial

Advancements Summary cont.

- Product line wiki
  - Organized to allow access to information either via a project perspective, or a product perspective
  - Helps reduce “silo” effect and aids knowledge re-use
  - Allows individual projects to maintain their areas
- Calculation of approximate defect discovery rates for several products
  - Leading toward a rule of thumb for detecting when testing program is reaching a limit
  - Needs more research to check wider applicability

Product Line Issue Tracking

Using an institutional JIRA system in a new way created for a product line:

Products

Two Dimensional Filter Statistics: EPL Main Issues

	Raised In Versions (all)							
Status	**CoNNeCT**	**Electra**	**Electra Lite**	**MAVEN Electra**	**TDS-DEA**	**TGO Electra**	**No version**	**T:**
Open	223	11	7	226	229	229	1	**231**
Total Unique Issues:	**223**	**11**	**7**	**226**	**229**	**229**	**1**	**231**

Showing **1** of **1** statistics.
Filter: EPL Main Issues

Issues that MIGHT apply to product

Components

Two Dimensional Filter Statistics: EPL Main Issues

	Components																
Status	**1553**	**Build**	**Doc**	**FW: HK**	**FW: HSD**	**FW: MP**	**GSE**	**GSE: ECS**	**HW: Cabling**	**HW: Parts**	**HW: PCB**	**Prox1**	**SW: APPSW**	**SW: BCSW**	**SW: Tables**	**Test**	**T:**
Open	37	5	10	2	3	5	5	2	1	2	1	53	133	63	3	12	**231**
Total Unique	**37**	**5**	**10**	**2**	**3**	**5**	**5**	**2**	**1**	**2**	**1**	**53**	**133**	**63**	**3**	**12**	**231**

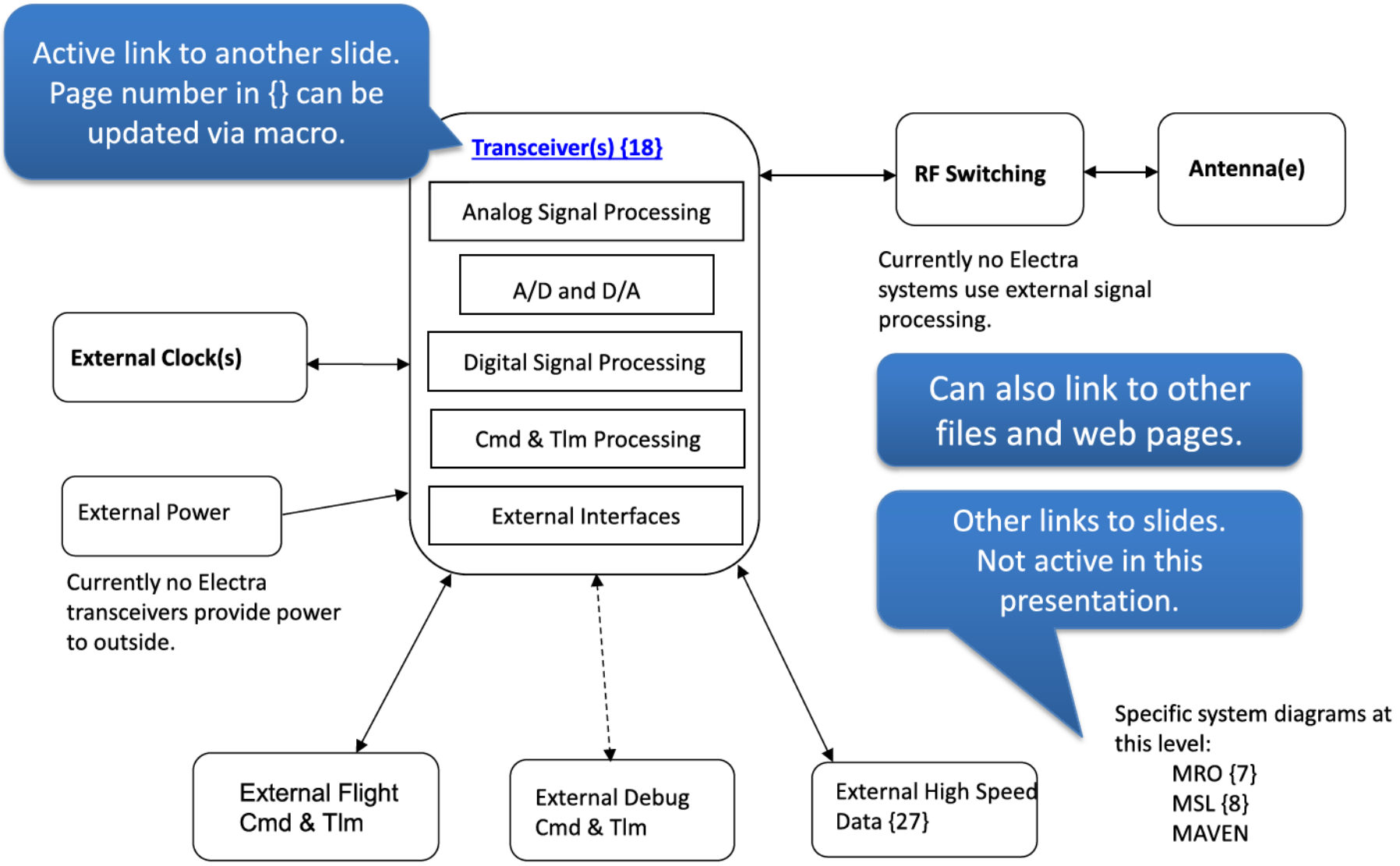
Two Dimensional Filter Statistics: EPL Main Issues

