Valuation, Policy & Software Strategy

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ABSTRACT

The emergence of the Virtual Observatory as a new model for doing science means that the value of a facility instrument is no longer limited to its own lifetime. Instead, value becomes the net effect of optimizing observational throughput, the quality and quantity of data in the archive, and the applicability of the data that can survive and be used for future research even after a telescope ceases operations. Valuation aims to answer two questions which are especially important to funding agencies: what am I getting for my investment, and why should I care? Policy establishes guidelines for achieving the goals that lead to increased value. The relative roles of valuation and policy in inventory control and archiving strategies, adoption of standards, and developing maintainable software systems to meet these future goals are examined.

Keywords: Quality, valuation, policy, strategy, archive, metadata, Virtual Observatory

1. INTRODUCTION

Valuation is the process of determining the worth of an asset, object, or entity. Because projects and software services such as data archives deliver value to the scientists who use the products to generate scientific discovery, the worth of such facilities can and should be evaluated or forecast before they are implemented. Such models can be helpful to an organization, particularly if a decision must be made between competing projects if there is not enough funding to support both.

Policy "can be defined from two perspectives: a definite goal, course or method of action to *guide and determine present and future decisions*" and "a set of rules to administer, manage, and control [physical or material] resources." (Westerinen 2003) The implication of these definitions is that policy may be established by management to expressly ensure that decisions related to technology selection and implementations follow the results from a valuation exercise. To be effective, policies should be dynamically instituted and frequently checked and reevaluated to make sure they are helping the organization produce desired results.

Policy is intricately related to the high-level architectural and design decisions related to software, because not all approaches to implementing a specific requirement or group of requirements will generate the same value. For example, if the decision is made to implement an application using technologies that are new to all of the software engineers in an organization, the time to deliver the new functionality to users will be longer. Not considering other factors, such as significantly increased maintainability if the new technologies are chosen, a project that involves writing new software using tools that are already understood would be more highly valued. Some questions that could be answered by considering valuation methodologies include:

- ► Should we archive all the raw and/or calibrated data we produce?
- ► Should we archive all the science products that are generated, whether manually or using automated methods?
- ► Is there a level of quality that can be defined, and should be achieved, in order for data products to be admitted into the archive?

The following pages explore the relationships between valuation, policy and software strategy, focusing on the ways those valuation techniques and policy decisions can be used to determine the best implementation strategies for a funded telescope facility. Although the concepts presented here could be applied to any project or service being considered for

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implementation by a telescope operations group, many of the examples focus on the organization's data archive or data warehouse. A specific distinction is not made in this manuscript between the science data and the metadata that characterizes the science data. Similarly, the term "dollar" is used to refer to a unit of monetary value for illustrative purposes, but any currency could be used in its place for value-based decision making for facilities in other countries.

2. PHILOSOPHY OF VALUATION

As stated earlier, valuation is the process of determining the worth of an asset, object, or entity. For-profit companies conduct valuation estimates by considering the future cash flow that an activity will generate, subtract off liabilities such as operating expenses and debts, and add back in operating assets. Organizations which do not drive revenue must be more creative in their estimates, and instead consider the additional value delivered to the organization or its customers as a result of performing an activity. Valuation can be performed for individual activities or tasks, parts of projects, or entire projects. An engineer might object to valuation methods on the basis that it is impossible to assign a real monetary value to an activity, given that the planning assumptions on which those estimates are based will change. However, valuation methods provide an excellent means of comparing one project or task to another at the same instance in time when the economic feasibility of developing or maintaining a new feature or capability is a concern.

It is critical to remember that different people or groups of people perceive value differently:

- A **scientist** in the middle of a research program will value a new, highly specialized software capability that he or she needs for that program far more than a different capability that is needed by many scientists.
- A **software engineer** will value a task that involves new design more than one that involves straightforward implementation for which the challenging questions have already been answered.
- The **senior managers** for a telescope will tend to value utilitarian solutions that deliver the greatest amount and magnitude of benefits to the largest segment of the user population.
- The **head of the business office** for a telescope facility will tend to value solutions with the lowest Total Cost of Ownership (TCO).

Every telescope is constructed to deliver innovative or unique capabilities, which *define the value* that will be generated by an instrument. Original research into methods, techniques and algorithms will typically be a required component of construction and operations. Research and development (R&D) organizations exist to create opportunity and growth, and according to Boer (1999), the R&D process itself is a "mode of converting cash to opportunity". The primary challenge is in the timing of activities, which must consider that certain tasks will deliver greater value if planned for earlier execution, and other tasks will deliver greater value if planned for later. An example related to astronomical systems is that the development of pipeline processes for automated data reduction should follow the capability to process observing modes manually, if the optimal integration of lessons learned is a goal.

