Business Justification of Open Architecture Control

White Paper Version 1.0

Executive Summary 3

Phase I: Justification 5

Phase II: Design & Development 7

Phase III: Acquisition, Build, & Installation 9

Phase IV: Product Production/Operation 13

Phase V: Maintenance 17

Phase VI: Reconfigure/Improve or Disassemble/Phase-out 20

Life Cycle Phases for Business Justification of Open Architecture Control

I. Justification

II. Design & Development

III. Machine Acquisition, Build, & Install

IV. Product Production/Operation

V. Maintenance

VI. Reconfigure/Improve – Disassemble/Retirement

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Executive Summary

Both process and discrete manufacturing industries are increasingly evaluating Open Architecture Control (OAC) technology as a means of achieving a variety of benefits such as reduced machine downtime, easy integration of custom technologies, and improved response to changing customer demands. When evaluating OAC relative to existing proprietary schemes, however, the bottom line is total life cycle cost comparisons. How does the total life cycle cost of OAC compare to traditional approaches, and what tools can be used to financially justify OAC from this perspective?

This paper presents the findings of the OMAC Working Group on Business Justification of Open Architecture Control. Identification and justification of costs associated with each phase of the life cycle of manufacturing equipment, and the impact of open architecture controls on those cost elements, are the focus of this report.

Also associated with this paper is a capital equipment justification software tool that can be used to analyze the life cycle costs of Open Architecture Controls. This tool has been used to compare costs of specific projects at different levels of openness.

Life Cycle Phases

The following life cycle phases have been identified by the Working Group and are the focus of the justification effort:

I. Justification
II. Design and Development
III. Machine Acquisition, Build and Installation
IV. Product Production/Operation
V. Maintenance
VI. Reconfigure/Improve – Disassemble/Phase-out

OMAC Requirements

Open control system definitions presented by Chrysler, Ford & GM in the original 1994 white paper, "Requirements for Open, Modular Architecture Controllers for Applications in the Automotive Industry" form the foundation of the business justification effort. Those requirements specify that open control systems must be:

- **Open** - allowing the integration of off-the-shelf hardware and software components into a controller infrastructure that supports a de facto standard environment.

- **Economical** – achieving low life cycle cost.

- **Maintainable** – supporting robust plant floor operation (maximum uptime), expeditious repair (minimal downtime), and easy maintenance (extensive support from controller suppliers, small spare part inventory, integrated self-diagnostic and help functions, etc.).

- **Modular** – permitting "plug and play" of a limited number of components for selected controller functions.

- **Scaleable** – enabling easy and efficient reconfiguration to meet specific needs of low to high end applications.

It is clear today that these requirements stipulate a complete paradigm shift in the controls industry. A variety of vendors, both established and new, have emerged to provide open architecture solutions that represent an alternative to traditional proprietary solutions. It is now possible to plug and play various hardware and software components and to extend the behavior of a control system to meet the requirements of a particular application.

New markets for these types of products are already emerging. For example, ARC Advisory Group reports that although the PC-based CNC market is currently in its infancy, it accounted for $7 million in revenues in 1998. Even more telling, ARC forecasts this market will grow at a compound annual rate of over 103 percent through 2003.

Many individual project costs are discussed in each of the life cycle phases presented here, including those impacted by OAC and those that are not. Costs likely to be impacted by OAC are presented in each phase. For example, the impact of declining prices for commercial PCs on control hardware costs is discussed in the Machine Acquisition section. Training costs for operation and programming are covered in Product Production/Operation. Maintenance costs, downtime and spare parts inventories are covered in the discussion of the Maintenance phase, while control re-configuration costs are detailed in the Reconfigure/Improve Phase.

Potential benefits such as these are not the only drivers behind the rapid growth rates predicted for open architecture control. The paradigm shift from proprietary to open architecture has broader implications and benefits that are yet to be fully realized. The move from bundled hardware and software to unbundled software reemphasizes the importance of standards while at the same time allowing customization through published APIs and third party applications. The move from support provided only by experts to user-installable consumer products brings the World-Wide Web, multi-media applications, and remote diagnostics to every operator station.

> OMAC requirements will result in a complete paradigm shift in the controls industry.

