Modernizing Your Automation System with I/O on Demand

A brown field system modernization case study concludes that using DeltaV™ CHARMs I/O mounted in field junction boxes will reduce costs when compared to traditional homerun cabling to a central rack room.

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Introduction

Market studies indicate that tens of billions of dollars worth of automation systems in operation today are reaching "end of useful life" economic and functional status. Plants with these legacy systems struggle to keep pace with best-in-class competitors. Upgrading to the latest technologies is essential for improved business results. [1]

The contribution made by automation to a plant's bottom line has increased significantly since the early days of pneumatic instrumentation and panel board operation. Advances in electronic transmitters, final elements and distributed control helped to improve plant efficiency and product quality. A major paradigm shift came with digital plant architectures which enable tighter integration of field devices and business systems with the control network. Technologies were developed to turn vast amounts of diagnostic data into meaningful decision support information for operations, maintenance and plant business management.

The latest advancements have been to reduce complexity, eliminate unnecessary work and embed essential knowledge into technology. These changes reflect Emerson's dedication to understanding work processes in order to determine and devise methods to improve the way people work. This area of study is called Human Centered Design (HCD), and its position on the continuum of automation system user experience is depicted in Figure 1.

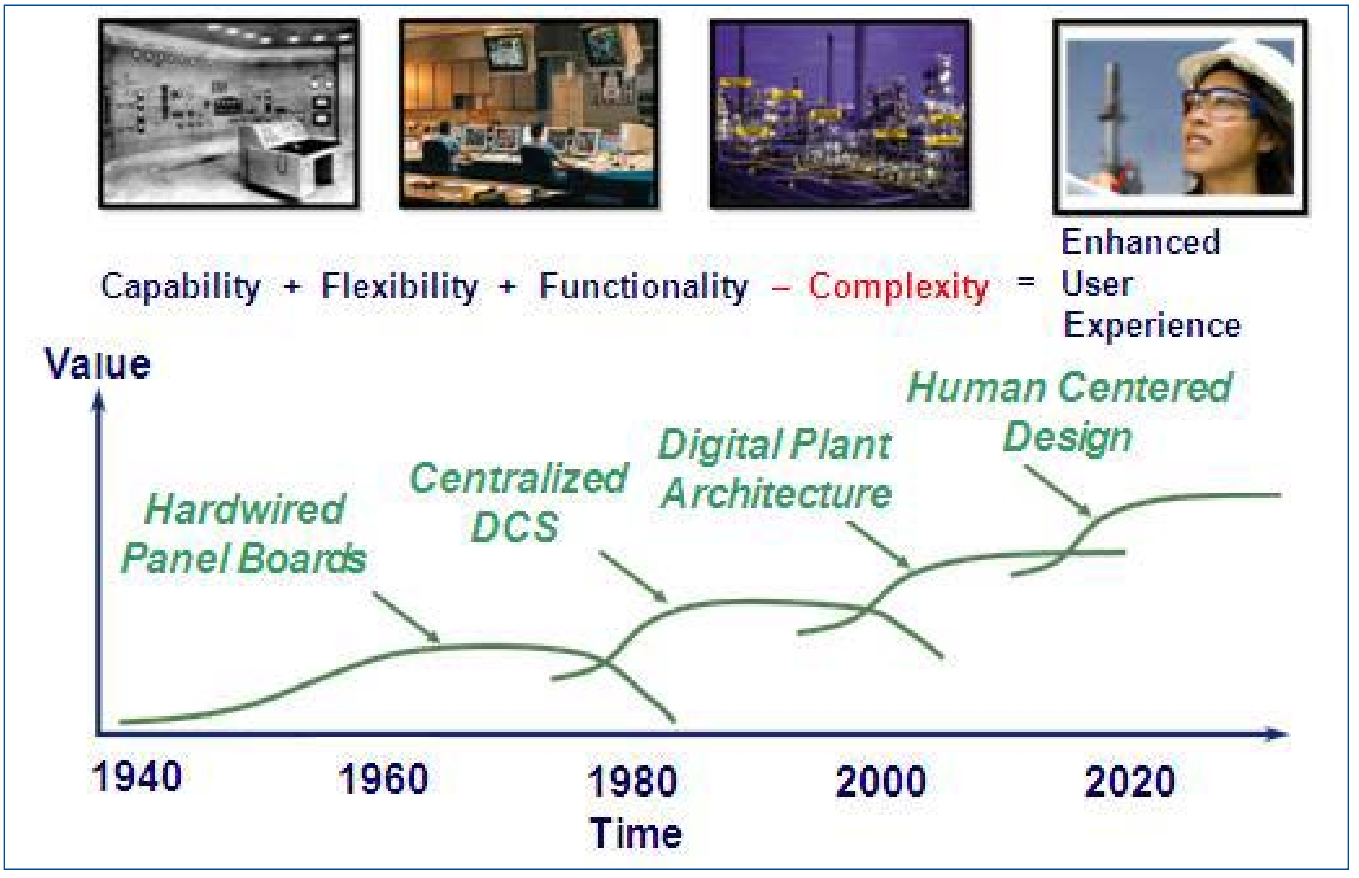

Figure 1 — *Value of Process Control Systems Increase as Technology Improves.*

In the 1980's, Emerson developed HART protocol, and later donated it for open use. Similarly, Emerson has broken new ground through HCD, incorporating it into all DeltaV™ version 11 products. One of the most innovative offerings is the highly flexible "I/O on Demand"[2], which includes DeltaV S-Series Traditional I/O , Electronic Marshalling, H1 Card with Integrated Power, Redundant Wireless I/O and more.

