ISA-TR-88.95.01

Using ISA-88 and ISA-95 Together

Approved 1 August 2008

ISA-TR-88.95.01, Using ISA-88 and ISA-95 Together
ISBN: 978-1-934394-78-6

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Preface

At the time of publication of this document, the editions of the standards referenced within this document were valid. All standards are subject to revision, and parties to agreements based on this document are encouraged to investigate the possibility of applying the most recent editions of the standards indicated within this document.

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Introduction

When the ISA-88 and ISA-95 standards are applied together in an application or project, some of the terminologies, models and key definitions in these two sets of standards need to be aligned to assist the users. A harmonization task group with members from the ISA88 and ISA95 committees has generated this technical report to document and map the overlaps, gaps, similarities and differences in these concepts, terms and definitions. This technical report is intended to enable an integration team to use these specifications jointly, in an application or project.

The purpose of the technical report is to

- Explain how ISA-88 and ISA-95 interrelate.
- Identify areas of overlap and gaps between ISA-88 and ISA-95
- Explain to practitioners how to use ISA-88 and ISA-95 together
- Reduce confusion in industry about the two series standards by answering such questions as:
  - Are they both needed?
  - Do they overlap?
  - Which should be used?
  - When is one more appropriate than the other?

Although the technical report does not take into account the recent proposed additions to both the ISA-88 and ISA-95 families of standards, the approach used in this harmonization task can be applied to facilitate the combined use of these two families of standards.

In particular, as the new parts of ISA-88, Part 4, Batch Production Records, and Part 5, Automated Equipment Control Models and Terminologies, and the additional parts of ISA-95, Part 4, Common Object Model and Attributes, and Part 5, Business-to-Manufacturing Transactions, become widely available, there are expected to be other areas of potential overlaps and gaps when these standards are used together.

However, the planned updates to the existing parts of both these standards families are intended to reflect some of the recommendations in this technical report in order to minimize the problematic areas and to facilitate their continued harmonization.

Readers of this technical report are encouraged to help further align these standards by providing comments to the ISA-88 and ISA-95 committees based on actual experience in applying these standards.

Using ISA-88 and ISA-95 Together

1 Scope

This technical report is targeted for industry stakeholders (individual or teams) intending to use ANSI/ISA-95 for enterprise-to-control system integration and ANSI/ISA-88 for control system integration within a common project.

The specific goal is to help such an individual or team understand the key issues involved in using ISA-88 and ISA-95 together so that they can make appropriate choices. This technical report is the result of an effort to identify key areas of overlap and gaps between ISA-88 and ISA-95. It will not discuss issues that are not pertinent to both of the standards.

2 References

The following documents contain provisions that are referenced in this text. At the time of publication, the editions indicated were valid. All documents are subject to revision, and parties to agreements based on this technical report are encouraged to investigate the possibility of applying the most recent editions of the reference documents indicated below.

— ANSI/ISA -95.00.01-2000, Enterprise/Control System Integration Part 1: Models and Terminology

— ANSI/ISA -95.00.02-2001, Enterprise/Control System Integration Part 2: Object Model Attributes

— ANSI/ISA-95.00.03-2005, Enterprise/Control System Integration Part 3: Activity Models of Manufacturing Operations Management

— ISA-88.00.01-1995 Batch Control Part 1: Models and Terminology

— ANSI/ISA-88.00.02-2001 Batch Control Part 2: Data Structures and Guidelines for Languages

— ANSI/ISA-88.00.03-2003 Batch Control Part 3: General and Site Recipe Models and Representation

— ANSI/ISA-88.00.04-2006 Batch Control Part 4: Batch Production Records

3 Narrative Overview

3.1 Introduction

When the ISA-88 and ISA-95 series of standards are used within the same plant-wide automation system in an enterprise, it is necessary to align the various definitions in both standards in order for industry stakeholders to reap the intended benefits. Clearly implementations of these two series of standards need to work together. If their interaction is not understood, the intended benefits will not be realized and costly integration problems are likely to arise. The automation, operations and manufacturing solutions providers and consumers will have to work closely together in order to minimize and eventually eliminate these integration problems. This technical report is intended to improve these stakeholders' understanding of both standards series as well as their intent.

Although both standards are intended to enable manufacturing operations and control, they are different in coverage and approach. Table 1 provides a high-level comparison.

Table 1. Comparison of approaches and coverage

	ISA-95	ISA-88
Orientation	Definition of workflow and information exchange for Manufacturing Operations Management.	Physical work execution for Batch and other types of manufacturing.
Conceptual Basis relative to Manufacturing Management Functions	Flexible structure of manufacturing management functions that interacts with business requirements.	Acknowledges but does not directly address manufacturing management functions.
Conceptual Basis relative to Process Control	Directly addressing most traditional process control activities is presently out of scope.	Well-defined equipment-oriented process control structure and function hierarchies extending to the bits and pieces of the manufacturing equipment itself.
Primary areas of concern	Addresses functionalities and applications at a level below enterprise business systems but above manufacturing control systems.	Addresses a lower level, directing, controlling and coordinating the people and equipment that perform or cause the physical transformation of raw or intermediate materials into final or intermediate products.
Affected Industries	Spans all types of manufacturing.	Written primarily in terms of batch manufacturing, but is often applied in other types of manufacturing.

A key task in attempting a combined use of the two standards is to recognize and identify where their definitions and models overlap and where there exists gaps when dealing with the information exchanges within the same application. When dealing with the overlaps and gaps, the user of the two standards has the challenging task of reconciling terminology whenever the two standards use either different terms to mean the same thing or the same term to mean different things. These tasks need to be accomplished to realize a successful combined use of ISA-88 and ISA-95.