Open Architecture Controls allow new insight into manufacturing operations. Control systems no longer simply control the machine, they now provide open access to real-time data and information that can be used to optimize manufacturing processes. Open architecture control systems can collect data from cycle times and feed rates to setup and inspection times, all of which allows continuous process improvement and increased productivity and quality.

The following sections contain further definition and explanation of the six life cycle phases inherent in the majority of manufacturing-related capital expenditure projects, whether impacted by OAC or not. Cost elements deemed to be impacted by OAC are highlighted in the discussion of each phase.

Although no one project or program will encompass all elements identified here, the goal is to provide enough breadth and depth to encourage the individual to think beyond traditional approaches when identifying potential costs and benefits associated with Open Architecture Control.

Phase I: Justification

The Justification Phase of a life cycle investment model typically consists of concept development and initial project planning. This is where the business looks at its strategic direction and defines a project or upgrade that the business expects will address a particular set of business needs. It is also where the business needs to assemble the resources necessary to understand the total scope of potential costs and benefits and to address the cost of this knowledge and the market opportunity presented by the new automation system.

The justification phase must identify the critically important process parameters to be controlled and address the total costs of implementation and maintenance over the entire life cycle. These costs can be broken down into one-time costs and recurring costs. One-time costs consist of design and specification, acquisitions, engineering, installation and application software development. Recurring costs consist of training, support, system maintenance and optimization, repair, and spare parts. Consideration must be given to the anticipated life of the system, expected upgrades, and financial measures such as tax rate and the cost of capital. Need for the proposed solution to address both short term and/or long term business objectives should also be evaluated.

Cost elements in the justification phase include both one-time and recurring costs.

These costs must then be evaluated against the potential benefits of the new or upgraded system. Some potential benefits include improved time to market, increased production yield, lower product cost, increased production capacity, reduced inventory, optimization of production workforce, and decreased overhead.

Key elements of the Justification Phase are listed below. Life cycle elements identified with an asterisk have been determined to be significantly impacted by open architecture technology and are explained further below:

* Cost of Knowledge
- Business Applications
- Technology, or the cost of assuring that all products will work together
- Financial Analysis, or the cost of running the numbers
- Requirements Planning
- Feasibility Studies

The market opportunity for flexible manufacturing should also be considered in the Justification Phase when open architecture controls are employed.

Cost of Knowledge

Cost of Knowledge is the key element impacted by open architecture controls in the Justification phase. This term refers to the internal or external understanding of the key process parameters of the business and/or product application to be addressed. It refers to the understanding of current technologies and how they come together in the automation system. Included in this element are the availability and use of tools to provide for feasibility studies, what–if scenarios, and financial analysis of the proposed automation system. Cost of knowledge also includes the costs associated with development and publication of the necessary plans and documents to support the automation system definition. Cost of Knowledge can be best assessed by a multidisciplinary team that includes internal organizations and key suppliers such as equipment providers, OEMs, and system integrators.

Cost of knowledge is the key cost element impacted by OAC during the justification phase

Phase II: Design & Development

The Design & Development Phase of a life cycle investment model will typically consist of the time and costs associated with the actual detailed design of the machine or system, including initial procurement activity. The costs incurred here will be minimized if adequate work and planning were completed during the justification phase. Changes made during this phase, although many times necessary, are one of the primary causes of overall project cost overruns. Manufacturing strategies over the life of the machine must be an integral part of the decision making process behind specification of the capital equipment.

Life cycle cost elements incurred in various phases of the Design & Development Phase are listed below. Life cycle elements identified with an asterisk have been determined to be significantly impacted by open architecture technology and are explained further below. Key metrics for each cost component are indicated in parentheses:

- Internal purchase order cycle/process costs ($)
- * Design and specification engineering time (hours)
    - Finite element analysis.
    - Simulation
    - Design Engineering Training (internal and external)
    - Design for Maintainability
- Design and specification drafting time (hours)
- * Engineering time for logic programming and configuration of controllers, HMI, and other system elements as well as part programming (hours)
- Manufacturing engineering drafting time (hours)
- Documentation (hours)
- * Personnel needs in areas such as skill set assessment and internal or external engineering training ($ and hours)

- Development support and preventative maintenance plans (hours)
- Failure Modes and Effects Analysis (FMEA) ($ and hours)
- Logistic support requirements (hours)
- Development of training courseware ($ +/or hours)
- Length of time to product change ($)
- Lead-time (hours)

* Factor for expediting delivery: factor applied, if necessary, to adjust the basic machine or equipment cost based on actual delivery date

- Opportunity cost associated with the time lag between market identification and exploitation. The formula for this is Cost = missed market x market share ($)

Additional considerations during the design & development phase include potential cost savings when the control and HMI are integrated into one box and the ability to choose best-of-breed, plug and play components.