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[1] *Considerations for Modernization are expanded in Appendix A*
[2] *I/O on Demand is further defined in Appendix B*

This paper presents DeltaV version 11 I/O on Demand in a case study involving a legacy or "brown field" system modernization to a DeltaV systemusing traditional wired I/O and field signal marshalling. This study shows actual costs and labor for the original project versus theoretical costs and labor using today's I/O on Demand where feasible, to reduce engineering and installation costs.

Modernization Case Study

In an effort to validate the magnitude of cost savings available with I/O on Demand solutions, Emerson engineers re-evaluated the brown field modernization project (Case A) that was completed at a North American chemical facility in 2006-2007,asking: "How would the project have looked, had electronic marshalling been available?" And, "How would the total installed cost have been affected?" The following case study (Case B) answers these questions and the results leave no doubt that electronic marshalling is truly a game-changing technology.

Case Study Assumptions

In the case study, some costs are held constant, at 2006 – 2007 levels, when the actual project (Case A) was executed. Here are the items that are unchanged for the new project estimate (Case B), which was developed in 2010.

- Construction staffing and project overhead costs for personnel at levels above general foreman
- Labor rates and materials pricing
- DCS configuration, display development, Factory Acceptance Test (FAT), Site Acceptance Test (SAT) and training costs
- DeltaV system hardware and software licensing costs

Also, areas in the original project that required no new homerun cabling were kept "as is" for Case B, i.e., they were not reassigned to any new I/O type or electronic marshalling.

Case A – Actual Project Scope of Work

The project replaced a late 1980's distributed control systems (DCS) in process and utilities plant areas with a new DeltaV process automation system. Scope of work included 85,000 home office hours. Project tasks included:

- Front end engineering design (FEED) and detailed engineering to reassign ~ 5,500 hardwired I/O to the new DeltaV system
- Replace ~200 field instruments
- Design and install new plant-wide fiber optic network
- Design and install power distribution and grounding as needed
- Configure DCS controls and displays.
- Design interfaces to third party equipment including safety systems, machine vibration monitoring, process analyzers, plant historian and an advanced control package
- Conduct FAT and SAT
- Train operators
- Commission loops and support startup
- Plan and implement cutover. Hot cutover[3] was used for approximately 50% of the hardwired I/O during initial startup, with remaining I/O switched over during a turnaround.

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[3] *Hot cutover is contrasted with cold cutover in Appendix C*

Case A Subset – Basis for Comparison with Case B

The case study comparison addresses only a subset of the actual project scope, as described here:

Marshalling, homerunsfield junction boxes

- Analog and digital I/O from 76 existing field junction boxes (FJBs) were terminated at new marshalling panels in the DCS rack room where DeltaV controller cabinets were installed
- 75 homerun cables from 76 FJB's were replaced due to deterioration from age
- To minimize downtime, existing marshalling panels that housed terminations of homerun cables being replaced, were not reused
- Designed and fabricated custom cabling between new marshaling panels and DeltaV I/O modules to expedite cutover during turnaround
- Prior to the plant shutdown, new homerun cables were terminated at new marshalling panels
- Made terminations at existing field junction boxes during plant shut down
- Installed 8 new FJBs to accommodate new I/O to replace pneumatic controls
- Pulled 8 homerun cables from these new FJBs to the DCS rack room

Thermocouples

- Rewired 473 thermocouple temperature signals from 22 existing FJBs to Rosemount 848T high density temperature transmitters using FOUNDATION fieldbus.
- 22 FOUNDATION fieldbus trunk cables were pulled back to the DCS rack room

Summary

- A total of 75 + 8 = 83 new homerun cables were pulled from the field to the DCS rack room along with cable for 22 new FOUNDATION fiedlbus segments
- 1,300 feet of new cable trays, tee supports and multi cable transits were required, and existing cable trays were utilized where possible

This project subset as originally installed is shown in the following figures. Figure 2 illustrates cross-marshalling to align field signals to assigned I/O modules.