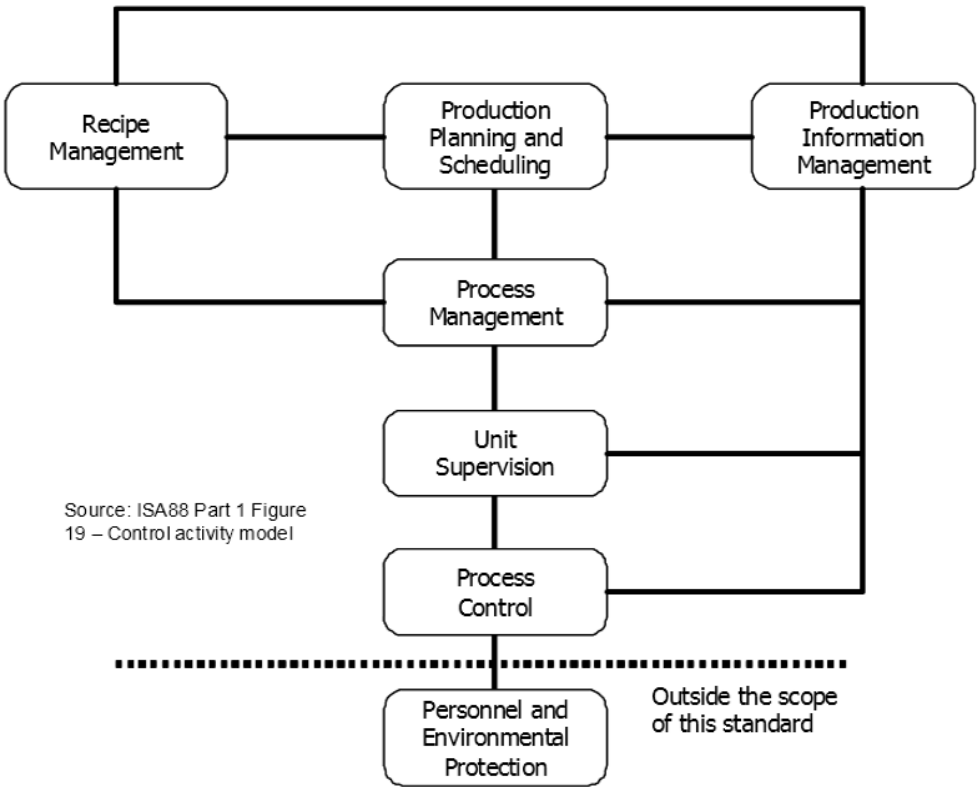


Figure 1 – ISA-88 Control Activity Model

3.2 Main areas of overlap

The control activity model in Part 1 of the ISA-88 standard is shown in Figure 1. It shows a hierarchy of three primary activities (i.e. Process Management, Unit Supervision and Process Control) that implement control. In addition, there are three other complementary activities (i.e. Recipe Management, Production Planning and Scheduling and Production Information Management) that exchange information with the primary activities to realize the effective and efficient production of the correct products.

In Figure 1, the Process Control activity represents the functionality required to accomplish traditional state oriented and regulatory control. Because ISA-88 is all about adding procedural control to more traditional.

Source: ISA88 Part 1 Figure 2 – Physical model

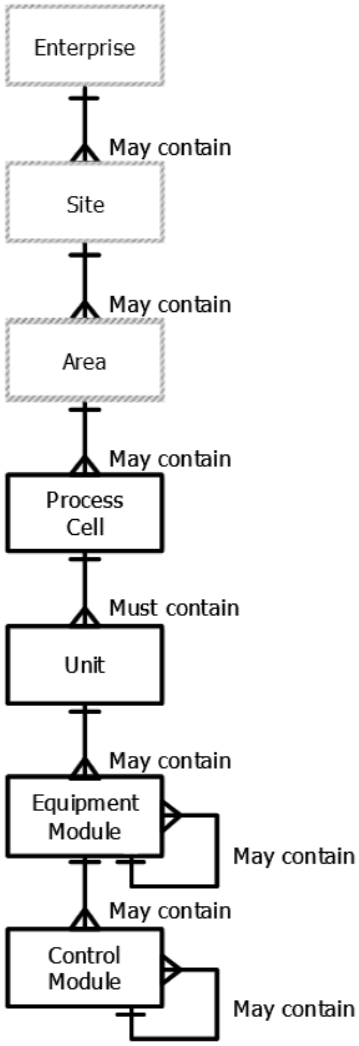


Figure 2 – ISA-88 Physical Model

Process Control, the Unit Supervision activity provides most of the functionality required to execute procedures and to direct the lower level functionality described in the Process Control activity. Since those procedures often must be performed in multiple units and common resources at the same time in a precise sequence with exact timing and because there could be many procedures active at the same time, a great deal of coordination is necessary. The coordination functions and the remainder of needed procedural control functionality are defined in the Process Management control activity. By their nature, the interconnection of the three primary control activities is viewed in ISA-88 as interactive and time sensitive. For that reason, they are essentially inseparable in any practical implementation where there is significant interaction of closely linked elements (units and common resources) of the manufacturing equipment being controlled.

While the control activities represent the functionality needed to implement procedural control, it is equipment that is, in fact, controlled. Unlike the more traditional view of process control that treats control as separate, abstract activities that focus primarily on manipulation of final control elements, procedural control addresses and provides functionality to groupings and assemblages of equipment.

ISA-88 defines a physical model (see Figure 2) with a hierarchy of four specifically defined equipment groupings and three higher levels, fairly abstract groupings that are depicted in dashed lines because they are specified as beyond the scope of the ISA-88 standard.

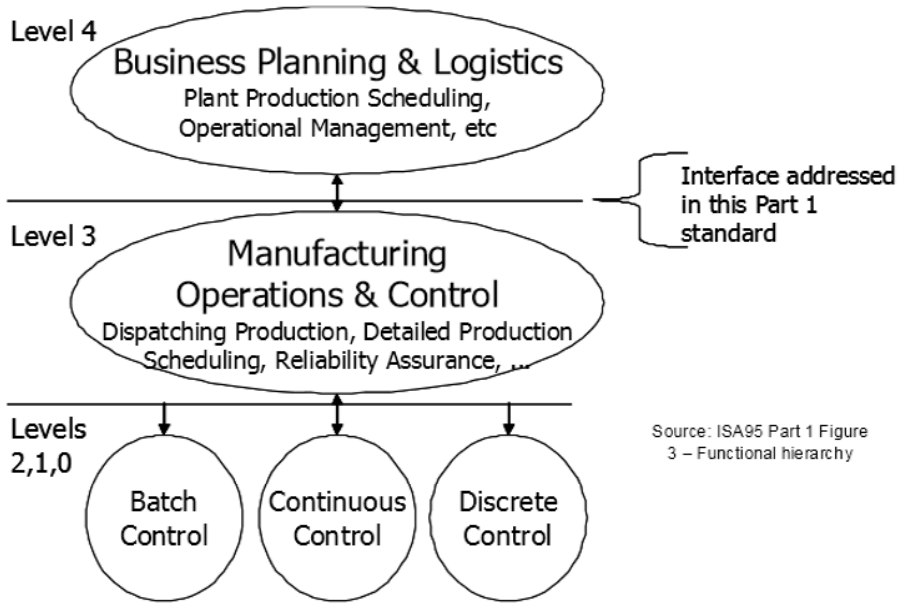


Figure 4 — ISA-95 Functional hierarchy

The ISA-95 activity hierarchy explicitly addresses the various categories of manufacturing operations management activities within Level 3 of the Purdue Reference Model (PRM) and their interactions with other levels, as shown in Figure 4 (from ISA-95 Part 1, Figure 3). Each manufacturing operations management category, such as production operations, maintenance operations and product quality testing operations can be further detailed in terms of a common generic set of detailed activities, as shown in Figure 5 (from ISA-95 Part 3, Figure 6).