Cost Element	Metric
Design & Specification Engineering Time	Man-hours
Logic Programming & Configuration, part programming	Man-hours
Training	$$$ and Man-hours
Delivery Expediting	$$$

Design & Development Phase Elements Impacted By OAC

The following sections highlight some of the elements of the design & development phase that will be significantly impacted by use of open architecture controls.

Design Engineering

OAC is intended to allow for a common hardware or software platform that is easily adaptable and scaleable across multiple applications. Once established, variables like I/O, communication, operator interface, etc. can be used across multiple designs. This significantly reduces re-engineering time and cost and enhances design reliability. Simulation tools could also be used across multiple designs, resulting in design consistency as well as flexibility.

Logic Programming & Configuration, Parts Programming

Open architecture control systems are intended to use open programming languages that enable companies to select and standardize on one format. This reduces the training time associated with configuring multiple control systems and maintaining multiple post processors. For example, ladder logic could be specified as the controller language regardless of control selection, therefore enabling a particular shop to take advantage of a technical staff already trained in the language. The OAC would also be able to easily adapt to a company's tool interface or reader without causing configuration changes.

Personnel Needs

Personal computers (PCs) are now common throughout industry. For the most part personnel are very familiar with the PC environment, especially new hires and college graduates. However, each company will experience different initial costs associated with moving to OAC depending on their current personnel skill levels. Costs associated with recruiting, hiring, and retaining qualified personnel should be anticipated. Initial engineering training costs associated with adapting the open mentality for existing staff must also be taken into consideration.

Phase III: Acquisition, Build, & Installation

The acquisition, build, and installation phase of a machine or equipment life cycle investment model consists of the time and costs associated with the actual build and installation of the capital equipment as well as the costs incurred in training the personnel to operate the new equipment.

Life cycle cost components in this phase are listed below. Life cycle elements identified with an asterisk have been determined to be significantly impacted by open architecture technology and are explained further below:

- Acquisition or Purchase Price of the following: ($)
    - Machine or equipment to be controlled

  - * The control system
  - All tooling necessary for start-up, whether capitalized or expensed. Most perishable tooling can be included in the initial capitalization of a project if used for prove out or run-off.
  - Any miscellaneous peripheral equipment associated with the project, such as cabinets, benches, etc.
- Machine or Equipment Capitalization Value: this dollar value usually contains all costs associated with the project that can be included in depreciation calculations, such as machinery or equipment, miscellaneous cabinets, some tooling, etc. ($)
- All material handling equipment necessary to the project ($)
- * Any special support equipment required to specifically support this machine or system, such as system analyzers, PCs, etc. ($)
- * Initial System Test and Evaluation ($ +/or hours)
- Fabrication, assembly, and test associated with equipment prove-out at supplier before allowing shipment of pre-production models. This component should include material costs for test parts, travel expenses, laser and ball bar validation of machine capabilities, analysis of results, etc. ($ and hours)
- In-house fabrication, assembly, and test of production models that duplicate supplier's pre-production run-off to assure that no changes occurred during shipment and re-assembly. ($ and hours)
- * Installation costs and time associated with software, labor, outside contractors, start up re-engineering, etc. ($ and hours)
- * Initial training costs ($ and hours)
- * Networking & direct numerical control (DNC) capability ($ and hours)
- Validation & Documentation (hours)
- Miscellaneous Initial Cost ($)
- Cost of not investing in the proper equipment to produce today's technology. This can translate to loss of revenue and/or loss of market share.
- Lead time: depending on project lead time, additional inventory may be required. This also includes transition and switching costs. ($)
- Outsourcing, or the cost of producing product through sub-contracts. There is an obvious cost to outsourcing a product for any duration in order to allow time for new equipment to come on line. ($)
- Foundation space preparation and contractor costs for foundation pour, if required ($ and hours)
- Cost of money or the capital discount factor ($)
- * Risk associated with system ownership
- * Vendor viability

- Tax rate and tax incentives
- Riggers ($ and hours)
- HVAC cost ($ and hours)
- Labor agreement ($ and hours)

Additional considerations for the acquisition, build, and installation phase include use of in-house staff for installations and the fact that open architecture controls support user independence.

