The Impact of Understanding the Need and Available Products in COTS Selection

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Abstract. Nowadays, more and more engineering solutions are built by integrating Commercial-Of-The-Shelf (COTS) products rather than building subsystems from scratch. The selection of COTS for defence acquisition and upgraded projects presents a great challenge to systems engineers due to the rapidly changing nature of electronic systems, particularly those related to sensors, combat and mission systems, weapons and countermeasures, avionics, and communications. This paper explores the issues associated with the selection of COTS subsystems to be integrated into a larger system. When the total number of COTS components of the same kind to be procured is very low, such as one unit, there are additional constraints impacting the selection and procurement process. A case study is presented based on the development of the Systems Integration Sandpit (SIS) for exploring systems integration issues, fostering model-based systems engineering and systems engineering education.

INTRODUCTION

Defence acquisition and upgrade projects involve the selection of COTS subsystems, and some system development, and the integration of the selected and designed components to provide new or upgraded systems (Defence, 2009). Thus, the use of COTS products is commonplace in system development. In part, this is because the design of any system must eventually be broken down to subsystems, components or materials which are produced by external suppliers. The external suppliers produce and offer their products, for reasons of their own motivation, in the expectation of achieving a sufficient market to enable a worthwhile business. However, the term COTS usually denotes some fairly substantial subsystem type assembly rather than low level fundamental components.

Use of COTS products is attractive because it is assumed that it will enable cheaper development of one's own system (Blanchard and Fabrycky, 2006). The reason for believing that incorporating COTS products will reduce cost is that one may look at a COTS product, and estimate the development cost, which is often considerable, and assume that one would incur that cost if one developed an equivalent for oneself. It is then assumed to follow that by use of the COTS product one can benefit from a development effort amortized across a much larger quantity than one requires, thus gaining a better component for the money expended, and also accelerate delivery of one's own system.

It is also assumed that since the COTS product already exists, and has known performance, that risk is reduced when it is incorporated into one's own system. This assumption leads to the incorporation of COTS products into systems in favour of custom subsystem development.

These two assumptions are often not supported by experience (Nandagopal, 2006; Do et al., 2009d). The risk of using COTS products is much greater than is commonly assumed because suppliers of COTS products have developed their products according to their own design imperatives, but only supplied documentation of the form which they choose to supply, which means that the information available to the engineer who incorporates it into a large system is significantly limited, and does not necessarily cover all aspects of importance to the engineer. The absence of complete design documentation results in the engineer using the COTS subsystem being, most likely, unaware of the full range of design requirements to which the COTS subsystem was designed, and having a void of information about some matters which may potentially impact significantly on the suitability of the COTS subsystem in the intended application.

This paper investigates the distinctive issues associated with very small quantity COTS subsystem selection, because this situation raises some interesting questions related to use of the systems engineering process in some situations. The selection of COTS products depends on the situation. Parameters of interest in evaluating the value of potential use of COTS subsystems include:

- Cost of candidate COTS subsystems;
- Estimated cost of development of a custom subsystem;
- Schedule of the whole project;
- The anticipated production quantity;
- The nature and magnitude of risks associated with the subsystem; and
- The degree of embeddedness of the subsystem within the system.

LOW QUANTITY COTS – A CATALOG SELECTION PROBLEM

We first consider a situation where a decision must be made to select COTS subsystems, required in low quantity. The function to be performed by the COTS item is desirable in the context of the total system in which it is to be deployed, and may or may not be mission critical. A catalog selection problem is defined here as a product selection situation in which potential suppliers present products which they have chosen to supply, with whatever self-selected description of those products they have decided to provide, such as marketing brochures, websites, and the like. The buyer must decide what product to purchase using these heterogeneous descriptions of the available products. The heterogeneity of the product descriptions prevents the buyer from making an effective 'like with like' comparison, which in turn makes a formal trade-off analysis difficult or impossible.