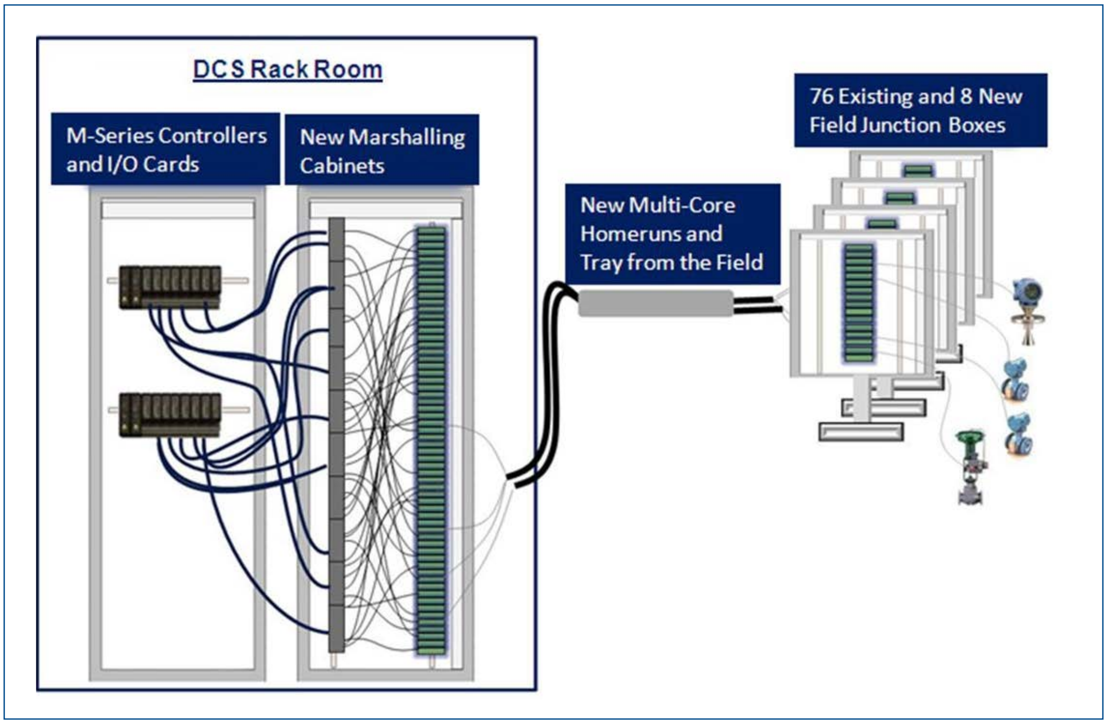

Figure 2 — *Case A, actual project cross-marshalling with 83 new homerun cables.*

Figure 3 shows engineering tasks around control, marshalling and junction box wiring.

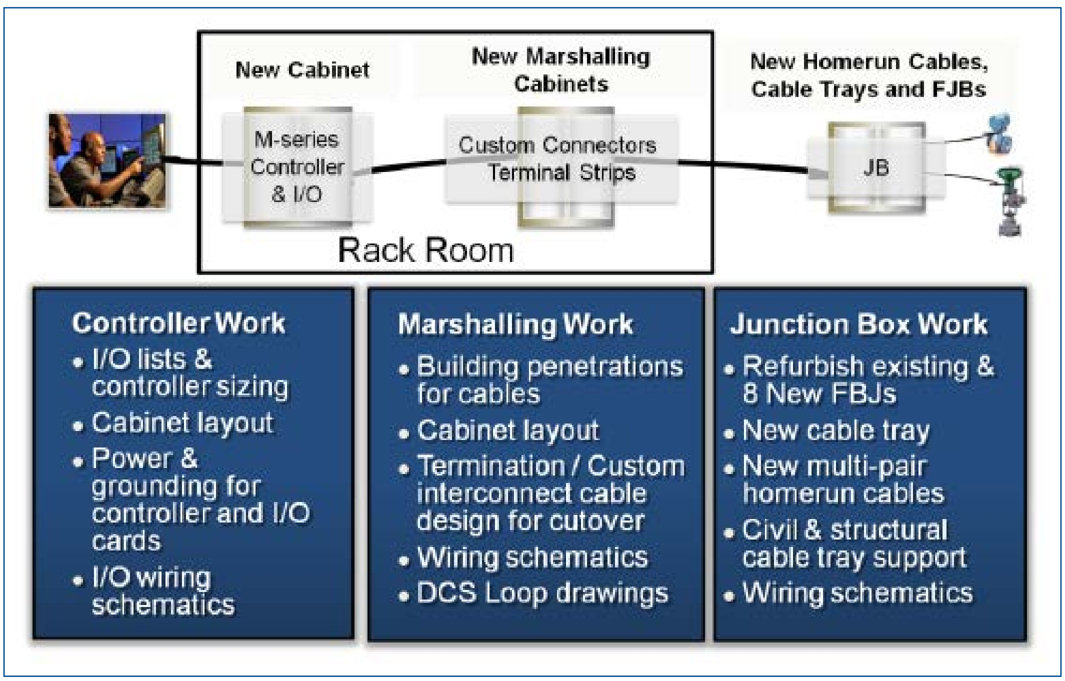

Figure 3 — *Case A, actual project E & I design and installation tasks.*

Case B – Electronic Marshalling Solution

In this scenario, CHARMs I/O[4] is mounted in the field and electronically marshaled to the DCS rack room. This eliminates the need to pull 83 homerun cables. Gone are cabinets, cross-marshalling and associated engineering and installation costs and labor.

Note: To ensure that the case study scenario is realistic, actual project team members who know the site layout were consulted.

Marshalling, homeruns, field junction boxes

- 1,100 I/O will utilize CHARMs installed in Emerson standard Factory Tested Field Enclosures.
  - o The engineering team evaluated retrofitting existing FJBs and mounting CHARMsS I/O inside. Due to size constraints, this was not practical.
  - o Rather, existing junction boxes will be refurbished and remain in place.
  - o The advantage of this approach is that conduit, wiring and terminations from field devices will not be disturbed.
  - o Short jumper cables are required in conduit from existing FJBs to new CHARMs enclosures.
- One CHARMs FJB can accommodate I/O from approximately three existing junction boxes. Therefore, only 30 new junction boxes are needed.
  - o These will be mounted in central locations to minimize jumper cable length.
  - o Each of the 30 new CHARMsFJBs require redundant UPS power, grounding and fiber optic cable terminations.
  - o Although purging was not required by area classification, in consideration of the site's harsh environmental conditions, purging all new junction boxes was deemed customer best practice. Design and installation costs for FJB purge is included in the case study analysis
- New instrumentation to replace pneumatics is included in the I/O count. Wiring from the new devices will run directly to CHARMs enclosures.

Thermocouples

- Converting 472 temperature signals to high density 848Ts with FOUNDATION fieldbus was deemed to be the best solution. The ability to mix and match in this way demonstrates the flexibility of I/O on Demand.
- Costs associated with running 22 FOUNDATION fieldbus segments are the same as in the original project.

[4] *CHARMs I/O is further explained in Appendix D*

Standard Factory Tested Field Enclosures: Emerson's standard factory tested field enclosures can have up to 48 CHARMs I/O. To allow for spares simply leave channels empty; and when needed, install a CHARM type appropriate to the new signal. Enclosures are shown in Figures 4 and 5.

