An approach to Return on Investment (ROI) for Independent Verification and Validation (IV&V) at NASA

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NASA IV&V

- The NASA IV&V Program was established in 1993 as part of an Agency-wide strategy to provide the highest achievable levels of safety and cost-effectiveness for mission critical software.
- The NASA IV&V Program was founded under the NASA Office of Safety and Mission Assurance (OSMA) as a direct result of recommendations made by the National Research Council (NRC) and the Report of the Presidential Commission on the Space Shuttle Challenger Accident.
- IV&V is an Agency-level function, delegated from OSMA to Goddard Space Flight Center (GSFC) and managed by NASA IV&V. The NASA IV&V Program's primary business, software IV&V, is sponsored by OSMA as a software assurance technology. Having been reassigned as GSFC, NASA IV&V is Code 180 (Center Director's direct report).

What is Independent Verification and Validation (IV&V)?

- Verification answers the question, "Are we building the product right?" Verification is the process of determining whether or not the software products of a given phase of the SDLC fulfill the established requirements for that phase.
- Validation answers the question, "Are we building the right product?" Validation evaluates the software products throughout the SDLC to ensure those products meet the mission and customer's needs.

Verification often a by-product of bugs i.e. Microsoft

Validation a by-product of mission failure i.e. AF C130J

What is Independence?

- **IEEE** defines independence in IV&V as three parameters:
- **Technical independence** is achieved by IV&V practitioners who use their expertise to assess development processes and products independent of the developer.
- **Managerial independence** requires responsibility for the IV&V effort to be vested in an organization separate from the organization responsible for performing the system implementation.
  - The IV&V effort independently selects the segments of the software and system to analyze and test, chooses the IV&V techniques, defines the schedule of IV&V activities, and selects the specific technical issues and problems to act upon.
  - Most projects view V&V as sufficient and do not recognize the added value the independence brings.
- **Financial:** Typically funded from Corporate General & Administrative (Expense). Projects may directly fund services.

What is Software IV&V?

- A systems engineering process employing rigorous methodologies for evaluating the correctness and quality of the software product throughout the SDLC.
- Is adapted to the characteristics of the project
- Independence is provided through various "authority"
  - Air Force - Independent Readiness Review Team (IRRT)
    - More reactive to already known troubled projects
    - Assigned by a committee/Senior command

      (The Role of Independent Assessments for Mission Readiness; Crosslink Fall 2007)
  - FAA – Designated Engineering Representative(DER)
    - Proactive with an assigned DER at project inception

      (FAA CONSULTANT DER DIRECTORY June 20, 2011)
  - NASA - NASA IV&V Facility; 100 University Drive Fairmont, WV 26554
  - Commercial Vendors – SAIC; TrustedQA; (and more; see slide 10)
- IV&V is Defect Discovery, and does not include fixing defects

Return On Investment (ROI)

ROI is a performance measure used to evaluate the efficiency of an investment or to compare the efficiency of a number of different investments. To calculate ROI, the benefit (return) of an investment is divided by the cost of the investment; the result is expressed as a percentage or a ratio.

A return on investment formula can be expressed as:

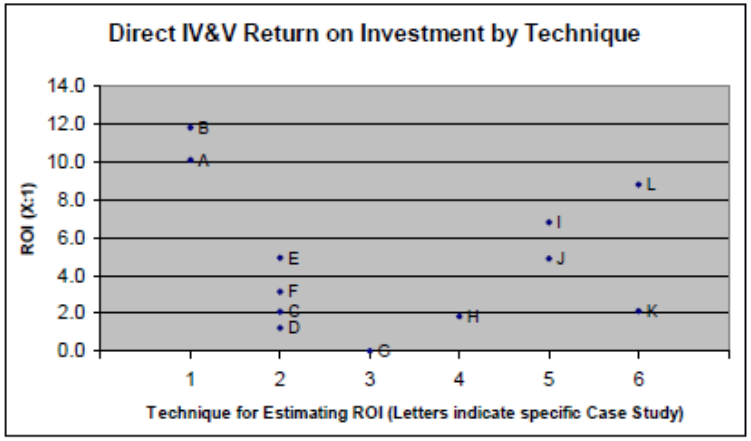
ROI = (Gain from Investment – Cost of Investment)/Cost of Investment

For NASA the key questions become:

1. What was the gain – Tangible and Non-tangible or fiscal and non-fiscal?
2. What was the cost of the investment?

IV&V Costs and ROI Data

- **Data from March 2008 KPMG WebEx**
  - **QA/IV&V can typically cost 5 to 10 percent of the total cost of an IT project, depending on the complexity of the project and the specific scope of QA/IV&V activities***
  - **Several studies indicate that the ROI on QA/IV&V investments can be 2 to 10 times the investment in QA/IV&V activities****



- ***NASA PAE 2008 Study show ROI values from 1.5 to 12; but says,*** **"There is a wide range of opinions and studies regarding the cost effectiveness of IV&V. The study team was unable to identify a common methodology for calculating ROI, and individual Case Studies using the same methodology resulted in a range of values.**

**Estimating Direct Return on Investment of Independent Verification and Validation using COCOMO-II, J.B. Dabney, G. Barber, and D. Ohi, 2006*
***A Case Study of IV&V Return on Investment (ROI), R.A. Rogers, D. McCaugherty, F. Martin, NASA, October 2000*

Additional ROI Studies

- **Using Software Process Simulation to Assess the Impact of IV&V Activities;** David M. Raffo, Umanath Nayak, Siri-on Setamanit,Patrick Sullivan, Wayne Wakeland; Portland State University,Portland, Oregon, USA
- **ESTIMATING DIRECT RETURN ON INVESTMENT OF INDEPENDENT VERIFICATION AND VALIDATION,** James B. Dabney (Department of Systems Engineering, University of Houston), Gary Barber, Titan Systems Corp., NASA IV&V Facility
- **ESTIMATING DIRECT RETURN ON INVESTMENT OF INDEPENDENT VERIFICATION AND VALIDATION USING COCOMO-II,** James B. Dabney (Department of Systems Engineering, University of Houston), Gary Barber, Titan Systems Corp., NASA IV&V Facility

All these studies have interesting approaches, but are difficult to apply when looking forward

How Does IV&V Differ from Project Testing

- The Key difference is "independence"
- Hailpern and Santhanam: "... debugging, testing, and verification activities can easily range from 50 to 75 percent of the total development cost." (Software debugging, testing and verification by Hailpern and Santhanam, 2002, seehttp://www.research.ibm.com/ journal/sj/411/hailpern.pdf)
- Data from The Case for Automated Software Testing (Bernie Gauf and Elfriede Dustin, IDT; Software Tech News)

Table 1. Survey result for question: "Time currently spent on testing in relationship to overall software development lifecycle"

Question Response Options	*% of Respondents*
Less than 30 %	28%
30 % - 50%	**48.6%**
50% - 75 %	**14%**
75% - 100%	7.00%
Other (please specify)	3.75%

What Should You Pay for IV&V

- You would expect IV&V cost to at least equal internal defect discovery costs – unless less testing is required
- An increase factor of up to 2.0 is not unrealistic for "complete" IV&V versus Internal Software Project Testing (source Bob Hunt)
- IV&V is, conceptually, pretty simple:
  - Identify the products and processes to undergo verification and validation (preferably before or in the early stages of development),
  - Determine the criteria with which each of those products and processes can be evaluated (starting with standards where available e.g. the IEEE-1012-2004 standard for software verification and validation),
  - Assess the products/processes while in production and upon completion to verify they meet the predefined criteria and note where they don't,
  - Re-assess products/processes when deficiencies have been addressed.
- IV&V Vendors are very protective of any internal methodology they use to estimate IV&V costs - Then they guess

IV&V Cost Equation

- Assumptions:
  - A Software Development program has a Total Development Cost of $**X** =($x/SM)(SM)* (simplistic express of software equations)
  - The Cost of Internal Software Testing (IST) is 30% of the total Software Development cost, or IST = (0.3)($**X**)= (0.3)($x/SM)(Zsize)
  - IV&V cost equals IST or IV&V=(1)(0.3)($x/SM)(Zsize)
  - There are Y delivered defects per size metric
  - The cost per size metric to rewrite code is the same as the cost per size metric to generate original code
  - The Cost of Defect Recovery and Removal follows the "1:10:100" rule and all "**Y**" defects would have been found after fielding
- **The simple cost Break Even Point is reached when:**
  - IV&V cost = IV&V Savings
  - (1)(0.3)($x/SM)(Zsize)= (100)(**Y**)($x/SM)
  - (0.3) Zsize = 100**Y**
  - (0.3)Zsize/100 = **Y**

*SM – size metric could be expressed as Lines of Code, Function Points, …

Some Data

- Assume 7 to 10 delivered defects per KSLOC
- Code Complete by Steve McConnell:
- (a) Industry Average: "about 15 - 50 errors per 1000 lines of delivered code.
- (b) Microsoft Applications: "about 10 - 20 defects per 1000 lines of code during in-house testing, and 0.5 defect per **KLOC** (**KLOC** IS CALLED AS 1000 lines of code) in released product (Moore 1992).