Even where the sales process enables the potential buyer to see a demonstration of the product, or to try it out, the conditions of such demonstrations or trials are usually quite constrained, limiting the scenarios attempted to those that the salesperson is willing to show, and will only be performed on an informal basis, often opportunistically taking advantage of the demonstration context to demonstrate elemental aspects of performance. Such demonstrations and trials are permitted by the sales person, not to enable profound testing of the product, but rather to show-off desirable aspects of its features and performance. Examples are home demonstrations of vacuum cleaners and test drives of vehicles from the new car dealer's showroom. This scenario presents a number of problems:

- First, that the proposed subsystem is probably not in a 'core business' area, resulting in there being little or modest in-house knowledge of the issues associated with its selection. Therefore there is a lack of expertise to even know what questions to ask of candidate suppliers about products they offer.
- Second, suppliers will be aware of the modest business they are likely to obtain through the potential deal. The single item ever purchase is, in the supplier's mind a very different item of business than a pilot purchase, as the first of what could potentially be a supply into a production run. Therefore, this particular deal is likely to obtain much lower priority on the supplier's side than other prospective sales for larger quantities of the product. Therefore discussions about the product are likely to be interrupted if matters related to larger customers intervene and the amount of effort expended by the salesperson will likely be less than for negotiations where there is a potential large purchase.
- Third, suppliers will have standard packages of product, documentation and accessory sets which they make available. Unless a significant premium is paid for customised combinations of products and service the buyer is faced with a catalogue selection problem.
- Fourth, the description of the product that is received by the buyer will be the description that the seller chooses to make available through the seller's design of promotional materials. Unless detailed product documentation is made available on the internet for those who are not yet owners the buyer will not be able to use the more detailed product information, such as instruction manuals or service manuals, to inform the purchase decision.
- Fifth, the level of expertise of the sales staff that the buyer consults is likely to be correlated with both the price of the COTS item and the total deal magnitude, so for a one-off purchase, the expertise is likely to be limited to what is necessary to enable a reasonable level of confidence that the product is likely to be suitable. However, if the buyer asked probing questions about the product, the answers received may not be useful.
- Sixth, the buyer is not in a position to do a significant test and evaluation process on the preferred candidate system. While, for example new car buyers may have the opportunity to test-drive a vehicle, this is likely to be under constrained conditions such as a short duration test drive, not long enough to take the vehicle to challenging terrain, with a sales representative in the vehicle, and a liability related to any damage caused by their manner of driving during the test-drive. The test-drive scenario does not enable independent testing of effectiveness for purpose. Definitely, the buyer is unable to buy the candidate products with a view to thorough testing of fitness for purpose, which is a strategy available for purchases of a pilot quantity before large volume commitment. In a single item purchase situation the budget allocated enables the purchase of one item, which cannot be destructively tested because the product must remain in satisfactory working order.
- Seventh, the buyer may feel under pressure to make the purchase decision rapidly, in order to get back to 'core business' activities.

THE RELATION OF THIS TOPIC TO SYSTEMS ENGINEERING

This topic is related to systems engineering and of interest to the systems engineering community in several ways. Various aspects of the issue of selecting COTS items, or of the catalog selection problem have been touched on in previous papers, by others, however this paper places this work in a more formal structure. Some of the earlier works have formalized the selection process as a decision making scenario (Ruiz et al., 2004; Land et al., 2008). The assertion that this is the application of a system engineering process is supported by describing the selection process as a process of identification of requirements related to the potential acquisition, and then evaluation of the catalogue of candidates with respect to the requirements identified using some form of trade study process (DoD, 2002).

The process described above is an aspect of the systems engineering process. In any project in which systems engineering is used there are a number of selection questions to be addressed, and these are appropriately addressed using a requirements identification and trade study process, but to reformulate any product selection and purchase decision as a systems engineering problem is to exalt requirement determination and trade studies, in combination, to become systems engineering. To give the appearance that requirements analysis and trade studies are systems engineering leaves out important aspects of systems engineering related to the design of appropriate product systems. In turn, the presentation of one part of the work under the name of the whole may lead to a sense of trivialisation of the whole as only supporting the part.