Figure 4 — *Electronic Marshalling Field Junction Box with 48 CHARMsS.*

Figure 5 — *ECHARMs base plate.*

Figure 6 shows the proposed CHARMs I/O solution used in Case B.

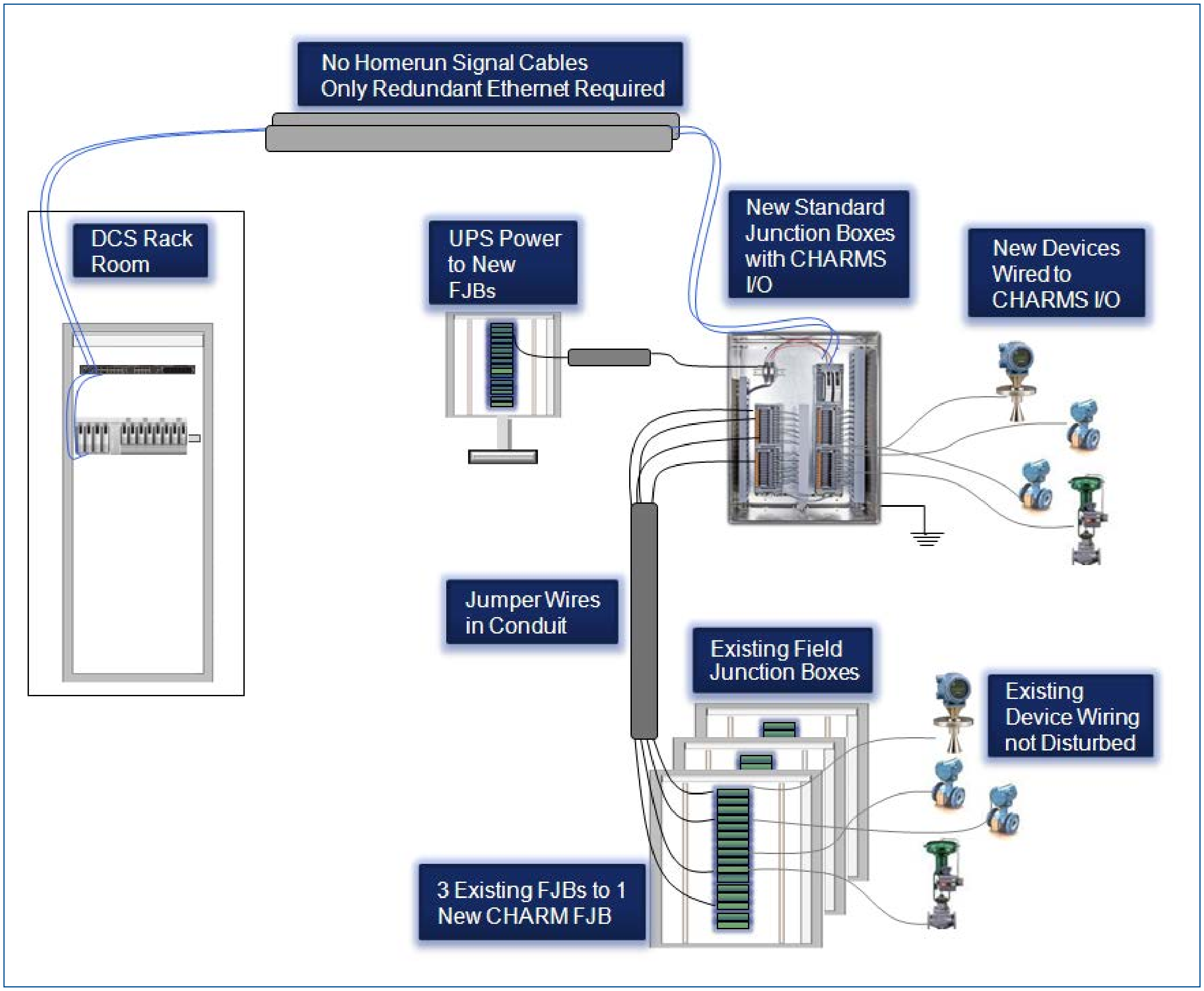

Figure 6 — *Case B, electronic marshalling in fField jJunction bBoxes.*

Figure 7 summarizes tasks required in the theoretical case, work added and work eliminated through the use of electronic marshalling solutions.