	Fix For Versions (all)							
Status	**CoNNeCT**	**Electra**	**Electra Lite**	**MAVEN Electra**	**TDS-DEA**	**TGO Electra**	**Unscheduled**	**T:**
Open	6	220	224	5	1	2	3	**231**
Total Unique Issues:	**6**	**220**	**224**	**5**	**1**	**2**	**3**	**231**

Showing **1** of **1** statistics.
Filter: EPL Main Issues

Issues KNOWN to apply to product

Top Level Abstract Model

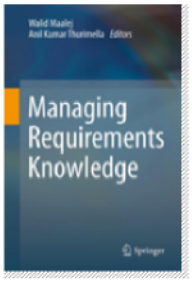


Book Chapter

- Chapter "Mining Requirements Knowledge from Operational Experience" published by Springer in "Managing Requirements Knowledge".
  - Waalid Malej and Anil Kumar Thurimella, editors

- Based on previous work including commonality/variability analysis of Electra product line

- http://www.springer.com/computer/swe/book/978-3-642-34418-3



Managing Requirements Knowledge

Maalej, Walid; Thurimella, Anil Kumar (Eds.)

2013, XII, 310 p. 62 illus., 3 illus. in color.

Available Formats:

eBook

Hardcover
(net) price
ISBN 978-3-642-34418-3
Due: May 31, 2013
» Add to marked items

$129.00
Add to cart

Like 8 Tweet 4 +1 0

ABOUT THIS BOOK | AUTHORS & EDITORS | REVIEWS

- Addresses crucial yet typically neglected issues in software projects
- Written by some of the most renowned researchers in the field with considerable experience
- Presents both novel theoretical approaches and practical experiences

Requirements engineering is one of the most complex and at the same time most crucial aspects of software engineering. It typically involves different stakeholders with different backgrounds. Constant changes in both the problem and the solution domain make the work of the stakeholders extremely dynamic. New problems are discovered, additional information is needed, alternative solutions are proposed, several options are evaluated, and new hands-on experience is gained on a daily basis. The knowledge needed to define and implement requirements is immense, often interdisciplinary and constantly expanding. It typically includes engineering, management and collaboration information, as well as psychological aspects and best practices.

This book discusses systematic means for managing requirements knowledge and its owners as valuable assets. It focuses on potentials and benefits of "lightweight," modern knowledge technologies such as semantic Wikis, machine learning, and recommender systems applied to requirements engineering. The 17 chapters are authored by some of the most renowned researchers in the field, distilling the discussions held over the last five years at the MARK workshop series. They present novel ideas, emerging methodologies, frameworks, tools and key industrial experience in capturing, representing, sharing, and reusing knowledge in requirements engineering.