CASE STUDY – SYSTEMS INTEGRATION SANDPIT

Introduction. The University of South Australia (UniSA), under the Centre of Expertise in Systems Integration (COESI) agreement, has undertaken work for DSTO on the Systems Integration Sandpit (SIS), previously known as Microcosm (Cook et al., 2008). The SIS was established to foster research, training and education in systems engineering, with the focus on undertaking research into better understanding how to manage the systems integration issues that arise in large systems. The SIS also explores and fosters research and development (R&D) in Model Based Systems Engineering (MBSE) as an aid in addressing systems integration issues.

The SIS aims to provide an environment that can be used to stage demonstrations, conduct experiments, support teaching programs and facilitate systems engineering research. The SIS is intended to be an evolutionary facility and has been designed to be expansible to meet the wider and longer-term aims of its stakeholders. The SIS has both physical and modelled systems, where every physical system or attribute has a modelled analogue. It consists of autonomous systems moving and interacting with each other and humans in a physical environment. SIS is not a technology program and is not about researching autonomous systems, or the science of autonomy. Rather, the SIS will use modelled and physical autonomous systems as a means to explore the systems engineering and systems integration issues of evolving systems (Do et al., 2009a).

In addition, the SIS is an open system, where the details of project interfaces, standards, configurations, component implementations, and other information, will be made available to developers and users. This will facilitate the addition of new components and capabilities to support specific stakeholder needs. Critical to the systems engineering context, the SIS is being developed using a tailored systems engineering process based on ISO 15288 and the INCOSE Systems Engineering Handbook (INCOSE, 2007) that identifies the design drivers and stakeholder needs, derives a functional architecture, and produces a system solution.

The first phase of SIS, termed Stage 1, was completed in December 2008, which provided a basis for initial experimentation and demonstrated several core capabilities. Similarly, SIS-Stage 2 was successfully completed by 30 June 2009, and comprises a set of enhancements to SIS-Stage 1 development. These involve enhancements to simplify operation, improvements to technical performance and the insertion of the indoor global positioning systems using Ultra-wide Band Technology (UWB), in particular to the system's knowledge of the position of the robots, and physical alterations to make the facility reloadable. This leads to the development of Stage 3, named Systems Integration Sandpit – Target Identification, Notification and Engagement (SIS-TINE).

SIS COTS Selection Process in Stage One. The process adopted for the SIS Stage One development was entirely based on the COTS approach, with a primary focus on exploring systems integration issues associated with the COTS based system development. The aim is to develop systems integration knowledge and experience of system engineering in-the-small as a precursor to systems engineering in-the-large (Relf et al., 2009). The SIS Stage One has demonstrated that even with a very small project the systems integration issues encountered were not at all trivial. Rather they resemble many issues faced by major complex system developments and system upgrade projects. Due to its small scale SIS Stage One was based on low quantity COTS product acquisition, where most components were purchased in quantities of one or two units. COTS items acquired include robots, long-range and short-range laser sensors, a magnetic compass, an inertial measurement unit etc, and a UWB indoor positioning system. The selection process involves a trade-off study, which was based on a multiple variable analysis method that compares the characteristics of candidate COTS products of interest against a set of criteria. The sum of the weighted scores determined the product. Note that the trade-off study was done based on the information provided by the suppliers' brochures and datasheets. This approach omits the issues of information completeness, integrity, and the equivalence of description of the products, which has led to interesting findings at the integration stage of the project. These lessons learned were documented in the SIS database. A few examples are discussed in the following section to illustrate the challenges in selecting low quantity COTS products in a COTS based project. In SIS the intention was to have minimal development of interface elements.

SIS Lessons Learned. Lessons learned databases are a collection of analysed data from a variety of current and historical events. Generally, these events are associated with failures, and involve the loss of valuable resources. Lessons learned databases themselves become a potentially valuable resource that can be used to rectify or mitigate the causes of failure, or to choose pathways that are likely to improve future performance. This section describes examples related to the issues of selecting low quantities of COTS items extracted from the SIS lessons learned database. These lessons were captured in a uniquely forgiving environment intended for the development of good systems engineering practices.