Cost Element	**Metric**
Control System Purchase Price	$$$
Special Support Equipment	$$$
Initial System Test & Evaluation	$$$ +/or man-hours
Installation	$$$ and man-hours
Initial Training	$$$ +/or man-hours
Networking/DNC	$$$ and man-hours
Risk of System Ownership	$$$ and man-hours
Vendor Viability	$$$ and man-hours

Acquisition, Build, & Installation Phase Elements Impacted By OAC

The following sections highlight some of the key elements of the acquisition, build, and installation phase that will be significantly impacted by use of open architecture controls.

Control System

The acquisition or purchase price of control systems varies dramatically depending on such things as manufacturer, number of I/O to be controlled, additional functionality required, etc. Depending upon the individual application, the initial cost of an open architecture controller could either exceed or be less than a proprietary controller. We believe that, as controller hardware standardization becomes more prevalent and downward price pressure continues, controller manufacturers will increasingly distinguish themselves on the basis of their software capabilities.

Initial System Test & Evaluation

This refers to the time and cost associated with additional system testing and evaluation to ensure proper and complete integration between machinery and controller. This cost element is identified as specific to open architecture projects due to probable additional costs incurred in this area vs. existing control systems. We believe this incremental cost disadvantage of open controllers will be minimized and ultimately phased out as more successful installations are completed and the increasing knowledge base is leveraged.

Initial Training Costs

This element measures the costs associated with training on the new equipment. This cost could initially be higher with an open architecture system since the labor force as a whole is still unacquainted with this technology. However, as the ability to incorporate common HMIs across multiple machines or systems becomes more available, this cost may ultimately be less than is currently incurred with the purchase of new equipment.

Networking & Direct Numerical Control Capability

This item refers to the costs associated with establishing communications to and from equipment. This includes, but is not limited to, DNC capability. This activity should include development of an internal, corporate-wide manufacturing communication strategy that encompasses communication software and hardware requirements, the information needed from the equipment and the format it should be received in, and who requires what data. This cost, however, should not be associated with any one capital equipment project, but should be amortized over the entire manufacturing base, or at least all of those projects within a given period that will take advantage of the communications capabilities.

Risk Associated With System Ownership

As with any new technology, until significant testing and implementation has been completed and a steady state is reached, there will be some degree of additional risk in the specifying and implementing of that technology. All responsible project managers understand this and will apply an appropriate risk/reward ratio. The benefits to be had from embracing an open architecture controller philosophy within any well-developed manufacturing strategy could show a high potential payback when compared to the associated risk. The larger risk to a given manufacturer may be to ignore the upside potential of an open, standard control architecture and continue with the "tried and true" proprietary controller.

Questions as to the long term viability of a product, the financial stability of the manufacturer/developer, and other questions of this type must still be analyzed and answered. New applications of technology encourage early adopters from the ranks of both producers and consumers. It is a natural evolution that not all who start the race will finish.

Vendor Viability

Many of the players currently in the open architecture controller development arena are smaller, less established companies compared to the major controller manufacturers, so there is an inherent additional risk in putting your eggs in their basket. This factor also plays a role in the risk associated with system ownership discussed earlier.

Phase IV: Product Production/Operation

The product production/operation phase recognizes the costs associated with day to day operation of equipment that has been purchased and installed to produce product.

Life cycle cost components in this phase are listed below. Life cycle elements identified with an asterisk have been determined to be significantly impacted by open architecture technology and are explained further below. Applicable metrics are indicated for each item where appropriate.