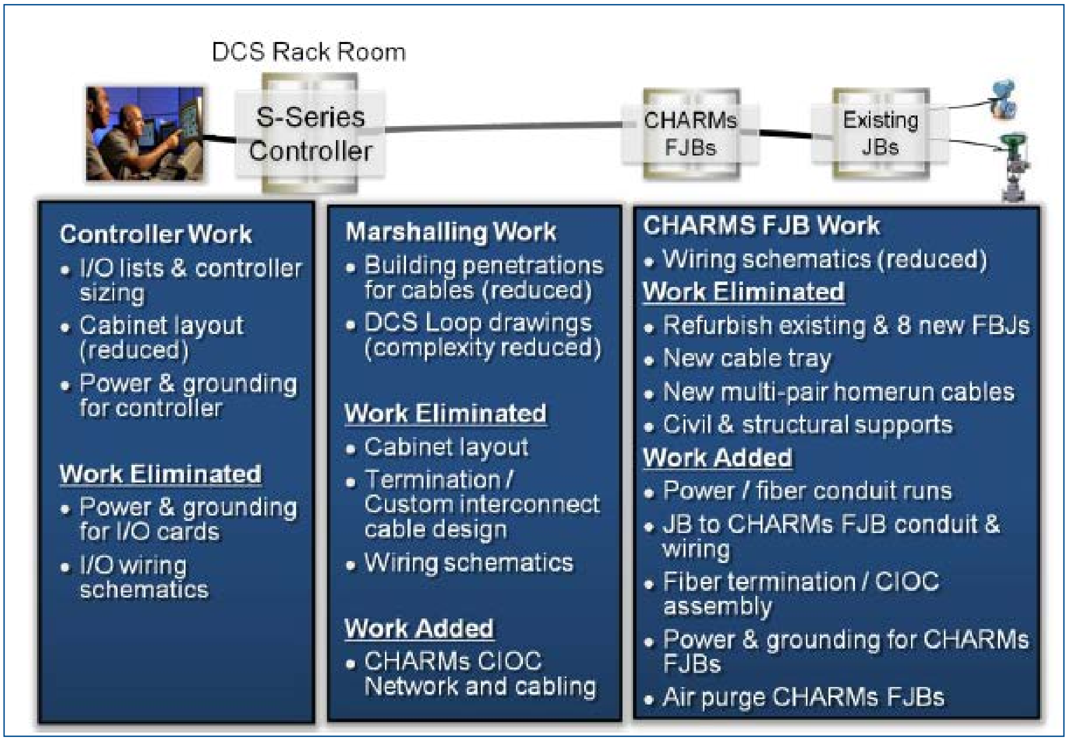

Figure 7 — *Electronic marshalling in the field tasks are equal, reduced, eliminated or added.*

Summary of Findings

The case study found that using electronic marshalling for this project would reduce design, construction and installation costs significantly. Net design labor savings is almost 1900 hours or 47 man-weeks. The biggest time savings is the elimination of work required for loop drawings. Table 1 details design work savings.

Table 1 – Electrical and Instrumentation Design Man Hour Savings

E&I Task	Required E & I Design Man Hours		
	Case A	Case B	Case B - Case A
Engineering Quality Checks	628	496	(132)
Design Quality Checks	1154	890	(264)
Marshalling Panel Layout and Wiring Design	280	120	(160)
DCS Loop Diagrams	3264	2089	(1175)
Power and Grounding Plans	95	175	80
Cable Tray Plans and Details	280	80	(200)
Fiber Optic Plans and Details	70	110	40
Cable Ppenetration Details	80	20	(60)
TOTAL Design Man Hours Savings with Electronic Marshalling (Case B)			(1871)

Electronic Marshalling eliminates engineering, labor and materials required for traditional cross-marshalling of signals. With no terminations in the DCS cabinets, fewer cabinets are needed and amount of work to create, check, edit and recheck drawings is dramatically reduced.. This reduces costs and rack room footprint. In this case, the number of I/O cabinets was reduced by more than half.

With CHARMS I/O mounted in Field Junction Boxes, the savings in cable, trays, conduit and structural work is significant. Table 2 summarizes construction and installation tasks and man-hours savings achievable with electronic marshalling, specifically DeltaV CHARMs.

Table 2 – Construction and Installation Savings

Construction & Installation Task	Hrs Required Case B - Case A	Description
Field Construction: Labor and Material	$63,000	Incremental cost to add 38 CHARM FJBs, 6 power distribution cabinets, fiber optic patch panels and air purging vs. homerun cables to existing FJBs
Scaffolding Rental	($240,000)	Large savings due to redundant fiber runs vs. homerun cables
Civil / Structural	($150,000)	Fewer cable trays and supports
Purchased, Engineered Materials	($127,000)	Marshalling panels and homerun cables eliminated vs. adding FJBs
NET Savings	($454,000)	Construction and Installation Savings with Electronic Marshalling

The incremental costs to install new CHARMS Field Junction Boxes are offset by substantial savings in materials and construction.

Omitting $240,000 in scaffolding rental also has a significant safety benefit, lowering risks associated with contractors working high above the ground.

For the actual project, engineers designed and fabricated custom cabling between the marshalling panels and DeltaV I/O cards to expedite the cutover. When modernizing a control system, the ability to complete the transition as quickly as possible is critical. Using CHARMs I/O in field junction boxes eliminated the need for custom cabling, because much of the work could be completed while the plant is still running.

Final analysis indicates that using electronic marshalling for part of this modernization project would result in ~ 9% overall savings. Table 3 summarizes categories of project work and savings for each, when using electronic marshalling.

Table 3 – Overall Project Savings

Electronic Marshalling Savings Summary	Cost, $K
E & I design engineering savings	$141
Construction and installation savings	$454
Total savings	$595
Electronic Marshalling vs Actual Project	**Cost, $K**
Actual project contract cost	$6,687
Net case study project cost	$6,092
Percentage Savings	8.9%

Conclusion

The flexibility with electronic marshalling and all of the I/O on Demand solutions gives users a unique set of options to design the best solution to move to digital plant architecture.

The case study comparison shows 8.9% savings in total installed cost when using CHARMsS I/O in field junction boxes versus traditional wired I/O in a central rack room.

Distance between field I/O terminations and controller is directly proportional to cost savings for design and installation, i.e., longer distance, greater savings. Electronic marshalling dramatically reduces numbers of cables, conduit runs, wiring terminations and associated drawings.

Appendix A. Considerations for Modernization

Phased Migration or Rip and Replace

Phased migration is preferable in many situations to rip and replace of a system, whether staying with the incumbent or switching to a new supplier. In horizontal phased migration, typically one replaces the human machine interface (HMI) with new console hardware and the latest operating system. This is a popular first step because

- Legacy consoles become obsolete long before controllers and I/O do, and
- Console replacements are low risk and relatively easy transitions for operators.

The downside is that little business value is realized while legacy controllers and I/O remain in service. By the time controller replacement business drivers are evident, another console upgrade may be due.

