Cost Effective IV&V Planning Activity derived from Experiences on JAXA’s Spacecraft Projects

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Session: The ISVV Process Improvement
Topic: Improvement/revision to the ISVV process as defined in the ESA ISVV Guide

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Current IV&V in JAXA

- Current Situation
  - Increase in IV&V needs from various projects
    - **Effective IV&V** should be tailored and performed for each project
  - Limitation of IV&V engineer, budget and schedule
    - **Effective IV&V management** should be applied
  - Increase in system and software complexity
    - **Effective IV&V techniques** should be developed and applied
Overview of Research

● Goal of Cost Effective IV&V
  ● Rationale for IV&V planning as best solution
    ● Selecting appropriate combination of IV&V techniques to achieve cost effectiveness:
      ▪ Risk reduction
      ▪ Cost performance

● Research Activity
  ● IV&V planning method based on experiences
  ● Empirical evaluation of IV&V techniques
    (collaborative project with NAIST)
Overview of Research

- IV&V techniques and combination

Selection (Depth)
- Full set
- Phases
  - Simulation
  - Modeling/Model Checking
  - Auto Test Case Generation & Robustness Evaluation
  - Test Case & Test Result Review
  - Hazard Analysis/SFMEA
  - Auto Equivalency Check
  - Manual Check (Tools Support)
  - Static analysis (Problem Reports)
  - In line Process Monitor (SMIP)
  - Methodologies

Completeness/Consistency
- Design Coverage & Timing
- Interface Validation
- Verification Coverage
- Risk Analysis (Robustness)
- Compliance/Traceability
- Process & Quality

IV&V Attributes (Sample)
Specific Question of Cost Effective IV&V

- Question

How to effectively feedback the experiences to the following IV&V activities

- Cost Effective IV&V database
- IV&V Planning based on experiences
- Implementation of IV&V for each project according to the plan
- Empirical Evaluation of IV&V techniques

Collaborative project with NAIST

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Cost Effective IV&V Planning Activity

• Motivation
  To perform IV&V by small group with low cost

• Proposed Solution
  To select appropriate combination of IV&V techniques for each project along a certain guideline

• Research Activity
  • Development of IV&V Planning Tool
  • Effectiveness Measurement of IV&V techniques
IV&V Planning Tool

- **Planning concept**
  - 1st Round: planning at concept design phase
    - Estimation of cost, expected risk, risk-reduction
  - 2nd Round: planning after S/W development start
    - Selection of appropriate IV&V techniques

- **Development of IV&V Planning Tool**
  - Input: e.g. system characteristics, project budget
  - Output: e.g. risk size, risk probability, cost
  - Needs to be improved:
    - accuracy of effectiveness estimation
### IV&V Planning Tool

#### Strategic IVV Planning Tool

<table>
<thead>
<tr>
<th>System Characteristics</th>
<th>IVV Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Control Type:</strong></td>
<td>Source Data:</td>
</tr>
<tr>
<td><strong>Required FT Degree:</strong></td>
<td>Natural Language</td>
</tr>
<tr>
<td><strong>Functional Type:</strong></td>
<td>Dev. Phase for IVV:</td>
</tr>
<tr>
<td><strong>Controlled Data Type:</strong></td>
<td>Requirement</td>
</tr>
<tr>
<td><strong>Action of Hazard:</strong></td>
<td>Evaluation Time:</td>
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<tr>
<td><strong>Hazard Control Type:</strong></td>
<td>Enough</td>
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<tr>
<td><strong>Architecture of Execution:</strong></td>
<td>Enough</td>
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<tr>
<td><strong>Sub Architecture Type:</strong></td>
<td>Enough</td>
</tr>
<tr>
<td><strong>Implementation:</strong></td>
<td>Source Code:</td>
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<tr>
<td><strong>Number of Components:</strong></td>
<td>Open</td>
</tr>
<tr>
<td><strong>Operation Results:</strong></td>
<td>Electronic Doc.:</td>
</tr>
<tr>
<td><strong>Reuse Parts:</strong></td>
<td>Read Possible</td>
</tr>
<tr>
<td><strong>Development Type:</strong></td>
<td>Scale (Doc. Volume, LOC):</td>
</tr>
<tr>
<td></td>
<td>Much</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Project Budget</th>
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<tr>
<td>Project Budget: [ ]</td>
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Effectiveness Measurement

- Measuring methods
  - Definition of metrics for each IV&V findings
    - e.g. priority, criticality, man-hours
  - Measured by both IV&V engineers and software development engineers
    - To improve the estimation accuracy by analyzing the difference between each values

- Current ongoing work
  - Trial measurement in some projects
Effectiveness Measurement

- Example: metrics in IV&V findings list
  - Measured by IV&V engineers for each finding
    - target function of the software
    - applied IV&V attribute and technique
    - man-hours to detect the finding
    - criticality and priority
  - Answer from software development engineers
    - criticality and priority

same measurement item
Summary and Future Work

- **Summary**
  - IV&V Planning Tool
    - Framework has been developed.
    - Estimation accuracy should be improved.
  - Effectiveness Measurement
    - Metrics has been defined.
    - Measurement will be put into practice.

- **Future Work**
  - Collect and analyze the IV&V process data
  - Feedback the result of empirical evaluation to Cost Effectiveness Database
Empirical Evaluation Based on Defect History

● Goal
  - Evaluate IV&V activities by analyzing detected defects

● Hypotheses
  - Good IV&V process can detect wide variety of defects
  - Good IV&V technique can detect “expected” defects
    - e.g. “traceability analysis” is expected to detect “inconsistency” between requirement spec. and design spec.
Approach

- Try to build the defect classification suitable for IV&V
- Identify expected defect classes for each IV&V technique (or perspective)
- Compare expected defects and actually detected defects on the classification map
Related work

- Orthogonal defect classification (ODC)*
  - Commonly used in enterprise software development.
  - Classification categories:
    - Function, Interface, Checking, Assignment, Timing/Serialization, Build/Package/Merge, Documentation, Algorithm
  - Categories are not independent enough
    - This makes classification more difficult
    - Classification depends on person
    - 30% of defects are often classified as “others”
  - “Verification bugs” and “validation bugs” are not separated

Our Proposal Method

- Two viewpoints
  - Function / Interface / Scenario
  - Verification / Validation

- Simple but easy-to-classify
- Evaluate both V&V activities
Expected Defects

- IV&V perspectives and expected defects

**IV&V Perspectives**
- Review based on Lessons & Learned
- Consistency between system req. and software req.
- Hazard analysis
- Interface review

**Function**  | **Interface**  | **Scenario**
--- | --- | ---
Verification |  |  
|  |  |  
Validation |  |  
|  |  |  

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Case Study

- Target Data
  - 49 defects detected by IV&V activities conducted in a software req. analysis phase of a satellite system

- We compared expected defects and actually detected defects in each IV&V perspective
“Hazard analysis” detected “interface-verification” defects while it is expected to detect validation defects.

These defects might be overlooked in “interface review.”

- Review based on Lessons & Learned
- Consistency between system req. and software req.
- Hazard analysis
- Interface review

Function | Interface | Scenario
--- | --- | ---
| | | 
Verification
| | | 
Validation

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Result 2

- “Model checking” detected “validation defects” as well as “verification defects”
- Validation problems were found during model construction

![Diagram showing validation and verification processes with Model checking and Document review marked as cross marks.]

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Summary and Future Work

● Summary
  ● We have built a defect classification to evaluate IV&V activities

● Future Work
  ● Seek for a better defect classification
  ● Compare detected defects among different IV&V phases (req. analysis, design, coding …) or among different systems