- Supplies (Hand Towels, Gloves, etc.) ($)
- Direct labor cost per production hour ($/hour)
- Burden hours (percent utilization) (hours/month)
- Material cost per operating production hour ($/hour)
- Power usage ($/kwh)
- Waste/lubrication and coolant ($/month)
- Durable tooling ($/year)
- Perishable tooling ($/part)

- Change-overs & setups per month (hours)
  - Depending on change-over, may incur additional costs for inventories & switching costs
  - Ramp-up to full production (hours to achieve)
- Scrap/rework (% of production)
- Production rate of quality product & reliability scrap (per production unit/hour or parts/hour)

* Annual engineering costs, including management (hours and $)
* Training

- Annual material handling cost
- Direct & indirect labor ($ and hours)
- Annual overtime (hours).
- Inspection & quality control ($ and hours).
- Performances percentage labor factor (%) – factor to be applied to account for labor inefficiencies

* Support personnel ($ and hours)
* System support from IT Group ($ and hours)
* Data collection and tracking, metrics ($ and hours)
* Planning and scheduling ($ and hours)

- Environmental concerns ($/year).
- Disposal of hazardous material ($/year).
- Miscellaneous costs ($/year).
- Machine space costs ($\$/ft^2$).
- Machine life (hours).

* Technology

- Product flexibility & customization, lead-time reduction cost

Additional considerations for the product production/operation phase include the following:

- Common look and feel
- Increased supply chain communications (vendor and customer)
- Information integration
- Improved quality
- Reduced purchase price (PPV)
- Elimination of sub-contracts
- Reduced in-house cost
- Scalability & ability to expand capacity

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Cost Element	Metric
Annual Engineering Costs	$$$ and man-hours
Training	$$$ and man-hours
Support Personnel	$$$ and man-hours
System Support from IT Group	$$$ and man-hours
Data Collection & Tracking, Metrics	$$$ and man-hours
Planning & Scheduling	$$$ and man-hours
Technology	$$$
Product Flexibility, Customization, Lead-time Reduction	$$$ and man-hours

Product Production/Operation Phase Elements Impacted By OAC

The following sections highlight some of the key elements of the product production/operation phase that will be significantly impacted by use of open architecture controls

Annual Engineering Costs

Manufacturing engineering in an open system environment will need to understand the interaction of the systems in place and be able to utilize those capabilities to maximize efficiencies. Engineers should be able to process product, taking advantage of data flow and the information systems that enhance manufacturing.

Programming skill will need to be available during start-up. Depending on the equipment, programmers will also need to be available on an ongoing basic for support and upgrades. Programmer skill may vary from system to system. Open systems may allow for additional efficiencies in programming support due to commonality.

Training Costs

This item reflects the potential for minimizing training costs through the look and feel of open systems.

Support Personnel Costs

Various internal support personnel assigned to the equipment may need additional training to take advantage of the capability that comes with implementation of an open system. Open systems will have additional diagnostic tools data available that can enhance a number of situations. Training for internal personnel supporting the system will also need to be taken into consideration.

Care also needs to be taken and cost consideration given to assure that support systems are in place with equipment suppliers that are installing new technologies.

System Support From IT Group

IT personnel will need to be educated on the entire system interaction available as a result of advanced system capabilities. Data will be available that can upgrade production and other business information in real time. The lines drawn between traditional IT personnel and control engineers are fading as open systems become more prevalent.

Distinctions between IT personnel and control engineers are fading as open systems become more prevalent.

Data Collection and Tracking, Metrics

Cost of data collection equipment needs to be established and understood. These costs may be higher for proprietary systems, as access to some information can be restricted.

Planning and Scheduling

Many material scheduling enhancements will be available due to additional computing power. A one time expense may be incurred to take advantage of the open system architecture.

Technology

This item includes the cost of assuring all products will work together, the cost of technology volatility, or the chance technology will change, and the risk associated with new technology or change.

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Product Flexibility & Customization

Due to the open system architecture, new equipment will be very flexible and will adapt to rapid product change. Reduced time to market will lead to market share increases. Data should be collected that gives consideration to profits generated as a result of technology advantages.

Reduced time to market through use of OAC will lead to market share increases.

Using OAC, equipment will be capable of being reconfigured at lower cost and with shorter lead-times. Each system being installed should have these savings estimated, and these savings should be considered as part of overall project evaluation.

Phase V: Maintenance

The maintenance phase recognizes the costs associated with maintaining machine control systems, and can often be where life cycle costs truly make an impact. Virtually all of the elements of the maintenance phase will be impacted by the use of open architecture controls.