Vertical modernization involves much beyond the control system. The entire automation infrastructure comes into play. To support the new state-of-the-art DCS, new networks, switches, cabling and instrumentation may be required. Additional capabilities may be desired, such as asset optimization to improve operational effectiveness.

A vertical strategy involves upgrading controllers, which is often perceived by plant management and engineering personnel as higher risk than HMI upgrade. Implementation planning and execution must enable the plant to resume full production safely, quickly and seamlessly with the new automation system. Control functionality must be equal to that of its predecessor, but the expectation is of improved performance.

Emerson advocates not doing replace-in-kind applications because

- Simply upgrading hardware without implementing new software applications would place unnecessary constraints on system capabilities and process improvements, and
- It is analogous to running 20-year-old MSDOS programs in a shell on Windows 7.

Emerson has developed tools and services to lower risks when modernizing applications. Analysis routines identify base level functions for automatic conversion, as well as functions for which advanced control applications may be applicable. These applications include model predictive control, neural networks, closed loop adaptive control or embedded control performance monitoring.

One step rip and replace modernizations require plant shutdown, severing connections to the legacy system and start up of new hardware and software. Risks can be minimized with

- Detailed installation planning,
- Rigorous testing using simulation, and
- Operator training.

Costs are concentrated heavily in the project front-end, as opposed to being distributed over time. Downtime costs present the biggest obstacle to justifying one step replacements. Some plants simply cannot allow sufficient downtime to complete this type of switchover, even though overall costs can be less than multi-year, phased migrations. To minimize process downtime, wiring solutions are available that allow field terminations to remain undisturbed, while connect ing to the new system using prefabricated cables or interface panels.

When It Makes Sense to Migrate

ARC wrote in the white paper titled "Emerson's Flexible Approach to Control System Migration". "When does it Make Sense to Migrate?" The question was answered as follows:

- Impending threat of unscheduled downtime/incident
- No longer cost-effective to support old system, system dead-ended or phased out, no spare parts availability
- Old system cannot support new information technology that provides economic advantage
- New or emerging business opportunity impossible without new system
- Old system is inflexible and cannot react to rapid shifts in customer demand
- Old system lacks visibility that could prevent abnormal situations, equipment breakdown, disruptions in supply chain etc
- Old system does not have the capacity or is not cost-effective to expand

Even when some or all of these conditions exist, before embarking on a modernization effort, decision-makers must be convinced that the risks will be manageable, costs minimal, and results will be profitable. Emerson has a great deal of experience helping customers achieve business results through modernization of automation equipment. Figure 8 depicts the types of services, solutions and expertise applicable for modernizations.

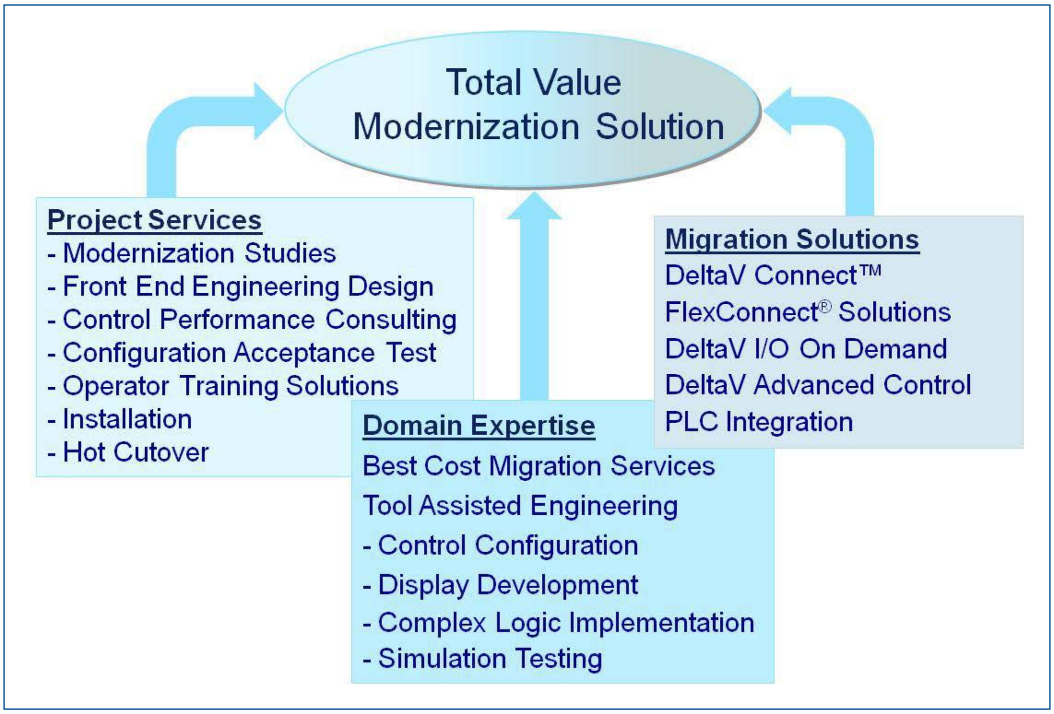

Figure 8 — *Total value modernization solutions.*

With an extensive portfolio of system migration solutions, domain expertise in all major platforms, a wealth of experience executing modernization projects and a clear leadership position in technology, Emerson is the ideal choice for an automation partner.

Appendix B. I/O on Demand

DeltaV S-series with I/O on Demand provides maximum choice and flexibility for both green field and brown field modernization projects. I/O on Demand allows users to decide what type of I/O they want, when they want it, wherever they want it. Bringing I/O into the control system can be accomplished using any combination of these four distinct ways:

- Traditional Wiring
- Electronic Marshalling
- Digital Busses
- WirelessHART®

These I/O solutions are depicted in Figure 9.