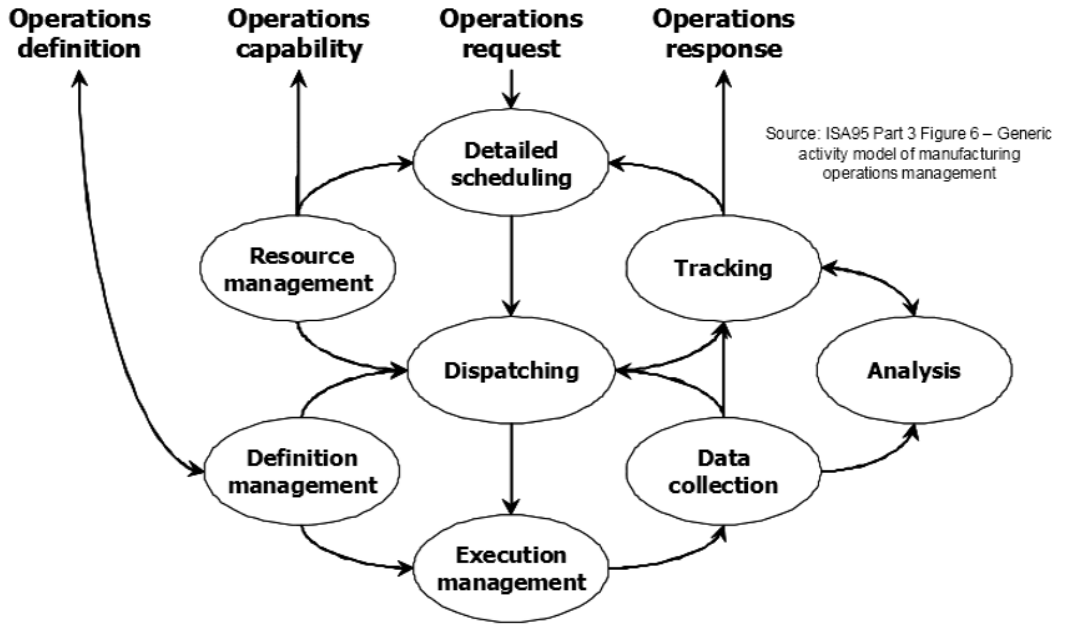
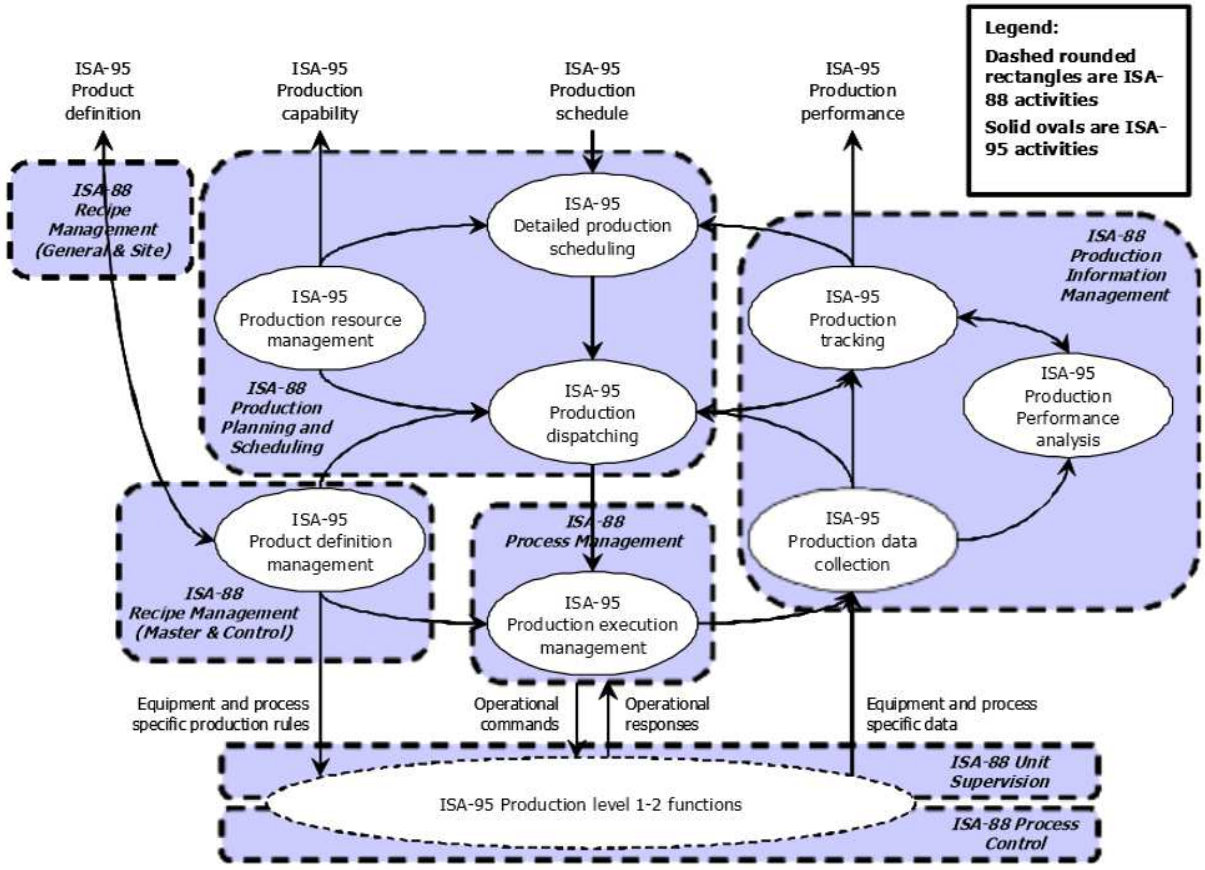


Figure 5 — ISA-95 Generic activity model: Manufacturing operations management

Although the activity names used in ISA-95 are slightly different from terms used in ISA-88, all three of the ISA-88 complementary activities (i.e. Recipe Management, Production Planning and Scheduling and Production Information Management) can be mapped to the ISA-95 Level 3 detailed activities as noted in Figure 6, from a perspective where the ISA-88 functional activities could have some aspects not considered within the ISA-95 definitions.



