Strategy to enhance IV&V activity in JAXA
IV&V Workshop in conjunction with 38th HICSS

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Abstract

Software Independent Verification and Validation (IV&V) has been boosted after unfortunate Space Shuttle Challenger accident since 1994. Japanese Aerospace Exploration Agency (JAXA) has been applied IV&V activity to 10 projects starting with the International Space Station program since 1996. Projects' IV&V experiences established strategic planning of IV&V activity for maximum results with minimum efforts.

In this paper, our concept of strategy to improve IV&V activity is introduced. Current issues for successful IV&V activity and necessary future works are also summarized.

1. Background

JAXA has applied Software IV&V to 10 projects such as the International Space Station, Satellites, and Safety-related Ground Systems with support by IV&V contractor, Japan Manned Space System (JAMSS), for 9 years, nevertheless our IV&V scheme is still in a period of transition to full scale IV&V.

The following problem lies upon the Software IV&V planning in JAXA;

- Rapid Increase of IV&V applied projects
- Difficulty to recruit new IV&V specialists
- Limitation of budget

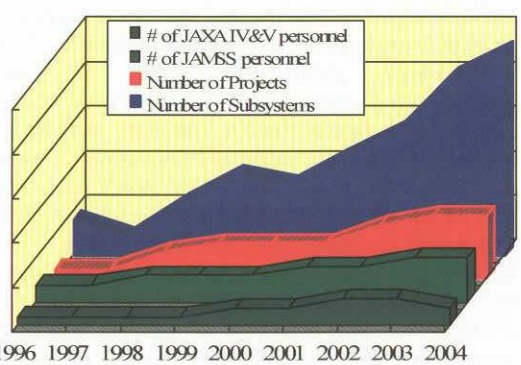

Figure 1.1 JAXA IV&V current situation

Figure 1.1 shows the number of JAXA and JAMSS IV&V personnel and the number of Projects and subsystems which the Software IV&V was applied to.

As one of good results from past Software IV&V experience, the number of Project Managers who are newly interested in application of Software IV&V methodology to their projects software development has been rapidly increasing. Since Software IV&V application has not been institutionalized yet in JAXA, however, managers who seriously realize importance of software IV&V are people facing on the problem during their development. In deed, 70% of Projects' IV&V has started at the end of development phase such as system integration testing, or after development completion. Therefore, IV&V team needs to prepare several different approaches to meet the project situation.

In JAXA and JAMSS, only small number of personnel is assigned to Software IV&V team. On average, one person has 3 or 4 projects' IV&V tasks in parallel. It is difficult to prepare new member and to adequately train them as a IV&V specialist.

Proposal 1
Establishment of IV&V Training Courses and Teaching Materials to educate IV&V specialists

On the other hand, two different resources invest the budget in the JAXA IV&V activity. Half of the budget is from research area. Another half is invested from Projects Team. Budget limitation is one of very important attributes to perform our strategic planning needless to say. For instance, the budget of unmanned spacecraft on-board software is one tenth of the one for manned system.

2. High Reliability Software Engineering

As mentioned in previous section, our IV&V team is small beyond compare. There is important circumstance worthy of special mention. Our IV&V team is responsible for not only JAXA agency-wide IV&V activity, but also new technology research about high reliability software engineering and agency-wide SPI (Software Process Improvement) deployment.

We asserted especially SPI and Software IV&V are inseparable. The SPI activity contributes to making high quality and reliability of software for project's success. In addition to this straight effectiveness, an evolved integrated software development process can

be newly defined and performed by both development team side and IV&V team side. For instance, in regard to coding phase, the activity of IV&V team used to be passive such as only review of development team code inspection record. However, we newly applied new process and defined responsibilities as described in Figure 2.1.

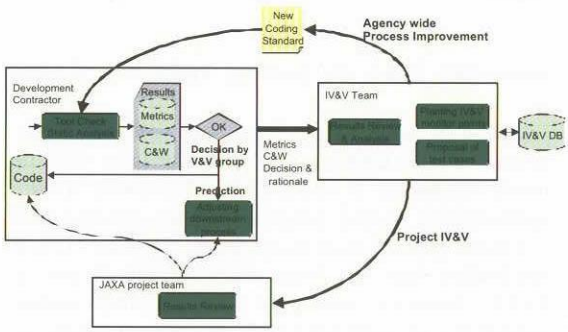

Figure 2.1 An integrated process of SPI and IV&V

Over 2 years, JAXA SPI team has enforced the use of code check tools to measure the metrics of code and analyze those data for the prediction and make feedforward to downstream process such as testing phase and review process. SPI team is now making the coding standard which defines not only code style but also critical pattern of code based on past aerospace and automobile problems and accidents. IV&V team reviews and analyzes the results of tool checks such as thousands of errors and metrics data with decision made by development contractor's V&V group. Planting the IV&V mandatory monitor points and making the proposal of test case is done with additional correction of code as compared with past other projects' data. From several projects cases, it is indicated that this collaborative process with SPI gives more the ROI to IV&V.

Proposal 2
Establishment of metrics database for IV&V community

Another key area needed to mention is a new development process. We are now studying a model-based software development process.

JAXA IV&V has applied modeling and model checking technique as a model-based IV&V. It is based on formal specification modeling language, SpecTRM-RL (SpecTRM Requirements Language) and SpecTRM toolset. SpecTRM is a system and software engineering environment designed to include safety engineering processes such as safety assessment and hazard analysis. The advantage of SpecTRM is not only to provide various model checking tools such as completeness and consistency, but also to have ability to maintain predictability, abstract modeling, and executability at any development phase. Requirement flaw or design flaws including major design changes were found in early development phase by model-based IV&V, instead of future risk such as retrogression. This model based IV&V gives more powerful application such as auto test case generation, auto traceability checking, measurement of various metrics. At the same time, however, several importance lessons have been learnt.