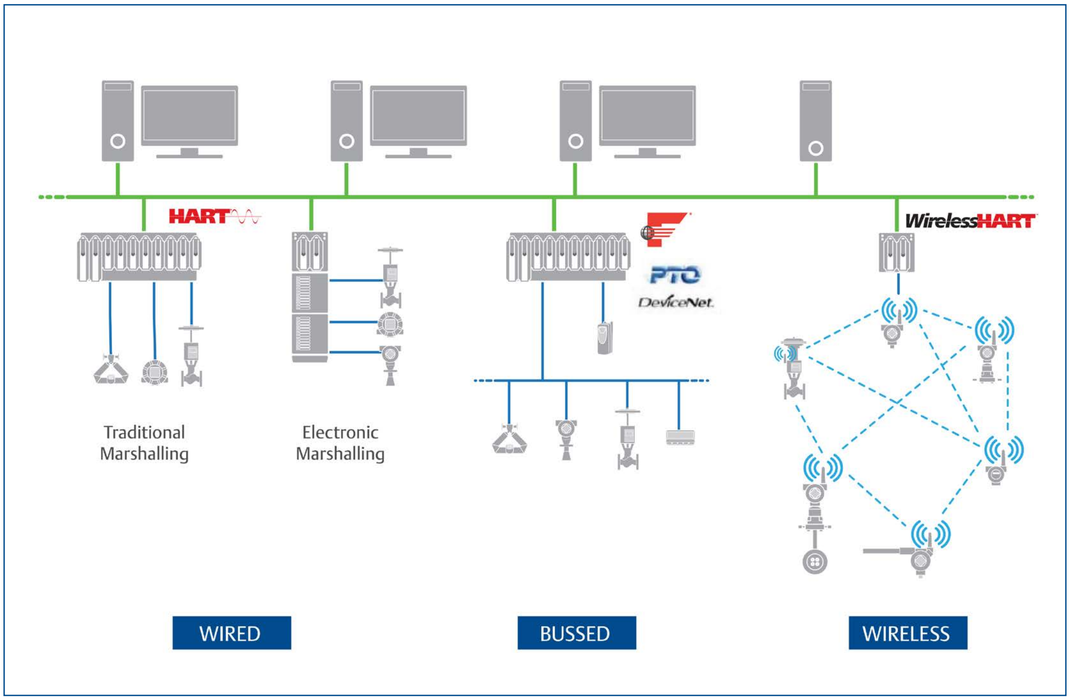

Figure 9 — *Four distinct ways of bringing I/O into the control system.*

Engineers make selections for the best, most cost effective approach for each situation. (For details and information on I/O on Demand and electronic marshalling, please see whitepapers, Electronic Marshalling Overview , Electronic Marshalling Robustness and Performance and the S-series Electronic Marshalling product data sheet.)

Appendix C. Hot Cutover versus Cold Cutover

Horizontal migrations can be performed easily with the plant running. Old and new systems can run in parallel until operators are comfortable with the new user environment. Conversely, one step replacements require a process shutdown for cutover. Partial vertical migrations (by process unit or area) are often accomplished by a hot cutover of non-critical loops and brief shutdowns for moving select equipment controls to the new system. This presents greater complexity for operators, temporarily, as they use HMI's from both systems until cutover is complete.

Some other factors to consider when planning a cutover strategy are:

General

- Real estate and space constraints
- Type of process (batch or continuous)
- Industry (example: offshore platform)
- Corporate best practice
- Current economic conditions

Cold Cutover

- Reduces process safety hazards during rewiring and commissioning
- Reduces "operational" safety for construction personnel
- Reduces potential for plant upsets, spills, and fires, due to human error
- Reduces risk of environmental violations
- Allows for thorough loop checkout before putting system into service
- Potential downside – may be unable to switch back to original system
- Significant operator training is required prior to process startup on new system

Hot Cutover

- Minimizes process downtime and is therefore economically more attractive for some processes
- Requires keen attention to details during design and implementation to ensure smooth cutover
- New system acceptance by operations is incremental with each area cut over vs. a one-tep change with cold cutover
- Start-up risks, including time to full on-spec production are lower

Appendix D. Electronic Marshalling for Migration

An innovative example of electronic marshalling for legacy I/O migration is given in the pProduct data sheet , S-series Electronic Marshalling for Migrations. The CHARM I/O card (CIOC) supports up to 96 individually configurable channels. CHARM I/O base plates, when mounted horizontally, allow for direct replacement of legacy hardware within existing cabinets. A migration to DeltaV S-series hardware can be done without having to add cabinets, custom cables, or extra marshalling. All communications are completely redundant from the channel (CHARM) to the DeltaV S-series controller. Figure 10 shows an electronic marshalling configuration suitable for migrations.

Install the CHARMs migration panel above, below, or even in front of the legacy termination panel and move wires a matter of inches to complete the installation. Since the CHARMsmigration panel is a standard CHARMs baseplate, it talks to the CIOC the same as the

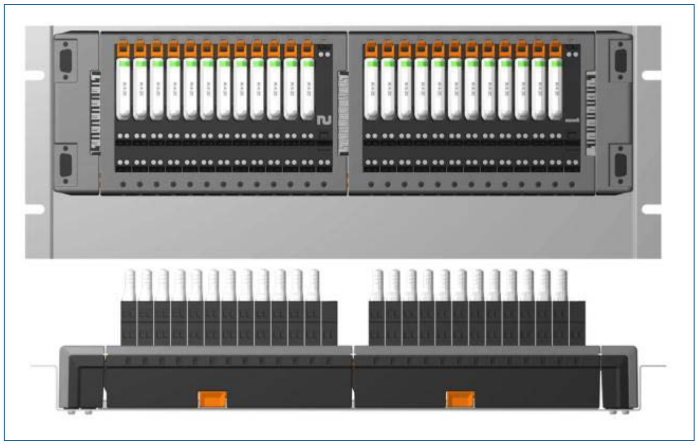

Figure 10 — *Electronic marshalling designed with migration projects in mind.*

standard vertical installation via the cable interface. This allows the migration panel to be mounted in the best location to facilitate a clean system cutover with no concerns about how to "stretch" I/O cables to a new termination. CHARMs baseplates can be mounted in any orientation as best fits the layout and needs.