Source: ISA95 Part 3 Figure 9 – Activity model of production operations management – objects spread out and relabeled, ISA88 Part 1 Figure 19 – Control activity model resized and rearranged to map onto the ISA95 figure

Figure 6 — ISA-88 control activities overlaid on ISA-95 activities

A similar mapping can be envisioned where the ISA-95 activities and functions may have specific aspects not included within the ISA-88 activities and functions. The more general coverage of ISA-95 is particularly evident compared to the three higher level ISA-88 control activities (Production Information Management, Production Planning and Scheduling, and Recipe Management) or when other ISA-95 operational categories besides Production (e.g. maintenance and quality assurance testing) are considered.

The three higher level ISA-88 control activities fit nicely within the ISA-95 structure. However, the three primary control activities align more loosely.

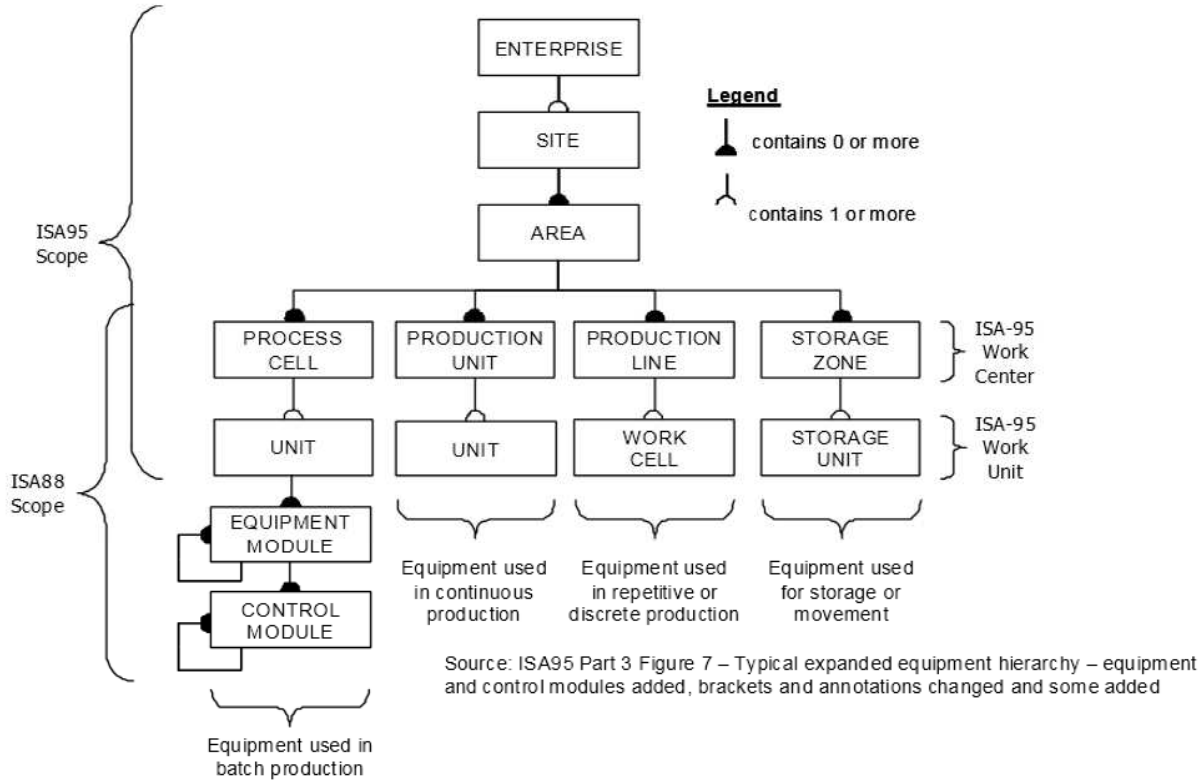
- ISA-88 Production Information Management activity can be considered a placeholder for ISA-95 activities including Data Collection, Tracking and Analysis.
- ISA-88 Production Planning and Scheduling activity can be considered a placeholder for the subset of ISA-95 activities including Detailed Scheduling, Dispatching and Resource Management.
- ISA-88 Recipe Management activity, on the other hand can be considered to be a specialized and, in some cases more detailed, subset of the much more generally defined ISA-95 Product Definition Management activity.
- ISA-95 defines a function called Production Execution Management that almost exactly corresponds to the ISA-88 control activity called Process Management. That is a clear overlap with a primary ISA-88 control activity and, unlike the higher level control activities, has the potential for significant confusion stemming from the interaction of the functions in the activity models with the physical equipment depicted in the related physical models.

- ISA-95 acknowledges the physical unit but specifically excludes definition of Unit Supervision or any physical equipment or functionality below the unit level so there is no overlap at all with those functions.

Both standards have physical models (see Figure 2 and Figure 3) that appear similar, differing only in number of types of manufacturing operations and control represented and the level of detail with which the models are defined.

Some of the types of physical equipment that correspond to the Work Center definition in the ISA-95 physical model are clearly equivalent or similar to the Process Cell in the ISA-88 physical model. Figure 7 shows examples of ISA-95 Work Centers, such as, a Production Unit in continuous production, a Production Line in discrete production or Storage Zone that are equivalent to an ISA-88 Process Cell definition.

In the ISA-88 standard, the Process Cell (or work center) is viewed as a module of equipment made up of smaller, more focused modules of equipment called Units and common resources, both of which are, in turn, made up of lower level equipment groupings such as Equipment Modules and Control Modules that do not appear in the ISA-95 model.