While the book primarily addresses researchers and graduate students, practitioners will also benefit from the reports and approaches presented in this comprehensive work.

Content Level » Research

Keywords » collaborative software development - global software engineering - knowledge management - mining software repositories - ontological engineering - requirements engineering

Product Line Wiki

Dashboard › Electra › Electra Home › Electra Assets Browse ▾ Kenneth Peters ▾ Search

JPL Electra Assets

Edit Add ▾ Tools ▾

Added by mjhicks, last edited by Milton Lavin on Mar 05, 2013 (view change)

The software-defined radio family, called Electra, was originally designed as a deep space transponder, but its design and many of its components have been adapted to other uses, as depicted by the Electra Family Bush. Core capabilities are indentified in an Analysis of Commonalities and Variabilities of Electra versions circa 2010. A CVA Summary Spreadsheet identifies common variations, provides information on the timing of design decisions, and illustrates the design impacts of selected variants. Some Future Versions of Electra, based on Electra Lite, were outlined in mid-2010. Current operational versions of Electra have inherited MRO capabilities and design. CoNNeCT/SCaN, is a re-implementation of Electra capabilities, compatible with the Space Radio Telecommunications System (STRS) Standard, and thus is designed to facilitate reuse. The software and firmware components of CoNNeCT/SCaN are intended to be prototypes for incorporation into the Universal Spacecraft Transponder (UST), currently under development at JPL.

Electra Version	Heritage	Data Sheet
Mars Reconnaissance Orbiter (MRO) Catalog	First Electra	MRO Electra Data Sheet
MTO Electra	MRO	none
Mars Science Lander (MSL) Electra Lite (ELT) Catalog	MTO, MRO	
Communications, Navigation, and Networking reConfigurable Testbed (CoNNeCT) Catalog	???	CoNNeCT Data Sheet
Mars Atmosphere and Volatile Evolution (MAVEN) Catalog	MRO, CoNNeCT	
Mars Trace Gas Orbiter (TGO) Catalog	MAVEN	
Moon Mineralogy Mapper (M3) Payload Controller Catalog	MSL - ELT	M3 Payload Controller Data Sheet
MSL Terminal Descent Sensor (TDS) Catalog	MRO	MSL TDS Data Sheet

Two access avenues are provided: 1) access to items for individual Electra versions, as cataloged on the child pages below, 2) access to selected work items, such as

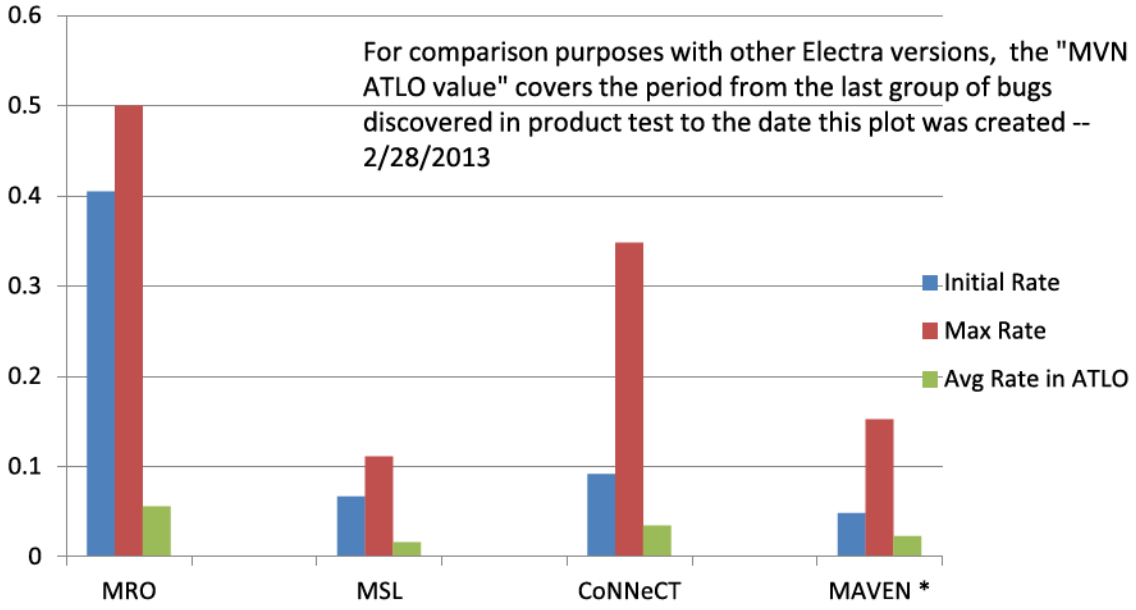
- Datasheets
- Management Plans
- Product and Software Requirements
- Software Design
- Software Releases (RDDs) and related documentation
- Hardware Design
- Ground Support Equipment
- Verification & Validation
- User Documentation