Lessons learnt 1:
Larger number of flaws was detected during modeling task rather than expected.

Lessons learnt 2:
IV&V Modeling task needs plenty of man-month, therefore it is hard to cover a whole system.

Lessons learnt 3:
It is hard to model hybrid (static and dynamic) system

Lessons learnt 4:
There is a difference between IV&V person to make a model and designer.

Lessons learnt 5:
The model is covered for only a part of functionalities and not an entire specification.

We are now studying system level modeling technique such as AADL. Meta-modeling technique which development contractors can apply into their software development process with a few impacts had also started in SPI activity. This will result in some solutions against IV&V lessons learnt.

Proposal 3
Research of space specific modeling technique and model language

3. IV&V Strategic Planning

In the present situation as mentioned in section 1, appropriate strategic planning is a key to success with small team and budget for large number of projects assessment.

JAXA IV&V has summarized all IV&V methodologies researched and examined empirically in actual projects in the document called "IV&V methodology guidebook". Most of those methodologies were found in the IV&V for the International Space Station Program, which is a manned system. It is called as "full set IV&V" when all methodologies are selected as IV&V plan. Main part of *full set IV&V* consists specification modeling and model checking. It is very powerful to analyze the complex safety-related software system such as the International Space Station. However, *full set of IV&V* is excessive selection of IV&V for unmanned system such as Satellites and Ground systems. The selection of methodologies and planning used to be done by coordination with Project Managers. It is too subjective (case-by-case basis) to evaluate sufficiency of IV&V, and to estimate the ROI of IV&V.

To improve and standardize the selection process, the template for each type of project/subsystem is prepared based on the problem reports analysis and the ROI of past projects. In Figure 2.1, the sample template for Satellite Attitude Control Systems is shown.

Key Area	Req. 35%	Design 25%	Code 10%	Test 15%	Op. 15%
Doc. Equivalency	-Review -Simulation	-Review -Simulation -Auto Checker	-Review -Auto Checker	-	-Review -Simulation
Spec. Validation -Completeness -Consistency -I/F equivalency -Design Coverage -Timing -Rationale -Testability	-Check List -Modeling/Model Checking -Simulation		-Simulation -Formal Proof -Check Tool -Metrics	-	-Modeling /Model Checking -Review -Simulation
Verification Coverage	-Review -Case Generation			-Review -Auto Test Assessment	-
Risk Assessment	-SFTA/HA	-SFTA/HA	-	-SFTA/HA	-Review
Process Assessment	-	-	-Inspection -Audit	-Inspection -Audit	-
QA/Problem Rep	-	-	-Review -Analysis	-Review -Analysis	-

% is percentage of total efforts

Figure 2.1 Sample Template of Satellite Attitude Controller

In JAXA, the prioritized selection list of methodologies is prepared for each type of the spacecraft according to different software development processes and software characteristics. However, the selection is based on the checklist by interview, and is still subjective.

Proposal 4
Establishment of IV&V international standard as an authority allowed IV&V international community to determine the selection of methodology and success criteria

Our planning process consists of three steps such as Prior Investigation, Planning, and Post-Planning.

A. Prior Investigation to planning

A.1 Interview

IV&V team performs the interview for 2 days - 15 days in total with Spacecraft Development Project Team members (Project Managers and Engineers in JAXA and development contractors) to clarify:

- Reason why software IV&V activity needs to start
- Goals or Expectation for IV&V
- Budget and Schedule
- Development data provided by the development project team
- IV&V staffs allowed to access the data
- Developers worries
- JAXA and Contractors Developers Activities

A.2 Pre-review

IV&V team performs the pre-review for 2 days - 5 days in total to investigate the developer situation (to measure developers' product and process quality etc.) by reviewing and analyzing specifications, plans, records and/or problem reports.

B. Planning

Strategic Planning starts based on Prior Investigation result, and drafted by selecting and combining several methodologies as shown in Figure 2.2, and by organizing IV&V team. In this process, the template mentioned above is used to adjust IV&V activity according to project and subsystem type.

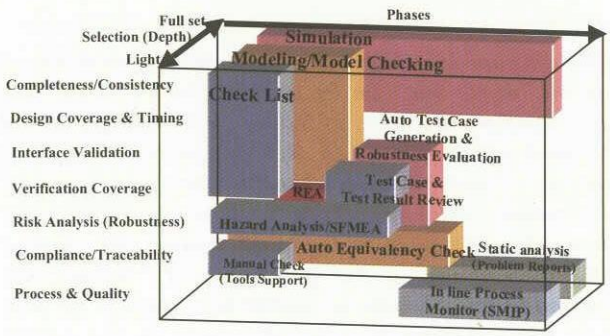

Figure 2.2, Selection and Scalability of Methodologies

C. Post-Planning

During and/or after IV&V assessment based on strategic planning, the ROI is evaluated. The ROI is not only calculated by the number of finding, but also estimated by the satisfaction for development team expectation. The ROI is evaluated with each methodology for development phases and characteristics of findings, and reflected on the IV&V methodology guidebook and selection strategy for future projects' planning.

3. Future Works and Conclusion

JAXA will continue to study the new methodologies by collaborated with SPI and model based development process. We also will challenge applying metrics to assess development process and product at the point of IV&V view and assess the ROI for IV&V activity itself.

In this position paper, the strategy to enhance the IV&V activity is introduced. SPI activity and new development process will promise to enhance the IV&V processes from our experience. The strategic planning process is also helpful one of approach to adjust IV&V planning. However, it needs more future works such as establishment of IV&V standard and development of common IV&V database among International community.