Source: ISA95 Part 3 Figure 7 – Typical expanded equipment hierarchy – equipment and control modules added, brackets and annotations changed and some added

Figure 7 —Overlap in physical models of ISA-88 and ISA-95

The overlap between the physical models in ISA-88 and ISA-95 is shown in Figure 7. The scope of each standard series is indicated by the vertical curly brackets in Figure 7. Each of the defined entities in the ISA-88 Physical Model is regarded, not just as groupings of equipment, but also as *equipment entities*, each a grouping of equipment with embedded control functionality that, in practice, is not separable. This is also true for common resources. Since common resources can be either Control Modules or Equipment Modules, common resources were not defined separately in the ISA-88 standard and no attempt was made to include them in the ISA-88 physical model as clearly defined entities. However, they are necessary and can't be ignored. Viewed as equipment alone, the ISA-88 Process Cell and the ISA-95 Work Center can be considered to be comparable, as can the ISA-88 Unit and the ISA-95 Work Unit. However, the

ISA-95 model definitions of workflow-related segments (i.e. process segment, product segment, production segment) and resources (i.e. equipment, personnel, material) do not readily allow for a detailed and straightforward correspondence with the ISA-88 model definitions of equipment entities, procedural control and processes, especially, in the regions of overlap.

Since ISA-95 focuses more on the information exchanges within and above Level 3 of the ISA-95 functional hierarchy, detailed definitions of a Work Center, Work Unit or any lower level groupings of equipment has not been provided. In spite of the differences in precision, the definition comparisons are adequate and should not be a problem. The big difference is that ISA-95 primarily addresses control and similar functionality from an information exchange point of view and does not consider the binding of equipment to the control functionality. This becomes an issue in the understanding of the Work Center or Process Cell.

For Batch Process Manufacturing and other manufacturing processes based on ISA-88 principles, the ISA-88 Process Management control activity and the ISA-95 Production Execution Management function are essentially identical in definition. However, they differ greatly in perspective. From an ISA-88 perspective, Process Management is an inextricable part of an *equipment entity* called a Process Cell. That *equipment entity* is made up of both the control activity called Process Management and the physical equipment contained within the Process Cell that it controls. From an ISA-95 perspective, Production Execution Management is purely an information function that is neither bound to nor bounded by specific equipment. Noting this fundamental difference is essential in the combined use of ISA-88 and ISA-95.

For practical purposes, it is recognized that the ISA-95 Production Execution Management function might well need to be implemented from an ISA-88 perspective. There is a need to identify an interface above the ISA-95 Production Execution Management function in the data models that would be the focus in a future part of the ISA-95 standard. That interface will allow a "clean" interface if most or all of the Production Execution Management function is implemented on separate platforms such as process control systems or other ISA-88 oriented automated systems that treat the Process Cell or Work Center as an *equipment entity* requiring very tight coupling between Process Management and Unit Supervision (or whatever the equivalent function(s) end up being called in a given implementation).

Depending on the choices of implementation, the virtual boundaries between the ISA-95 functional and physical levels may or may not be exposed; furthermore, the actual boundaries implemented may not correspond to the boundary between Level 3 and Level 2, as defined in the ISA-95 standard. A key focus of the ISA-95 standard is to model information flow among functional entities while the ISA-88 standard focuses on modeling the flow of control among equipment entities. Problems tend to arise in the way these entities are implemented. ISA-88 is much closer to being a physical implementation model than ISA-95. By treating the ISA-95 models as abstractions of physical implementation models and by recognizing the ISA-88 implementation models of *equipment entities*, one can realize the combined use of these two standards.

To avoid problems due to overlaps, terms need to be rationalized, operational correspondence clarified and implementation examples given. Fortunately the functional boundaries in the two standards appear to be quite similar and the included functionality appears to be nearly the same. It is only when function is combined with and bound to equipment that confusion is likely. The ISA-88 *equipment entity* concept and ISA-95 *segment* concepts need to be recognized and understood to improve clarity where the two standards must interact. In particular, extending the much more broadly defined ISA-95 *segment* concepts from Level 4 to Level 3 (as is commonly done in practice, but not currently defined in the standard) provides a layer that resolves into the ISA-88 *recipe entities* that affect its *equipment entities*.

Both standards, in practice, are not only used for automation purposes, but are also useful to clarify and promote communication about manufacturing concepts, systems and technologies

between people and groups. This often leads to the need to choose between terminology and models.

3.3 Key gaps in models, definitions and terminology

In addition to overlaps in the terms, definitions and models, there are gaps between the two standards that also need to be recognized and understood. There are terms, definitions and model elements in ISA-88 that are not included in ISA-95, as well as, vice-versa. Some of these "gaps" are mentioned in the detailed tables in Clause 4.

A significant gap in the two standards is in the types of production operations being addressed. ISA-95 is designed to apply to several types of production, including batch production, while ISA-88 was originally intended for batch manufacturing alone; however, ISA-88 can potentially be extended beyond batch to other types of manufacturing as described below.
ISA-88 was written in terms of batch manufacturing, even though there was no intention to limit it to batch alone if there are worthwhile applications elsewhere. The reason for the batch focus is obvious. ISA-88 was written because there was no standard way to address automated procedural control in process manufacturing. This was particularly evident in the case of batch manufacturing and that was the problem the standard addressed. Though focused on batch, the standard actually defines an effective and internally consistent way to apply procedural control to many types of manufacturing processes. It is certainly not the only way to apply procedural control, but it has been successfully applied in many cases to many diverse types of manufacturing. In spite of this, the terminology and details remain a problem. Because it is couched in very batch oriented terms, if one reads the words literally and without interpretation, it can be easily dismissed as a niche standard applying only to batch manufacturing. Increasing use of ISA-88 in other types of manufacturing, though, has demonstrated that it may be a desirable guide in other kinds of applications and may be the desired approach to automation whether the application is batch or not.

The use of ISA-88 in a broader array of manufacturing technologies is beyond the scope of this technical report. However, to minimize confusion, it is worthwhile to recognize that it may be used in those applications and to understand why and a little bit of how it might show up. Practice has demonstrated that understanding the potential use of ISA-88 approaches in some continuous and discrete applications of projects is needed because few manufacturing processes are 100% pure batch, pure continuous, pure discrete or pure anything. Even within batch manufacturing, for example, the product (the batch) is quite often not a directly saleable product until is packaged or subjected to further processing. Auxiliary manufacturing processes are needed, often as part of the same overall manufacturing facility. There are advantages to using the same general approaches to automation of closely related equipment as long as they are applicable. It is not difficult to visualize possible approaches utilizing ISA-88 principles in some continuous, discrete and/or storage situations.

Continuous processes are a good example. They differ from batch processes in several ways. They tend to have more processing equipment, be more costly and generally do not make very many different products. They are highly productive in terms of pounds of product per labor-hour. The regulatory control is often very sophisticated and expensive because even a tiny improvement in throughput or yield can, over days or weeks or years, result in large benefits. In many continuous processes the procedures for startup, shutdown and grade change are manual.