  (c) "Harlan Mills pioneered 'cleanroom development', a technique that has been able to achieve rates as low as 3 defects per 1000 lines of code during in-house testing and 0.1 defect per 1000 lines of code in released product (Cobb and Mills 1990). A few projects - for example, the space-shuttle software - have achieved a level of 0 defects in 500,000 lines of code using a system of format development methods, peer reviews, and statistical testing."
- Capers Jones assumes 5 to 7 defects per function point

IS IV&V Worth the Cost

- It depends on who is paying for it , but the answer is yes

- When critical safety and life issues are at stake (and accidents are averted), the answer is again yes

- But what does it really cost –
  - Although numbers vary by project and environment, the costs to fix defects average what has come to be known as the "1:10:100" rule. (Achieving Software Quality Using Defect Filters; Randall Rice)
  - A defect that costs $1 to fix in requirements or design costs $10 to fix in a traditional test phase and $100 to fix after the product goes into production (live) use

  Most ROI studies assume any defects found in IV&V would have made it to production (live usage)

NASA IV&V Benefits

So Far I have Only Looked At Benefits That Can Be Measured In $

1. **The IV&V Program increases the likelihood of uncovering high-risk defects early in the development lifecycle**
2. **The IV&V Program provides ongoing status indicators and performance reporting to NASA program level managers**
3. **The IV&V Program provides stakeholders with the visibility into progress and quality of the system-software development effort**
4. **The IV&V Program reduces the need for rework by the developing contractor, and thereby reduces the total costs to programs and development projects**
5. **The IV&V Program reduces defects in delivered products**
6. **The IV&V Program may save lives**

IV&V Life Cycle Functions

- IV&V Process provides tools and analysis procedures appropriate to each phase of the software development life cycle:
  - Formulation Phase:
    - Is development process sound, repeatable, and managed?
  - Requirements Phase:
    - Verify that system and software requirements are correct, complete, traceable and testable
    - Analyze system-level requirements: Are test plans and acceptance criteria sufficient to validate system requirements and operational needs?
    - Are testing methods sufficient to verify and validate software requirements?
    - Are the correct software development, management, and support processes in place?
  - Design Phase:
    - Does the design support the requirements?
    - Are test plans and test environments sufficient to verify and validate software and operational requirements?
    - Does the design have any characteristics that will cause it to fail under operational scenarios? What solutions are appropriate?

IV&V Life Cycle Functions

- Typical IV&V functions by Software life-cycle phase (cont.):
  - Coding Phase:
    - Does the code reflect the design?
    - Is the code correct?
    - Verify that test cases trace to and cover software requirements and operational needs
    - Verify that software test cases, expected results, and evaluation criteria fully meet testing objectives
    - Analyze selected code unit test plans and results to verify full coverage of logic paths, range of input conditions, error handling, etc.
  - Test Phase:
    - Analyze correct dispositioning of software test anomalies
    - Validate software test results versus acceptance criteria
    - Verify tracing and successful completion of all software test objectives
  - Operational Phase:
    - Verify that regression tests are sufficient to identify adverse impacts of changes

IV&V Life Cycle Functions

- IV&V identifies deficiencies in program's test planning
- Program changes their procedures to address deficiencies vice IV&V independently test
- IV&V may independently test highly critical software using an IV&V test bed
  - White box
  - Stress
  - Endurance
  - Limit
- Developer motivated to show software works
- IV&V attempts to break software

Concerns

- No salutatory requirement for IV&V, but probably a good policy
- $25 M to $30 M annual budget for NASA IV&V Facility – cost related to specific programs are spread over several years
- No consistent/agreed to measure of ROI – this would be helpful
- Most analyses of ROI assume that defects would not have been found until fielding – therefore they apply the 100 rule (see slide 9)

Closing Thoughts

- No software is delivered defect free
- The larger/more complex a system is the more likely IV&V will result in positive outcomes
- It is about critical safety and functionality more than cost
- Key Benefits:
  - Early detection.
  - Improved quality
  - Lower Total Cost of Ownership (TOC) cost
  - Reduced management burden
- IV&V is hard work that takes expertise independence, and a degree of rigor -
- There is no professional certification of IV&V "engineers"
- Understand you need competent, experienced professionals but this is not a mystical art.

- *Bottom Line: IV&V is worth the cost*

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