1. The first lesson learned relates to *commercial-off-the-shelf (COTS) and military-off-the-shelf (MOTS) product integration*. This lesson relates to one of the requirements for the SIS-Stage One operational scenario (Cook et al., 2009). The sensor selected for this mission was the SICK (LMS-291 2006) laser scanner. This sensor provides a fast scan of up to 180^{o} at a rate up to 50Hz and with a range up to 80 meters. The sensor was supplied with the manufacturer's supplied demonstration software running at 9600 baud rate, which provides a scanning rate of less than 1Hz. Although the laser sensor is capable of operating at faster baud rates (up to 38400 using the RS232 communication protocol and 500kbps using the RS422 communication protocol) the manufacturer's supplied demonstration software cannot be changed to higher baud rates. This was discovered after the unit was procured.

In order to address this, a customized RS422 compatible cable was built, and a RS422-to-USB converter was procured to connect the sensor with the computer's USB port. Although the convertor is designed to work with high baud rates (up to 960kbps), it still did not work correctly. The reason was that the sensor operates at a non-standard RS422 baud rate (500kbps), and the convertor works only with standard baud rates (480kps or 504kps). This issue is typical of standardized interfaces with vendor exceptions. Once again, an additional PCI RS422 interface card was purchased to connect the sensor to the computer at the required 500kbps baud rate. However, the second convertor did not include software that supports 500kbps, and in-house communication software had to be developed. The additional hardware and software development required an extra six weeks of engineering effort. This leads to the question of whether this issue could be anticipated and mitigated prior to the commencement of the project, for better project management and resource allocation. From this it is clear that integration of COTS and MOTS components can require unexpected resources. We also learned that the performance and interfacing of COTS products may not be easily determined from their data sheets and manuals.

An antagonist could argue that an experienced engineer would have known about these issues. This is so, but the experienced engineer only knows about these issues because they have suffered the effect of something very similar in a previous project. In that case, the present project delivery to plan is a benefit of the cost over-run on the earlier project in which the engineer did the learning. This issue also illustrates the problems identified above in the list of issues under the heading 'scenario description'. The details of the various computer communications protocols are not core business of the acquiring organization; the fact that each purchase was a one-off acquisition of a relatively low value item made the sale unattractive to the vendor to provide much assistance; the standard documentation packages did not alert the inexperienced to the integration issues to be confronted; and the integration problems would have been addressed through a T&E process in a lager acquisition.

2. A second lesson learned was related to the problems of Electro-Magnetic Interference (EMI) and Electro-Magnetic Compatibility (EMC). EMI is the unwanted disturbance that affects an electrical circuit due to either electromagnetic conduction or electromagnetic radiation emitted from an external source. The disturbance may interrupt, obstruct, or otherwise degrade or limit the effective performance of the circuit or system. A major component in a robot's on-board sensor suite is a magnetic compass that measures the vehicle's orientation. This sensor is crucial for the autonomous navigation task, in the total system architecture adopted, as angular errors cause uncontrolled robot positioning. In recognition of the potential effect of EMI between the robot's electronic circuits and the magnetic compass, a mechanical buffer was implemented to position the compass far enough from the robot's electronic circuits to ensure the EMI effects were small enough to not impact system performance. Further to this, an electromagnetic compensator was designed and implemented to reduce the EMI effect on the compass accuracy. These measures improved the compass accuracy by three orders of magnitude, but were not effective in reducing the environmental EMI between the compass and other electrical and electronic devices in the SIS test space (electric wires, computers, an Ultra Wide Band (UWB) positioning system, safety and security devices, and other components). As a result, the magnetic compass was replaced by an inertial navigation system (accelerometers and gyroscopes). This required local physical modifications of the robot's

on-board navigation system, as well as global data fusion to derive an accurate position estimate. The change of sensor technology resulted in a change of sub-system architecture because of the change in the kind of information obtained, and therefore the need to modify the data analysis methods.