However, if continuous processes are examined only in the context of procedural control, most continuous processes can be thought of as batch processes with a long, unchanging in-process step. It is true that to apply ISA-88 to most continuous processes requires that we interpret the intent of the standard's batch specific "rules", but this is often worth the effort. Certainly, startup and shutdown under automatic procedural control is useful in many "continuous" applications. Since these are the times of greatest uncertainty, with the greatest need for extensive and immediate exception handling, procedural control automation may be desirable or necessary. It

would appear that expanding the ISA-88 standard to encompass both batch and continuous would not be difficult except for the tedious business of determining what to call things when they have multiple names. If an expanded and broadly accepted view becomes common, ISA-88 principles will become even more prevalent in continuous (and other) manufacturing processes.

Discrete processes are more of a challenge, not because the principles are different but because the implementations are so diverse. ISA-88 is being applied to some discrete manufacturing processes including such examples as packaging lines made up of multiple automatic packaging machines. Generally, control modules and equipment modules may be buried in the proprietary machines, but units are not hard to identify and the entity that controls a procedure to convert a defined quantity of raw material (perhaps potato chips) into a finished or semi-finished product (perhaps bags of chips) is not hard to find.

These examples are not an argument to force fit a batch standard to replace either existing systems that work or other approaches that are better. The point is that ISA-88 can be used with some benefit if it is generalized to make clear how it fits the different environments and, for that reason, may be encountered in many different kinds of applications. Though not yet published, Part 5 of ISA 88 is attempting to address some of these very issues. Neither continuous nor discrete processes exist in a vacuum and are frequently intermixed with each other and with batch. While ISA-88 (or a derivative of it) is unlikely to become a universal standard for manufacturing, having a more or less standard approach to procedural control in all of the manufacturing entities in the same facility could be, in many cases, beneficial and something an individual or team applying ISA-95 may well encounter outside of “pure” batch applications or projects.

Some of these issues have already been considered. The ISA-95 committee has elected to generalize the names of the various entities that are roughly equivalent to the ISA-88 Process Cell and the ISA-88 Unit. ISA-88 Process Cells and their equivalents in other types of manufacturing and storage/retrieval applications are all called ISA-95 Work Centers. Likewise the term ISA-95 Work Unit has been defined as the general term that refers to the unit in a batch process and similar structures in all types of manufacturing. This is a powerful concept. Since the Work Units are likely to be specific to the type of manufacturing and/or storage, it should be possible to have a continuous oriented work unit as part of a batch process cell (or work center). This solves many problems not addressed by ISA-88. In reality, batch work units are frequently part of predominately continuous work centers. Things that look like storage oriented work units are not strangers in any work center.

From a very general standpoint, the mappings and overlaps noted in Figure 7 are similar to those depicted in Figure 6. In those cases where an ISA-95-based application involves a mix of batch, discrete and continuous production control, the nature of the overlaps in Figure 7 can be different from those noted in Figure 6.

Another significant difference in the two standards involves other categories of manufacturing operations management that ISA-95 explicitly addresses in addition to production operations, such as, maintenance operations, quality assurance testing operations, and inventory movement operations.

The ISA-95 generic activity model shown in Figure 5 can be replicated for each of the manufacturing operations management categories. Additional diagrams similar to Figure 6 can be constructed but with the term "Production" replaced with either "Maintenance", "Quality Assurance Testing" or "Inventory Movement/Storage/Retrieval." The ISA-88 models relate directly to the ISA-95 Production Model, however ISA-88 models may also relate to such activities as ISA-95 Inventory Movement/Storage/Retrieval and Quality Assurance Testing models in that ISA-88 recipe and equipment models may be used for automation and manual control of such activities.

Another gap in the models is in the range of type of equipment resources that need to be handled by the ISA-95 Production resource management and ISA-95 Production execution management functions. Although several ISA-88 Process Cells and ISA-88 units could be envisioned to be handled by an ISA-88 Process Management function, it is necessary to allow other forms of ISA-95 Work Centers and ISA-95 Work Units when applying these standards to compound forms of manufacturing operations in a mix of batch, discrete and continuous production applications.

3.4 Summary

Overlaps and gaps need to be recognized and understood. Many potential conflicts in the overlaps in terminology and functional descriptions are resolved in this document, but others may be encountered and must be dealt with.

Gaps need to be filled and will be filled one way or another. It is important to recognize and understand that the gaps having to do with the physical handling or converting of material, in particular at Level 2 and below, may be filled by ISA-88 extensions or ISA-88-like models. The definition of other ISA-88-like models to address these gaps is beyond the scope of this technical report, but work on that front is underway as this is written and it is important to recognize and understand it and its special considerations when and where it is encountered. Gaps involving information exchanges, in particular within Level 3 and between Level 3 and Level 2 may be filled by ISA-95 extensions or ISA-95 like models. Similarly, efforts are underway to investigate these extensions.

Following this narrative overview are much more technically focused discussions dealing with the following issues:

- Comparison and generalization of Physical Models in the two standards
- Categories of information exchanged
- The ISA-88 Control Activity Model and the ISA-95 Production Operations Management Model and the way they map to each other
- ISA-88 Process Management and ISA-95 Production Execution Management Activities – the similarities and the differences
- ISA-88 Recipe Management and ISA-95 Product Definition Management Activities – the mapping and the interactions
- ISA-88 Planning and Scheduling and ISA-95 Dispatching/Detailed Scheduling Activities – the interdependences and the more specific requirements of ISA-88
- ISA-88 Production Information Management and ISA-95 Data Collection, Analysis and Tracking Activities

4 Physical/equipment model and information model comparisons

4.1 ISA-88 Physical model and ISA-95 equipment hierarchy model comparison

A physical model is a tool to organize the various types of physical resources in an enterprise and to represent their roles and relationships. It is a way to describe equipment resources available for a process or product.

ISA-88 defines a "Physical Model" while ISA-95 defines an "Equipment Hierarchy," both of which are illustrated for comparison in Figure 8. (Note: The ISA-95 Part 1 equipment hierarchy was expanded in Part 3 to include storage zones, storage units, and [continuous] units.)

The ISA-95 equipment hierarchy was derived from the ISA-88 physical model, so the ISA-88 model maps well to the ISA-95 model. Viewed as equipment alone, their differences lie in the depth and breadth of what each standard was developed to address. ISA-88 provides additional detail below the unit level that is too granular to consider in ISA-95, while ISA-95 replicates the process cell and unit concepts for other types of manufacturing besides batch. ISA-88 also defines an "Equipment Entity Model," which maps exactly to the Physical Model at and below the process cell level and is often referred to as the Physical Model but, unlike the ISA-95 Equipment Hierarchy and the true ISA-88 Physical Model, it includes all associated equipment control capabilities.