Figure 11 shows how s/O Cards (CIOCs) can be installed in an existing cabinet.

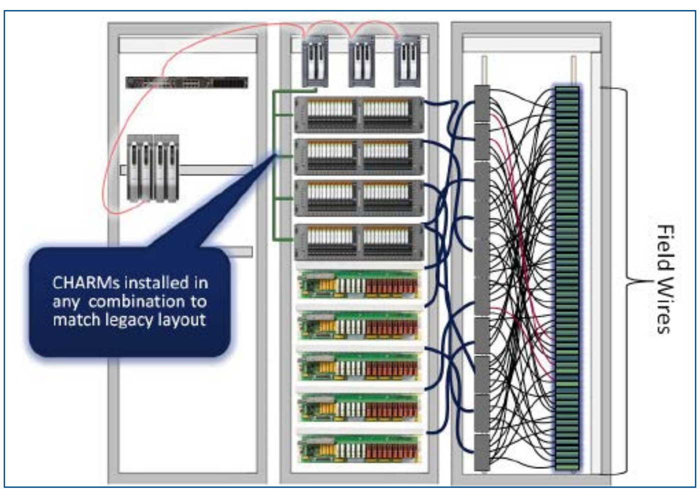

Figure 11 — *Replace old termination panels with horizontal CHARMs baseplates.*

Horizontally mounted CHARMs baseplates replace legacy termination panels in the same footprint and the wires for each channel can simply be moved a few inches and re-terminated. The signal types do not matter as a matching CHARM is all that is needed.

Another option shown in Figure 12 is to eliminate marshalling altogether and re-terminate field wires directly to CHARMsI/O.

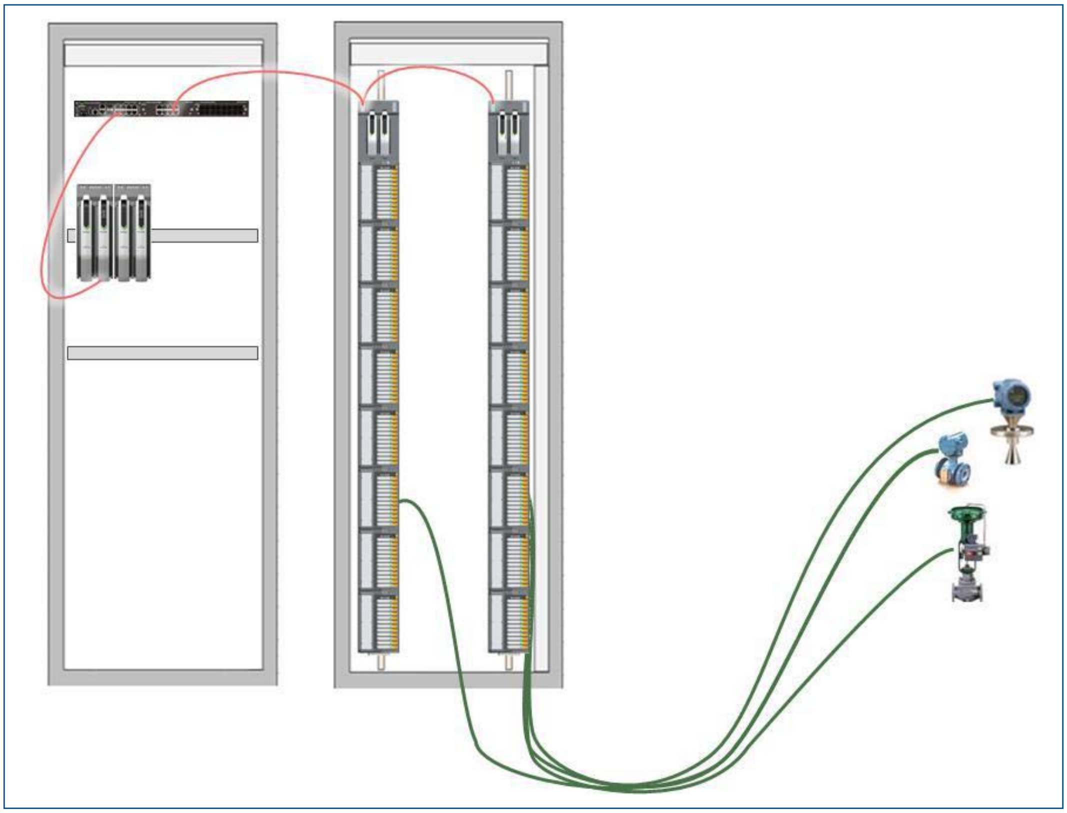

Figure 12 — *Terminate field wires directly,and eliminate cross-marshalling.*

The case study in main body text uses CHARMs I/O mounted in field junction boxes.

Emerson
North America, Latin America:
+1 800 833 8314 or
+1 512 832 3774

Asia Pacific:
+65 6777 8211

Europe, Middle East:
+41 41 768 6111

www.emerson.com/deltav

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