Access by project.

Access by product.
For example, requirements docs for all projects.

Q. When Is Testing Value Diminishing?

A. When avg. ATLO defect rate is about 10% of max rate!



	Defect Rate ~defects/day		
	Initial Rate	Max Rate	Avg Rate in ATLO
MRO	0.4048	0.5	0.056
MSL	0.0667	0.1111	0.0162
CoNNeCT	0.0916	0.348	0.0347
MAVEN *	0.0483	0.1523	0.0227

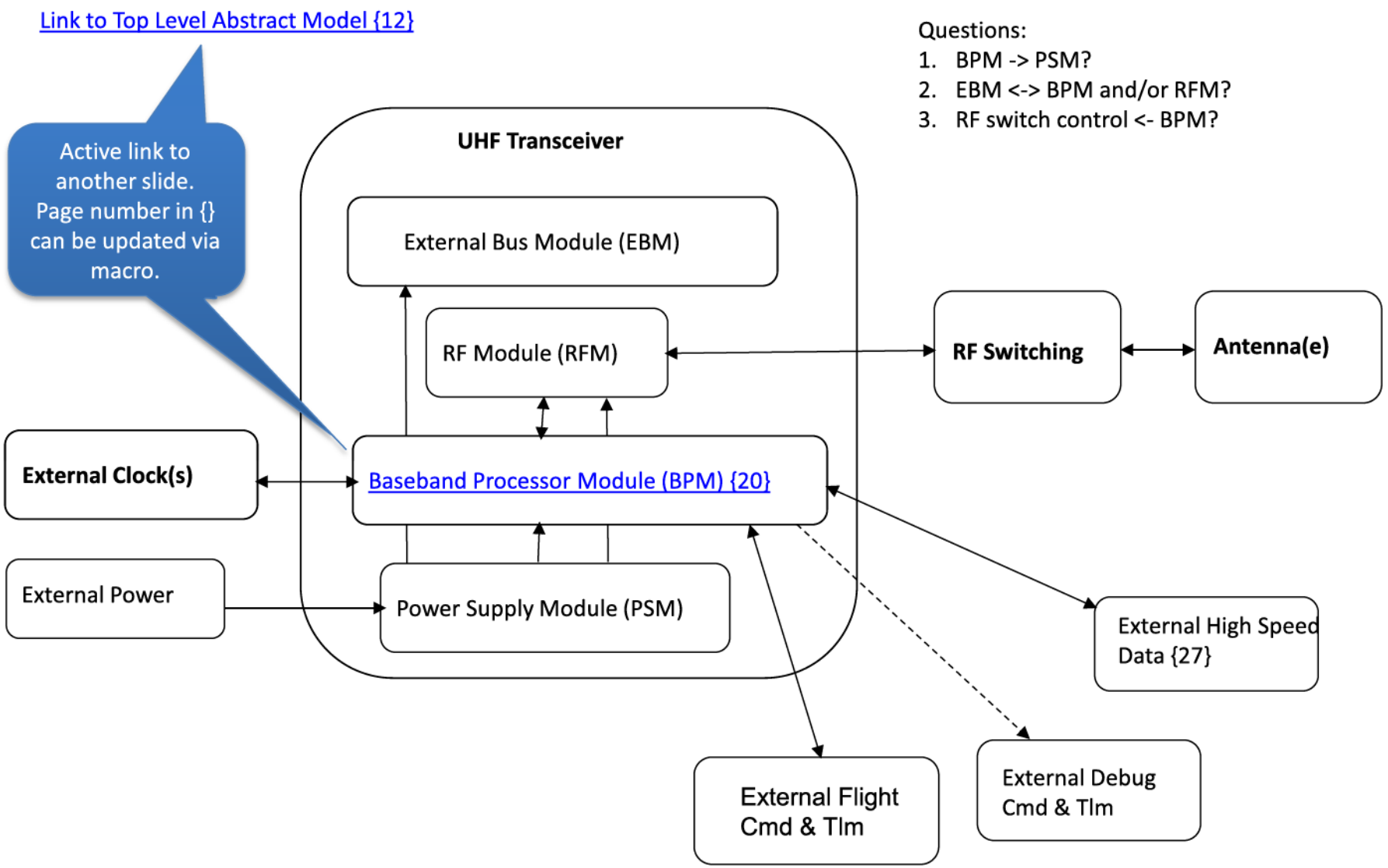
Plans – FY13/FY14

- Continue developing product line model
  - Expand architecture coverage
  - Connect architecture to detailed variation descriptions
- Publish paper describing product line issue-tracking methodology
  - ISSRE 2013, Pasadena CA
- Work with JPL Core Flight Software group
  - Begin infusion and cooperation
- Develop tutorial/class on existing methods and artifacts
  - Use to motivate long-term sponsorship for Electra applications
- Emphasis on infusion activities
  - Suggestion of other methods welcome – NASA Engineering Network, NASA Tech Briefs, etc.

Plans – FY14/FY15

- FY14/15 Advanced Goals (new extension research)
  - Connect model with requirements and test procedures
    - Select components from model, use data from existing products to automatically build requirements document and bring in necessary test procedures
  - Investigate static analysis and code inspection feedback
    - Collate results from various products and make visible across the line
  - Develop procedures for certification of modules in product line
    - Minimize testing and assurance effort while maintaining quality and safety
- These goals stem from feedback from the collaborating Electra projects
  - especially MAVEN and SCaN Testbed

Transceiver Model Midlevel View



Model-based Guidance of an Emergent Product Line

Initiative Overview

Description/Goals

- **Produce simple techniques to infuse product line methods into developing product lines**
  - Using the Electra family of programmable telecommunications systems as a test bed
- **Facilitate transition from current "clone-and-own" practices**
- **Develop strategies to ease infusion**
- **Define product line documentation to better support NASA's assurance activities**

Value to NASA

- **Make it easier to propose/cost/build new products**
- **Improve quality and safety of new and old products**
- **Increase testability and "assurability" of new and old products**
- **Develop an Electra product-line reference architecture model with defined variation points**

FY13 Advancements

- **Initial high-level product line model in hyperlinked PowerPoint** - Easier infusion than AADL
- **Calculation of approximate defect discovery rates for several products**
  - leading toward a rule of thumb for detecting when testing program is reaching a limit
- **Book chapter for edited book "Managing Requirements Knowledge" published by Springer/Computer Science Editorial.**
- **Composed paper on issue-tracking methodology for product lines** - Not yet accepted to conference