Figure 8 also shows the ISA-95 functional levels in relation to the Equipment Hierarchy. ISA-95 was developed in some alignment with the Purdue Reference Model (PRM) and part of ISO 15704 referencing the Purdue Enterprise Reference Architecture, which describes organizational levels; therefore the ISA-95 functional hierarchy is drawn using levels. ISA-88 was developed independently from PRM and does not use such levels. Mapping ISA-88 to ISA-95 functional levels can be difficult since no direct mapping between them based on functional level has been developed in the current standards.

In ISA-95, levels only refer to functional levels with activities mapped to them. These functional levels do not have rigid mappings to the equipment hierarchy, so the depiction in ISA-95 part 3 Figure 7 shows only how the functional levels "typically" map to the equipment hierarchy. Note that a similar figure in ISA-95 part 1 shows different "typical" mappings of level 3 and 4 activities onto the equipment hierarchy, with the cross over point located between site and area, rather than in the middle of the site level. These are both typical mappings of activities to the equipment hierarchy because there is no single rigid mapping defined in the standard.

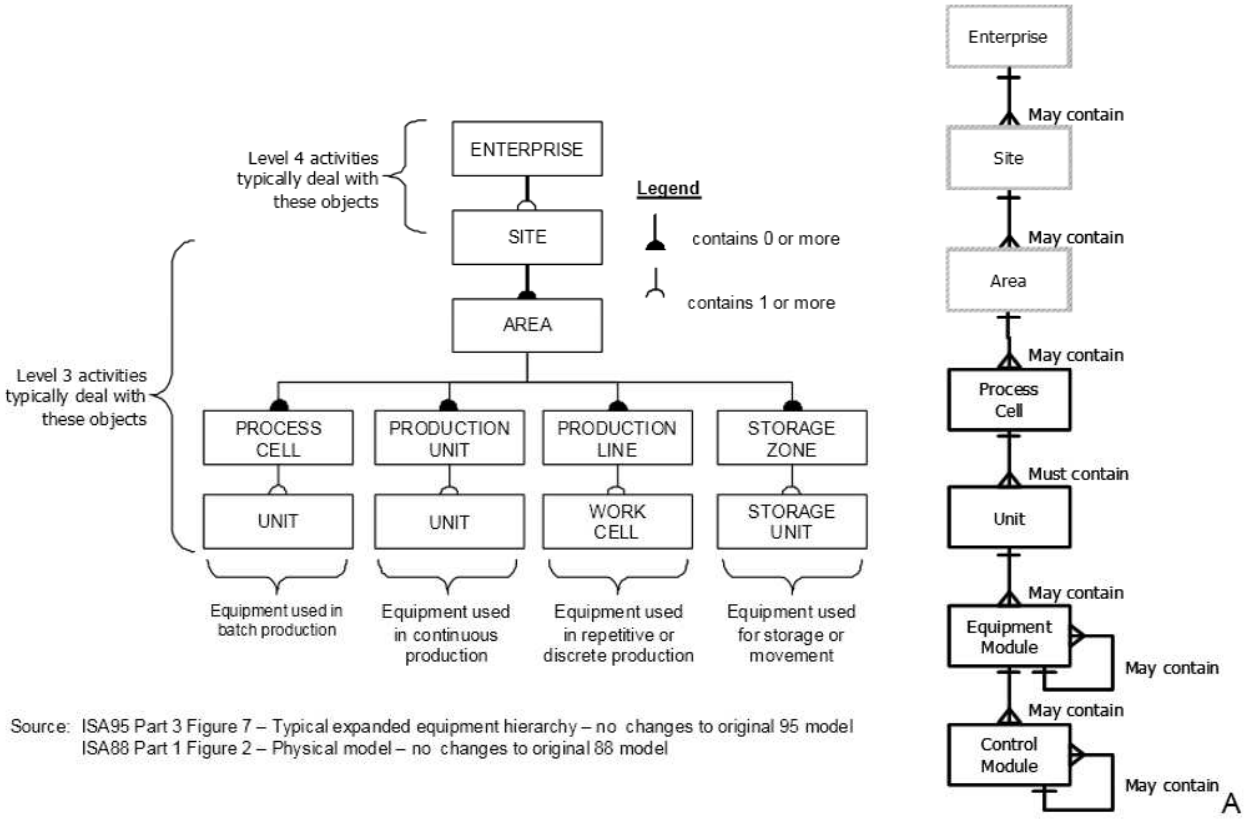


Figure 8 — ISA-88 Physical Model and ISA-95 Expanded Equipment Hierarchy

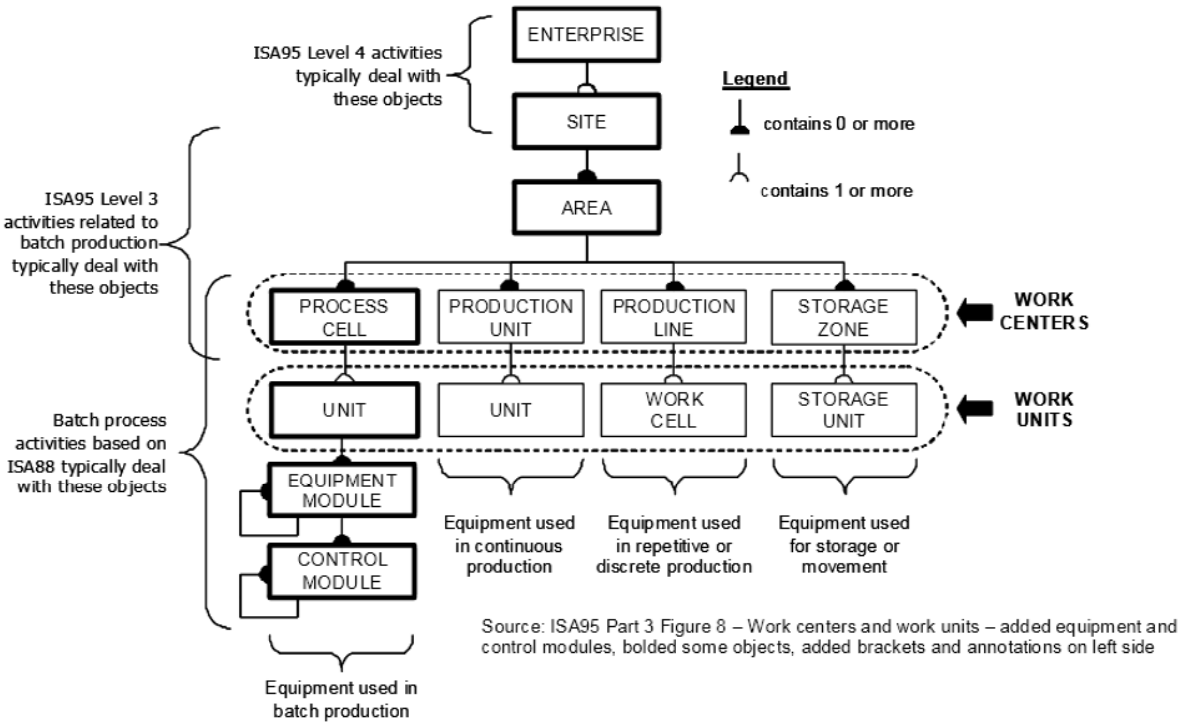


Figure 9 — ISA-88 Part 1 Physical Model Overlaid onto ISA-95 Part 3 Expanded Equipment Hierarchy, showing Work Centers and Work Units from ISA-95

The ISA-88 standard does not use the concept of functional levels. The term level is used widely in ISA-88 part 1, but it does not refer to functional levels as ISA-95 does. ISA-88 uses the term level to identify parts of hierarchies such as the physical model, process model, recipes, control activity model, and the procedural model. It is not a basic conceptual foundation as in ISA-95. Therefore, in this technical report, the term “level” is generally used to refer only to ISA-95 functional levels.

