Model-based Guidance of an Emergent Product Line

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(with thanks to Milton Lavin)
Model-based Guidance of an Emergent Product Line

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 “silos” 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:

### Two Dimensional Filter Statistics: EPL Main Issues

<table>
<thead>
<tr>
<th>Status</th>
<th>Raised In Versions (all)</th>
<th>Electra</th>
<th>Electra Lite</th>
<th>MAVEN Electra</th>
<th>TDS-DEA</th>
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<td>7</td>
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Showing 1 of 1 statistics.
Filter: EPL Main Issues

### Two Dimensional Filter Statistics: EPL Main Issues

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

### Two Dimensional Filter Statistics: EPL Main Issues

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<td>2</td>
<td>3</td>
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</tr>
</tbody>
</table>

Showing 1 of 1 statistics.
Filter: EPL Main Issues

Issues that MIGHT apply to product

Components

Issues KNOWN to apply to product

This document has been reviewed and determined not to contain export controlled technical data.
Top Level Abstract Model

Transceiver(s) {18}

- Analog Signal Processing
  - A/D and D/A
- Digital Signal Processing
- Cmd & Tlm Processing
- External Interfaces

RF Switching

Antenna(e)

External Clock(s)

External Power

Currently no Electra transceivers provide power to outside.

External Flight Cmd & Tlm

External Debug Cmd & Tlm

External High Speed Data {27}

Can also link to other files and web pages.

Other links to slides. Not active in this presentation.

Specific system diagrams at this level:
- MRO {7}
- MSL {8}
- MAVEN

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


Model-based Guidance of an Emergent Product Line
Book Chapter
Model-based Guidance of an Emergent Product Line

Product Line Wiki

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 identified 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. CoNeCT/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 CoNeCT/SCaN are intended to be prototypes for incorporation into the Universal Spacecraft Transponder (UST), currently under development at JPL.

<table>
<thead>
<tr>
<th>Electra Version</th>
<th>Heritage</th>
<th>Data Sheet</th>
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<tbody>
<tr>
<td>Mars Reconnaissance Orbiter (MRO) Catalog</td>
<td>First Electra</td>
<td>MRO Electra Data Sheet</td>
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<td>Mars Science Lander (MSL) Electra Lite (ELT) Catalog</td>
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<td>Communications, Navigation, and Networking reConfigurable Testbed (CoNeCT) Catalog</td>
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<td>MAVEN</td>
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<td>Moon Mineralogy Mapper (M3) Payload Controller Catalog</td>
<td>MSL - ELT</td>
<td>M3 Payload Controller Data Sheet</td>
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<tr>
<td>MSL Terminal Descent Sensor (TDS) Catalog</td>
<td>MRO</td>
<td>MSL TDS Data Sheet</td>
</tr>
</tbody>
</table>

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!

For comparison purposes with other Electra versions, the "MVN ATLO value" covers the period from the last group of bugs discovered in product test to the date this plot was created -- 2/28/2013

<table>
<thead>
<tr>
<th></th>
<th>Defect Rate ~defects/day</th>
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<tbody>
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<td>Initial Rate</td>
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<tr>
<td>MAVEN *</td>
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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

Questions:
1. BPM -> PSM?
2. EBM <-> BPM and/or RFM?
3. RF switch control <-> BPM?

External Clock(s)

External Power

UHF Transceiver

External Bus Module (EBM)

RF Module (RFM)

Baseband Processor Module (BPM) {20}

Power Supply Module (PSM)

RF Switching

Antenna(e)

External High Speed Data {27}

External Flight Cmd & Tlm

External Debug Cmd & Tlm

Link to Top Level Abstract Model {12}

Active link to another slide. Page number in {} can be updated via macro.
Model-based Guidance of an Emergent Product Line Initiative Overview

<table>
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<thead>
<tr>
<th>FY13 Advancements</th>
<th>Plans (FY13/14)</th>
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</thead>
<tbody>
<tr>
<td>• Initial high-level product line model in hyperlinked PowerPoint - Easier infusion than AADL</td>
<td>• Continue developing product line model</td>
</tr>
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<td>• Calculation of approximate defect discovery rates for several products</td>
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BPM Abstract Block Diagram

Link to Transceiver Midlevel View [18]

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