It can be argued that since several of these sensors were required for the project that it may have been good to obtain one for testing first. However, this view has the counter-position, that the two purchases of items adds administrative overheads in raising two orders, and increases delays, which can be of the order of weeks or months to get orders through the organizational purchase system and receive delivery, often from overseas suppliers. These difficulties of dividing a small order into a pilot of one unit to be followed by the remaining few militate against the more cautious purchase strategy. A staged purchase would have enabled discovery of the integration problem after the purchase of one unit, but would not have saved calendar time for delivery of a satisfactory system. Information from the supplier's brochures and datasheets provide very little or no information regarding the problems associated with EMI effects. Any even if the information were published, and available prior to purchase, the problem of interpretation of the data into a good decision about purchase in an organization in which this kind of design activity is not core business would remain.

Again, the knowledge required to anticipate the problem and to meaningfully interpret the information provided about the issue requires some significant expertise based on experience, even if the data is available, and the problem is recognized, because the area of concern is not a major part of initial engineering education.

Strategies for COTS Selection

In this section we discuss some strategies which can be used to address the problem of the single or very low quantity acquisition of COTS items. We propose several strategies with which to deal with the issue of selecting low quantity COTS products, which can be bifurcated into: Mission Critical and Non-Mission Critical COTS components:

Mission Critical COTS. In some situations the COTS item is mission critical. In such cases the critical dependence upon the satisfactory performance of the COTS item justifies a substantial investigation of the suitability of the particular COTS item in contrast or comparison with the various other candidates to ensure the most appropriate is selected. Even where the total quantity required is one, in a mission critical situation it may be justified to select the one which, on vendor furnished datasheets, appears the most suitable, and then to thoroughly evaluate its effectiveness for the purpose. If the impact of failure is potentially high, it may be justifiable to spend multiples of the COTS item purchase price to perform this evaluation. The decision of whether or not a COTS product is classified as mission critical or non-mission critical can be based on the following aspects:

- The function provided by the required COTS product lies within the critical path;
- The reliability of the COTS product has direct impact on the overall reliability of the system;
- Risk and safety impact of failure of the COTS item; and
- The maintainability impact.

We observe, also, that the recognition of the factors associated with these issues is often challenging, particularly where the nature of the COTS item is far from the core business and expertise of the acquiring organisation. For example, engineers who do not have direct experience of a particular kind of technical issues, such as the communication protocol issues encountered in the SIS – Stage One case 1 above, may be unaware of what questions to ask to evaluate the possible implications of a choice. Similarly, assessment of the risk, safety and maintainability implications of a particular COTS items is very difficult for engineers without direct experience of the modes of failure associated with the item or class of items, and therefore makes it difficult for them to even know where to look for the information they require to make an informed judgement of the impact of their choice.

Since the function of the COTS product is mission critical, although the item purchased is intended to be the one deployed in the finished system, if a test demonstrates that it is unsuitable, then that COTS item would be rejected and an alternative would be selected and tested for appropriateness. The investigator would have gained very useful value from the discovery of the unsuitability in a test situation. Thus, for mission critical COTS products, it is justified to allocate considerable resources to the selection process because the impact of the decision is of the magnitude of the impact of the implications of failure, on any one or combinations of:

- The successful completion of the system mission;
- The impact of failure on the system, users and other stakeholders; and
- The cost and availability impact of maintenance that may be required.

To this end, it is justified to use methods such as Model-based Systems Engineering (MBSE) or possibly to establish a tender process in which the supplier is required to demonstrate the item's capability with respect to the critical operational issues. The major difficulty is that people without experience of particular technology may be unaware of when they are extending beyond their knowledge.

SIS MBSE COTS Selection Approach. Model-based systems engineering (MBSE) consists of two major areas:

1. The use of a model-centric as opposed to a document-centric systems engineering paradigm; and
2. The use of models to inform system design.