The following sections highlight some of the key life cycle cost components related to the maintenance phase. Key metrics for each cost component are indicated in parentheses.

Number of Support Personnel (hours x rate)

It needs to be determined who will support open architecture systems: the same personnel as have supported proprietary systems in the past or should IT people already trained in open systems also be included.

Maintenance Personnel Training ($ and hours)

Do the maintenance people already have the training in open systems? If no, initial training costs could be higher. If yes, training costs could be lower. Training requirements could also lessen from increased commonality.

Training for Trouble Shooting ($ and hours)

Personnel need to be trained on how to troubleshoot open systems. Because multiple vendors are likely to be used on open systems, the training required may come from several different sources. Training on available remote diagnostics tools may also be required.

Downtime Costs ($ and hours)

Because open systems are more of a commodity, hardware repair costs are often less. Open systems may have a shorter life cycle due to available incremental technology upgrades, so parts replacement due to product obsolescence may increase. Users must understand the life cycle of the system components and assess the costs and benefits of replacement.

Lost production costs are a function of MTBF and MTTR. Due to availability of a broader range of troubleshooting and preventive diagnostic, lost production costs could be lessened in an open system.

Downtime costs include repairs, lost production, MTBF, and MTTR.

The hardware MTBF can be largely dependent upon whether the correct hardware was purchased for the application, e.g. a desktop system installed in a rugged industrial environment will have a significantly lower MTBF than an industrial grade system. The software MTBF can be dependent upon how well the various applications have been tested to insure they interoperate correctly.

Mean Time to Repair (MTTR) is largely dependent upon the expertise of the support personnel to maintain the open systems. There may be commercially available tools for open systems to aid in shorter MTTR. At times it is possible to run into problems that make it hard to determine which vendor's hardware or software is causing the problem. This can lead to longer MTTR due to vendor finger-pointing.

Total Spare Parts ($)

If open systems become widely used the parts cost can be much less since the same open system parts can be used in multiple applications. The hardware cost of these open systems is also usually less than proprietary hardware due to the commodity nature of open systems. The turnover of these spare parts will be faster since open systems have a shorter life cycle. Spare parts carrying costs are also a factor in this equation.

Software Maintenance and Configuration Control ($ and hours)

Open systems software is usually subject to a more rapid rate of change, and therefore requires more software version upgrades. The testing of new ver-

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sions of multiple vendors' software packages on a single system requires integration testing often done by the system owner. The upside is the incremental benefit obtained with each upgrade.

Ongoing Preventative Maintenance ($ and hours)

Open systems often contain some diagnostic capability that can be easily leveraged. Some of this diagnostic capability is dependent upon the software vendor leveraging what is available. Other elements of this component include diagnostics, corrective action, and failure analysis.

Maintenance and Optimization Maintenance Contract ($)

A maintenance contract is available for most software and software systems. Contract terms can range anywhere from phone support to on-site support. This cost could be less on open systems due to the commonality of components.

Support Costs (hours)

Commercially available software can be leveraged to make back-ups simple to do. Some applications will do automatic unattended backups.

Revision control can be time consuming due to the speed at which hardware and software revisions occur. This revision control often requires the user to test multiple applications to ensure the complete system will continue to operate reliably. There will be a cost associated with the development and maintenance of test suites used to validate changes. Software support contracts are usually required to obtain the revision updates.

Technology

The task of assuring that all products will work together is typically done by the end user or a systems integrator. As for technological volatility, or the chance of technology change, the life cycle of open systems is relatively short versus traditional control systems. Open systems may become obsolete faster than traditional control systems because of the shorter life cycles of their hardware and software. Open systems are also often not tested to the same level of robustness that mature control systems have been, resulting in higher risk for some applications.

Additional considerations for the maintenance phase include:

- Multiple and local source of parts.
- PC, mass market prices.
- Less requirement for specialized maintenance staff
- Training for maintenance staff reduced

Phase VI: Reconfigure/Improve or Disassemble/Retirement

The primary differences between traditional systems and open-architecture systems lie in their ability to adapt to new environments. In this section, we describe the major elements that are affected by those changes. In any evaluation, these elements should be captured as much as possible with quantitative information. We recognize that many of these values are quite uncertain and difficult to judge.