3. VALUATION METHODS

There are three broad approaches to valuation: historical cost methods, market value and utility value. In the first category, a task or product is worth what it cost to produce. Measures of the value of an hour's worth of observing time, which often consider the costs to construct and operate the instrument over its expected lifetime, apply this method. Market value considers the amount someone else would pay to acquire the asset, and so is the valuation method of choice for sectors such as real estate. Utility is the most appropriate valuation method for the purposes of telescope operations, since monetary value is derived from the expected benefits to be realized as a result of implementing a new feature, capability or service.

Discounted cash flow (DCF) techniques are appropriate when the return from an investment or an implementation is captured entirely in the future, which characterizes most of the software developments a telescope facility will encounter. These methods seek to quantify what an organization is willing to invest today to gain benefits later in time, and are formed from the concept that a dollar today has more buying power than a dollar will in the future. It is important to note that many valuation methods are in place to compare options for new development, and the estimates often do not reflect the actual dollar values saved or expended to produce new capabilities. Although this is an extremely distasteful proposition for engineers, it is perfectly acceptable to accountants and often yields sound value-based decisions regardless.

3.1 Estimating Tangible and Intangible Benefits

The most critical aspect of any valuation exercise will be estimating the monetary value of benefits to be realized. Although for-profit operations can generate tangible returns in the form of generating more revenue or bringing the revenue in more quickly, non-profit telescope facilities must look to other measures to estimate the benefits of software and systems implementations. The most common candidates are increased productivity, cost containment, and information resource consolidation.

Increased productivity should be measured in terms of actual cost savings from materials and labor that no longer must be allocated for a given purpose. For example, if you implement a proposal handling process that reduces the amount of time two administrative staff members make available for manual processing from 2 weeks to 2 days, the proposals are processed three times a year, and the fully-loaded cost of those employees is $50,000 (including salaries and benefits), the valuation of the increased productivity would be:

(14 days – 2 days) x ($50,000 x 2 / 260 workdays) x 3 proposal deadlines = $11,538.46

In this example, the monetary estimate produced represents a real cost savings: the administrative staff are free to work on tasks other than the manual work associated with proposal handling. Sometimes, the benefits that are produced are not as straightforward to quantify, but links must be attempted between intangible and tangible as in the following examples:

- *Shortening the learning curve* for users to adapt to new telescopes or new observing modes will produce tangible benefits in the form of a) reduced staffing requirements for maintaining and updating documentation and training programs or b) reducing the cost to acquire a new user
- *Broadening access* to facilities is an intangible benefit that could be quantified by gauging how many observing hours the demand for a telescope would increase if new capabilities were added and translating this to the dollar value typically ascribed to each observing hour; increasing demand is both a hedge against variability in demand in the future, and a means of generating new users for archived data
- *Making additional data available to more staff within an organization*, which would occur when multiple data stores are consolidated and custodianship is federated, will yield the intangible benefit of being able to make better decisions faster; this can be quantified by estimating the amount of time saved trying to locate typical pieces of data and multiplying this by the number of people affected and the fully-loaded cost of the average employee impacted by the improvement
- *Reducing software bugs* produces the tangible benefit of less time spent pursuing operational support; note that there is also an opportunity cost here, because time spent fixing bugs is time that could alternatively be used to add new capabilities (if the bugs were absent)
- An effort to *build high performance and responsiveness into a software application* could, if successful, yield tangible benefits in the form of eliminating future needs to benchmark an existing system and make additional improvements

When performing valuation analyses, also ask your budget managers over how many years they typically calculate benefits. In the proposal handling scenario above, the benefits might be assessed for three years after implementation, but could not be tracked indefinitely for decision support.

3.2 Evaluating Return on Investment (ROI)

Calculating a return on investment assumes that future benefits are expected. Much like estimating the value of tangible and intangible benefits, calculating ROIs often yields valuable metrics for comparing activities but does not often reflect actual tangible financial returns from projects due to the difficulty of accurately predicting expected returns. For software projects, it is typically calculated as a ratio and expressed as a percentage:

(value of benefits expected) ÷ (value of total information assets)

However, you might note that although the value of derived benefits can be assessed, valuation of an organization's information assets presents a unique challenge. For that reason, alternative methods to evaluate the return on investment can be used which include net present value (NPV) and payback period.