The former has been the main focus of the INCOSE MBSE Initiative working group, where a comprehensive survey of the state-of-the-art developments in MBSE executable models are surveyed and reported (Estefan, 2008). This section focuses on the latter, and reports on its application in the process of COTS product selection. The implementation of the SIS - Stage Two was informed by the lessons learned in Stage One, in which the COTS selection process was extended to include the development of simulated models to evaluate the added capabilities and performances of selected each candidate COTS product, and validate against what can be obtained from the product brochure, datasheets and through direct contacts with supplier representatives. This has led to much better performance and eased the systems integration process significantly (Do et al., 2010). Although, this was achieved at the expense of additional effort in modeling various aspects of the COTS products under investigation, the cost of the effort is comparable with the cost of the COTS units, however, this was justifiable as the COTS unit was mission critical.

Use of an MBSE based approach is dependent on having the right kind of data available to describe the candidate COTS items. Without the right data there is no foundation to construct the MBSE analysis and the method is ineffective. In turn, this approach demands that the acquirer be able to obtain the necessary data to feed the analytic models. Construction of effective models is an expert activity, demanding knowledge of the relevant factors pertaining to the situation

Establish a Tender Process. The acquirer could establish a tender process in which tenders are called for against a specification of the item required, with the stipulation that the technical description be against an acquirer defined specification template, and the transaction to happen according to a set of acquirer defined terms and conditions. Interested potential suppliers would be required to complete bid documentation, submit in the required manner, and await the acquirer's response. This process presupposes that the acquirer is a competent buyer, and has knowledge of the class of product which enables writing of an effective call for tenders documentation pack, and that the acquirer has the ability to appropriately evaluate the tenders received. Both these assumptions are quite strong, and in many cases will not be adequately supported by the personnel available to the acquirer, particularly where the COTS item sought is outside the normal expertise of the acquirer.

A further difficulty with the establishment of the tender process is the cost of the acquisition process itself but justifiable if the COTS product is classified as mission critical. The acquirer must prepare a technical description of the COTS item sought which is general enough that any item which satisfies the acquirer's needs would be eligible, but would exclude any item which would not satisfy the need. Writing documentation which would achieve this purpose is a significant technical challenge for any item, and extremely difficult, if not impossible, in cases where the reason for seeking a COTS item is that the technical area is outside the expertise of the acquirer. In addition, the cost of the legal documentation will be considerable, even if the preparation work is simply to tailor a standard form acquisition contract to fit the specifics of the case. These acquisition processes are only effective where the item to be acquired is of substantial value.

The tender process also presents a problem from the supplier's side. The cost of the effort to respond to a call for tender, even where the solution offered is a standard item from the catalog, is considerable unless the acquirer has taken particular effort to simplify the tender's task. If the acquirer has demanded a description of the product offered against a set of acquired defined specifications, if these do not match the marketing brochures of a prospective supplier it will be difficult for the tenderer to prepare their documentation, and for modest value items, such as motor vehicles, the cost of obtaining the non-brochure information may exceed the profit margin that the supplier would expect to make in a normal price sale, thus leading to a no-bid decision.

In such cases the most useful approach to obtain as broad a range of offers as possible may be to approach potential suppliers, possibly from a pre-determined list of accredited potential suppliers, with a request for product descriptions and prices of their product range that fit the desired class of product. Soliciting their 'best offer' and standard product marketing documentation is likely to provide the most useful range from which to select.

Non-Mission Critical COTS. In this case, in theory, a failure of the COTS item to perform as expected will not prevent satisfactory completion of the prime mission of the system with which it is associated, and the failure should not produce serious impacts related to safety, maintenance, availability and sundry other classes of risk. For example, the failed COTS item may be left in-situ in its failed state until the next maintenance opportunity, during which the COTS item could be repaired in parallel with other maintenance activities.