A fundamental assumption in the evaluation of reconfiguration, improvement, and disassembly or phase-out is that a full equipment life-cycle is considered and not just its use for a single product or model. Suggested metrics for each cost item are indicated in parentheses.

Recovery or Salvage Space Costs ($)

These costs should include all cash flows associated with re-using the space originally occupied by the system under consideration. Costs may include the need to re-fit the space for other uses, potentially negative costs (i.e., net revenues) for selling space, and any costs associated with future environmental concerns. The salvage value of some open systems hardware may be diminished due to the short technology life cycles.

Reclamation and Disposal of System Components ($)

These costs should include all cash flows associated with changing or eliminating the use of system components for a different purpose or design.

Salvage Value of Equipment at End of Life/Cycle ($)

This reflects the value of any equipment sold at the end of the system's use. Attention should be given so that the salvage value is a net future cash flow.

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The calculation should include the difference between salvage and book value that results in cash flow on taxes.

Costs for Banking or Outsourcing Over Changeover ($)

These are the total costs associated with running over-time or outsourcing production in order to accommodate a change from one product or process to another. These costs would be discounted to the current time based on the date assumed for changeover.

Modification Requirements: Rebuild, Retrofit or New

These costs should include all of the labor and additional equipment costs that will be necessary to ensure continued production after some change in production.

Training Costs ($ and hours)

These costs include all costs associated with training personnel for any new uses of equipment or additional equipment necessary for using original equipment for a new purpose.

Technology

These costs include the amounts required to purchase and install new technology into original-purpose equipment. These costs are broken down among the following items:

- *Cost of assuring all products will work together*: This includes the cost to check that all products work together or for paying outside vendors to guarantee such compatibility.
- *Technology volatility (chance of technology change):* This factor should be a multiple of all costs associated with adjusting to technological change so that markets with higher rates of technological change have higher costs here.
- *Equipment lifetime and chance of obsolescence:* As with technological volatility, this is a multiple of technological change and other changeover costs that should increase with the chance of equipment becoming obsolete. In the case of using old equipment, this factor should increase as well.
- *Risk associated with new technology or change*: This is again a multiple of other costs associated with technological change. It refers to additional

costs incurred only because of the risk (not just the expectation) associated with technological change.

Demand Volatility and Market Dynamics

Analysis of the factors listed above should incorporate the specific costs associated with changing product lines. Product volatility, or the range of variation in demand over the years, should incur additional costs among all potential equipment installations. This factor should increase with the volatility in demand and chance of product change but be less for open-architecture than for dedicated equipment.

Additional Considerations

Beyond the cost elements described above, the benefit elements during this stage are quite difficult to quantify but are especially affected by the choice of open architecture compared to traditional equipment. Some potential benefits include:

- *Ability to apply new technology to existing machines:* this factor should be considered in the re-use of the equipment above. However, intangible factors may play a role in these decisions.
- *Reconfigurability*: the ability to reconfigure existing equipment to meet new needs is a particularly power capability.
- *Portability*: this factor is not explicitly incorporated into the computations given above, however an organization generally achieves efficiencies by installing a particular kind of equipment in several facilities. This allows that technology to be portable among different installations. The installation savings at these places leads to additional savings that should be considered here.
- *Scalability or the ability to expand*: these costs may be captured in the calculations above or can be considered an expanded benefit that is calculated here.

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Acronym Reference: For a complete list of industry acronyms, refer to ARC's web page at http://www.arcweb.com/world/docs/term.html

API	Application Program Interface
CNC	Computerized Numeric Controller
DNC	Direct Numerical Control
HMI	Human Machine Interface
OAC	Open Architecture Control
OMAC	Open Modular Architecture Control
PLC	Programmable Logic Controller

ABOUT THE OMAC USERS GROUP

The OMAC Users Group was formed to create an organization through which companies could work together to:

1. Establish a repository of open architecture control requirements and operating experience from users, software developers, hardware builders, and OEMs.
2. Facilitate accelerated convergence of industry and government developed APIs to one set, satisfying common use requirements.
3. Collaborate with European and Japanese Groups in pursuit of a common international API standard.
4. Promote open architecture control development among control builders
5. Derive common solutions collectively for both technical and non-technical issues in the development, implementation, and commercialization of open architecture control technologies.

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