The expression for *net present value (NPV)* is used as a basis to compare the future value that is expected to be delivered by upcoming projects, and can be used to compare and evaluate projects with each other to determine the best opportunities to pursue. To calculate NPV, add up the benefits realized each period (C) from all times t between t=0 and t=N (the final period in the project) and divide by $(1 + i)^t$ where *i* is the discount rate. Discount rate is the return on funds that your organization expects from its investments; you should contact your budget managers to determine what discount rates to use in your calculations. What this boils down to is that the only value a project manager needs to estimate is a value (tangible plus intangible) for the benefits that will be derived from an activity, and knowledge of approximately when those benefits will be realized. The expression for NPV is displayed as Figure 1.

$$\mathrm{NPV} = \sum_{t=0}^{N} \frac{C_t}{(1+i)^t}$$

Figure 1. Expression used to evaluate net present value (NPV) from http://en.wikipedia.org.

Note that from this equation, projects that deliver outcomes earlier will have greater NPV values if all other factors are equal, but projects that deliver the greatest net benefits will still emerge as the leaders when activities are evaluated collectively.

Central to the interpretation of NPV is the related concept of yield, or *internal rate of return (IRR)*, which represents the break-even discount rate for which the expected future value flowing in and the investments expended equate to zero in today's dollars. If you ask your budget manager for a discount rate to evaluate your activities against, you will likely be provided with your organization's internal rate of return.

4. IMPACTS OF VALUATION

The purpose of constructing a large-scale telescope facility is to enable new scientific discoveries; that is, to generate the raw and calibrated data from which those scientific inferences and discoveries can be made. Considering that the Virtual Observatory is gaining momentum, data products from current and future telescopes can be expected to survive and be used for research even after the telescope is no longer producing new data. As a result, optimizing the scientific return from a telescope must include optimization the quality and quantity of information stored for future access from an archive.

Because data storage hardware has become commoditized in recent years, it may be tempting to archive all of the data produced by a telescope. However, as more data is produced, additional infrastructure is required to manage that data including personnel, additional space, and most importantly – more sophisticated data mining techniques to wade through all of the additional data.

4.1 Influence of Valuation on Software Strategy

There are many important concepts, innately tied to the principles of valuation, which can influence software strategy decisions. These include:

- **Time Value of Data.** Part of the value of a dataset is time-dependent, and as a result the value of a dataset may decrease as time progresses. For example, a new area of science has been identified for which emerging electronics technology is particularly appropriate. Five institutions have launched similar projects to build and commission these instruments. One organization will generate the first data products, and will lay claim to the first discoveries made. The second facility will produce additional datasets, which will be used to verify the discoveries from the first instrument. The remaining three organizations, if they do not abandon their efforts, will produce additional datasets. The datasets produced by the "first movers" will ordinarily have greater value than the datasets produced by the fourth or fifth instrument.

- **Inventory Holding Costs.** There are always costs associated with stocking products in warehouses, and these are referred to as "holding costs". Often, excess inventory is held to hedge against fluctuating demand or delays in getting components from suppliers. It provides a means of storing the overflow that is produced for future use. For products like this, the inventory holding costs are comprised of additional costs for maintaining the space to store the products, extra insurance to cover the additional product, the cost of capital to finance the additional inventory, and the opportunity costs of keeping the additional product. Opportunity costs would be the extra cost incurred by holding more products, when the funds used could generate more value being used in a different way. Within a data warehouse, however, the rules are different. A dataset is not consumed, but is either reproduced or used as a master from which science products are derived. As a result, the inventory level in a data archive is cumulative; it will always increase unless data is selectively removed from the storage facility, which also takes additional resources to manage. The challenge becomes being able to quickly identify pertinent information, access it, transform it as needed, and convert the results to new knowledge.

- **Creating Value through Accessibility.** For most assets or products, the value decreases as that asset is used more. More miles on your car means you can get less when you sell it; as computer technology becomes outdated and comparatively slow, its resale value shrinks. This is not the case with information assets, where "there is no degradation in information based on the number of times it is viewed." (Loshin 2003) Furthermore, Loshin asserts that the value of information will increase when people in an organization know where to find it, how to access it, and how to utilize the information. "If data is stored, managed, and never used, there is no added value, and… it actually becomes a liability."

- **Opportunity Costs.** As indicated by the NPV equation, there is also value associated with delivering the greatest benefits at the most appropriate times. This occurs because if resources are being spent now on delivering capabilities that are not needed for a number of months or years, opportunities are continually missed for delivering capabilities that bring additional intangible benefits. These intangible benefits could include improving relationships with users, attracting new users, improving employee morale and productivity by generating a sense of accomplishment, and developing resources that can readily be used to generate value elsewhere in an organization.