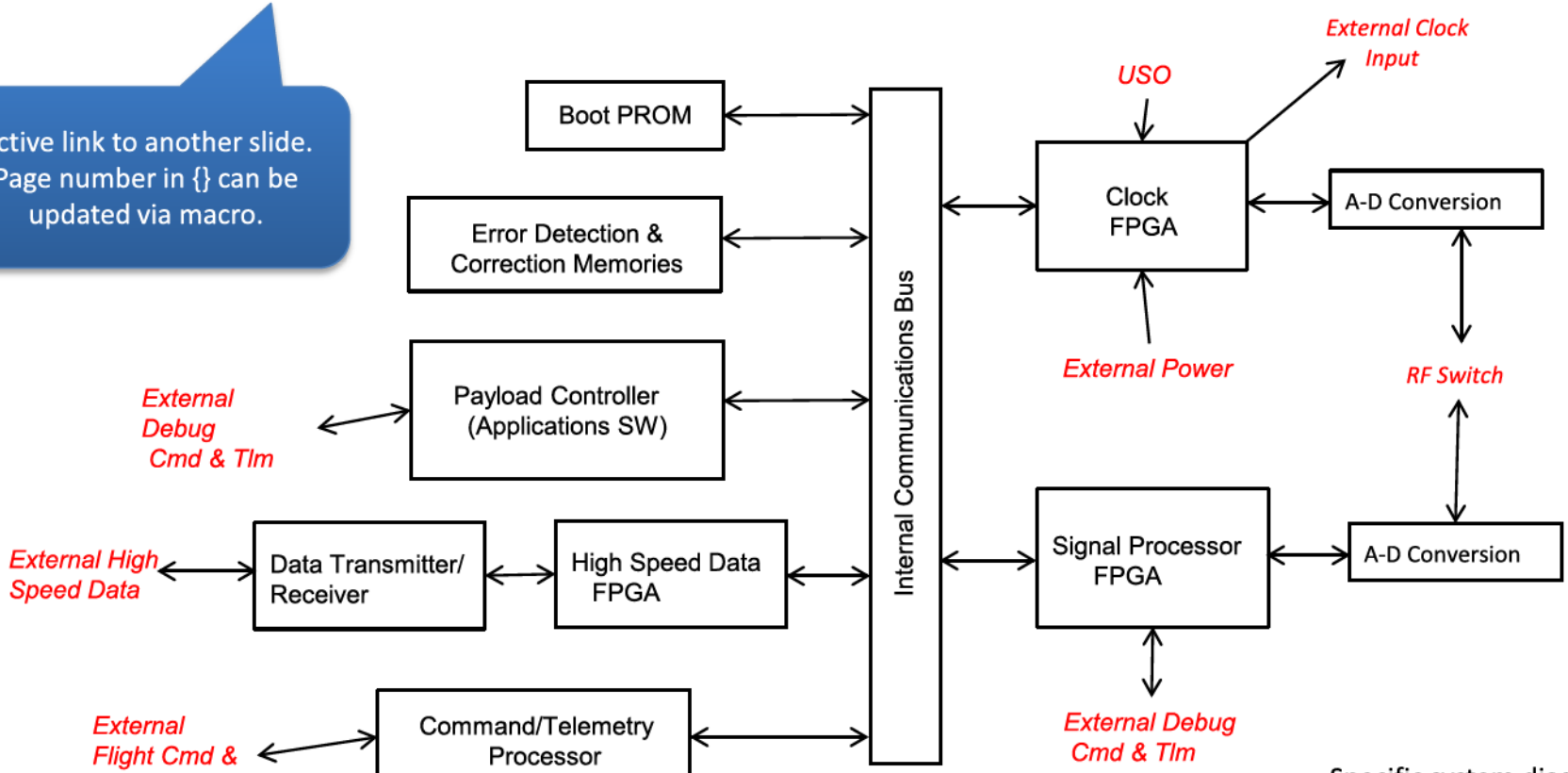
Plans (FY13/14)

- **Continue developing product line model**
  - Expand architecture coverage
  - Connect architecture to detailed variation descriptions
- **Publish paper describing product line issue-tracking methodology**
  - ISSRE Oct 2013, Pasadena CA
- **Work with JPL Core Flight Software group**
  - Begin infusion and cooperation
- **Develop tutorial/class on existing methods and artifacts**
  - Use to motivate long-term sponsorship for Electra applications

BPM Abstract Block Diagram

Link to Transceiver Midlevel View {18}

Active link to another slide. Page number in {} can be updated via macro.



Other links to slides. Not active in this presentation.

Specific system diagrams at this level:

- MRO {13}
- MSL {15}
- MAVEN {14}