However, caution is required in dismissing the effect of failure is because once system users become accustomed to the presence of the service provided by the COTS item it may become, at least, psychologically important. One of the reasons that one desires the non-mission critical COTS item is that it provides an enhancement to the situation. Users of the system may become accustomed to its presence, and desire its capability, perhaps to the extent that in the event of failure, that failure becomes a source of distraction to them and results in diminished fulfilment of their mission task. Alternatively, users may become so accustomed to the presence of the COTS item that the manner with which they interact with the system presumes the presence and capability of that item, and in its absence they are unable to perform tasks because in their manner of use of the system they have not practiced the use methods associated with the absence of the effect of the COTS item. That is, there are cases when the impact of loss of effect from a non-mission critical item may have a deleterious effect on whole system performance associated with the loss of the desirable effect which it was meant to have once users of the system have become accustomed to the presence of the COTS item. For example, in-seat entertainment systems are non-mission critical in civil aviation, but where an installed system fails it irritates a paying customer, possibly to the extent that their airline preference may change, or it may affect the customer's perception of the quality of other, less visible, maintenance activities, which may also impact airline preference.

Any COTS item selection process is likely to have a significant selection cost overhead, because of the need to obtain product information and transaction offer information in order to provide basis for a selection decision. It is likely that a selection overhead of 10-15% of the product price may be incurred, with lower value items incurring a higher proportion of their purchase value in the selection process, largely because of the value of the time consumed in the information gathering process. Since the non-mission-critical COTS item is, by definition, non-critical, in the event that an unsuitable choice has been made, the worst outcome is that the item be not commissioned to service. If it is the kind of item with a reasonable second-hand market, the availability of low-cost per-to-peer trading networks, such as e-Bay, enables disposal with the opportunity to recover a significant proportion of the initial outlay, further reducing the risk of wrong product selection.

Get the Real User to Select*t.* In some cases products are obtained by an acquiring organisation with a view to the items being used by certain people in the organisation. Two scenarios can be identified:

1. The organisation obtains the items and provides them as the tools for particular individual staff to use;
2. The organisation obtains the items for pooled use by any staff member.

Where items are obtained for pooled use, the acquisition decision needs to made centrally so that the required items are provided and any staff member using the item will have an equivalent item to use. The acquisition process would be well advised to avoid a purely clerical decision process, and to involve either a group or a single representative of the user community, such as the person responsible for the organisational unit in which the tool will be used. This kind of involvement in the decision process ensures that specialist knowledge of the activity that could impact tool choice is incorporated into the selection process, without the overhead of a substantial documentation process which can still suffer from the imposition of unrelated selection criteria imposed from the administrative side for the transaction.

Where items are individually allocated, such as tools for trades people, centralised decisions often lead to frustration that the items acquired suit the central purchasing criteria, but not the individual users, and so there is a problem of a 'one size fits all' type of acquisition. At the same time, the acquiring organisation needs to control expenditure to meet budgetary criteria, and the cost of including each user in a central purchase process would be prohibitive. However, a simple alternative exists, provide each final user with an allowance or voucher to purchase their choice of item, possibly restricting the choice of supplier. This approach enables each end user to select the item they will use, enabling them to feel involvement in the item choice and to provide them with the ability to select from the range available the item that they feel most comfortable using. From the acquirer's viewpoint, the overhead of deciding which particular item will be purchased, and the development of selection criteria for that decision is removed, although there is a new overhead of dealing with a number of accounts for separate purchases, although the new overhead could be managed by choice of the particular process used. This approach would overcome the problem of the $500 hammer.

SUMMARY

The use of Commercial-of-the-shelf (COTS) items in deployed systems is becoming increasingly commonplace due to increasingly rigorous drives for demonstration of cost efficiency, rapid technology evolution in many commercial product fields and the variation of system requirements during projects. This paper has discussed the issue of appropriate COTS product selection based on the classification of prospective COTS items as mission-critical and non-mission-critical. Based on this classification, it then justifies the level of efforts to be allocated to the COTS selection process. The effort expended on non-mission-critical COTS item selection would often be in the range of 10-15% of the purchase price. For mission-critical COTS products much larger selection costs, possibly of multiples of the COTS item price are suggested. The cost saving mechanism suggested in the case of mission-critical COTS selection is to work sequentially, using the vendor descriptions of products, through the list of candidates in rank order of *a priori* preference. A case study based on our Systems Integration Sandpit and external examples were reported to illustrate the complexity and flexibility in the COTS selection process for the acquisition of COTS products.

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