► **Creating Value through Policy.** Time is wasted whenever policy is not available to guide the generation of requirements and decisions made during design activities for software development. For example, after reviewing meeting minutes and development plans for the implementation of a Scheduling-Block based observing system at NRAO in Green Bank, it was discovered that 15 months of elapsed time could have been saved. This would have been possible if there was a policy stating that the GBT (like the VLA, EVLA, and ALMA) would be required to build its observing systems around the Scheduling Block concept. The lost 15 months were spent debating whether Scheduling Blocks presented an appropriate and potentially optimal means of scheduling GBT observations, however, the choice was central to increased collaboration across the Observatory (an objective supported by executive management).

4.2 Hidden Costs Erode the Value of Realized Benefits

The TCO of the archive itself is the sum of the initial investment (cost to develop the archive), plus the costs of maintaining the infrastructure (which includes storage hardware, connectivity, disaster recovery backups, administrative personnel, and computing personnel). Beyond the initial investment, these costs will essentially be fixed until an organization has the requirement to increase its capacity.

However, there are many hidden costs that must be considered when an archive and archiving policies are being developed. Based on his 1997 dissertation, De Long (1999) used empirical data to determine that the most damaging hidden costs in archive or data warehouse development could cause a penalty of up to 50% on the organization's data warehouse ROI. The top four results determined were:

Area of Hidden Cost	Description	ROI Penalty
Weak Data-to-Decision-Making Links	Inappropriately focusing on user requirements at the expense of understanding how the data in the warehouse will be searched for, mined, and used for decision making can result in excessive holding costs for data that will rarely, if ever, be used.	30 – 50%
Lack of Collaborative Culture	High levels of trust and cooperation are required to ensure that data stores can be shared, cooperatively managed, and opportunities are not missed for linking data together for decision making. An excellent example of this would be an organization that has multiple databases storing information about telescope users; a single data store, shared by individuals and applications, can increase the organization's ROI on its shared data resources by nearly a third according to the investigator.	20 – 30%
Undue Optimism About	De Long found that many organizations	10 – 20%

Standardization	believed standardization was the ultimate technical mark of achievement for their data archive, but that a key "lesson learned" in most organizations was that the standards were often settled upon only as the needs of the users were changing, thus reducing their value.	
Not Anticipating Inevitable Turnover	Technical personnel are bound to change jobs, and adequate training programs can prevent losses due to not anticipating problems in the archival process.	10 – 20%

Figure 2. Hidden costs of data warehouse implementation determined by research from De Long (1999).

5. EMERGING CONCLUSIONS

Every innovative organization produces more ideas for new development than its resources and funding are capable of supporting, even for the most envied of institutions for whom funding seems more than adequate from the outside. This discrepancy is an indicator of progressive thought and vision, but in its presence project managers and budget managers will always be faced with the challenge of choosing among competing initiatives when resources are not available to accomplish all of them. Valuation methods provide one basis for making these comparisons and supporting decision making.

Exploring the relationships between valuation methods, software strategies and policies to guide those strategies is a complex matter, in part because "real world valuation is a mix of organizational issues, complex strategic questions, and analytic methods." (Boer 1999) The work of understanding how these concepts interrelate, and how using these concepts can aid in decision making and yield tangible operational improvements, is in its infancy.

Several conclusions were gathered from reviewing the relevant literature on valuation and data warehouse implementation, and by reviewing project artifacts to discover lessons learned in project planning for GBT software over the past few years. These include the following.

- Policy provides important guidance for software architecture and strategy, and can be used to ensure that high-level strategic decisions of an organization constrain and are reflected in user requirements. This will eliminate fruitless debates for which strategic decisions have already been made, recouping time and effort that can be used for delivering capabilities to users faster.
- Greater volumes of data in an archive do not necessarily translate to greater value. A better metric for value would be the number of downloads or accesses to a dataset *as a proportion of* the total amount of available data.
- Standardization of data formats and archival processes was not determined to be the radically positive factor at many corporations that instituted data warehouses, according to research by De Long (1999).
- Policy-based management, which is employed whenever heuristics are used to make decisions, requires that the users trust the automated policy decisions. This suggests that the value of the policy-based systems can be optimized if time is built in to cultivate trust of the methods within the user population.

Many additional conclusions are expected as these concepts are explored further. According to the results from previous studies, one conclusion that is suggested is that the greatest added value to be provided by the data mining tools that are being developed as part of the Virtual Observatory will be from information merging. "If we can take two pieces of information, link them together, and infer something new that could not have been learned independently, we can exploit that information." (Loshin 2003) Perhaps future work will reveal whether or not this is the reality.

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