Figure 9 illustrates the ISA-88 physical model overlaid onto the ISA-95 equipment hierarchy and the curtailment of ISA-95 Level 3 activities that is required to avoid conflicting with ISA-88 control of scheduled batches in process cells.

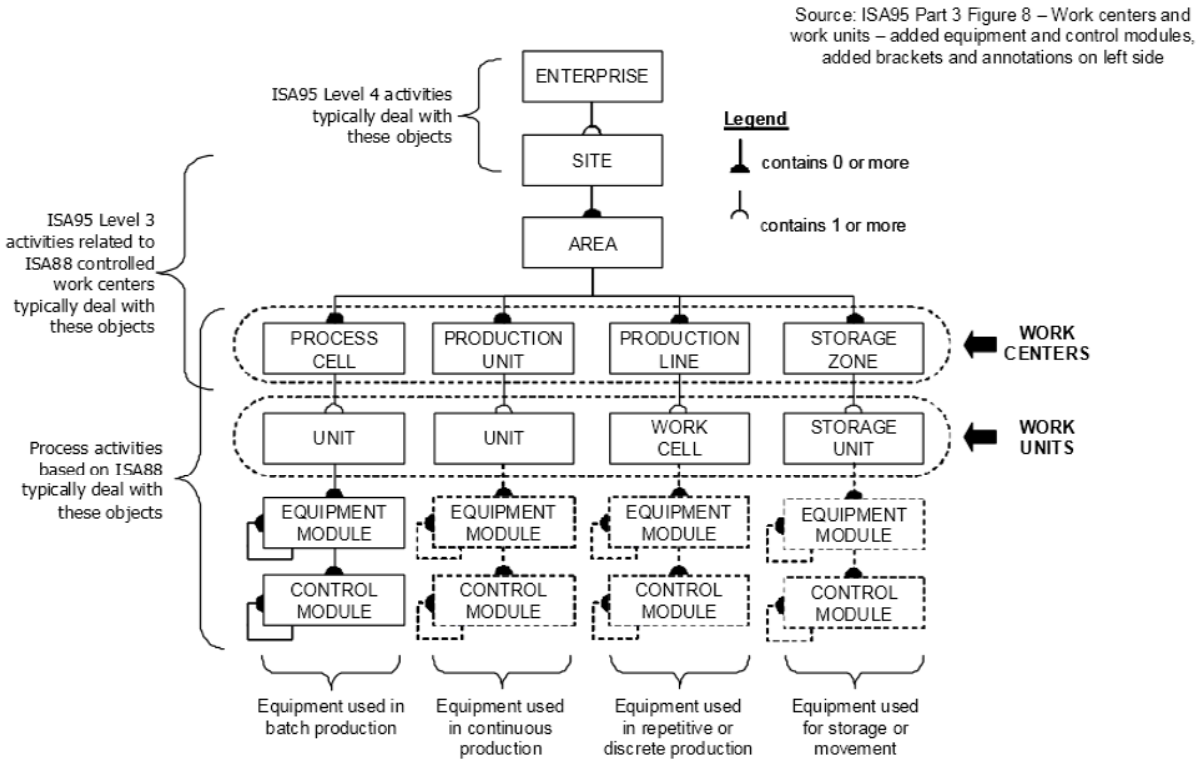


Figure 10 — Overall Physical/Equipment Model for using ISA-95 Part 3 together with ISA-88 Part 1 applied to all Work Centers and Work Units

Also illustrated in Figure 9 is the ISA-95 part 3 concept of work centers and work units, which directly correlate in batch production to the process cells and units. Although not its original scope, ISA-88 control is increasingly being applied across multiple manufacturing domains, not just for batch production, and could formally encompass them in the future. In such scenarios, the depicted curtailment of ISA-95 level 3 activities applies equally within the corresponding work centers in addition to process cells. This is depicted in Figure 10, along with the ISA-88 equipment modules and control modules that would be (and in most cases are already) used to implement most of equipment control requirements within the work centers and work units.

4.2 Categories of information exchanged

ISA-95 is focused on the information exchanged between business and control systems. The data exchanged is limited to the information the business systems need to know to plan and schedule manufacturing processes and record production information from the manufacturing process.

The ISA-88 standard focuses on the detailed information needed to run the manufacturing process, This is more technical information than is needed by the business systems to plan, schedule and record production data. The categories of information exchanged are thus generally limited to those illustrated in Figure 11 (from ISA-95 Part 3, Figure 4) and the contents summarized below.

ISA-95 Product Definition Information

- Recipes
    - General recipes are typically owned and maintained as a level 4 function
    - Site recipes could be level 3 or 4 functions
    - Master recipes are typically level 3 functions

- Control recipes are created as a level 3 function but are sent to and used by level 2 functions

Source: ISA95 Part 3 Figure 4 - Categories of information exchange

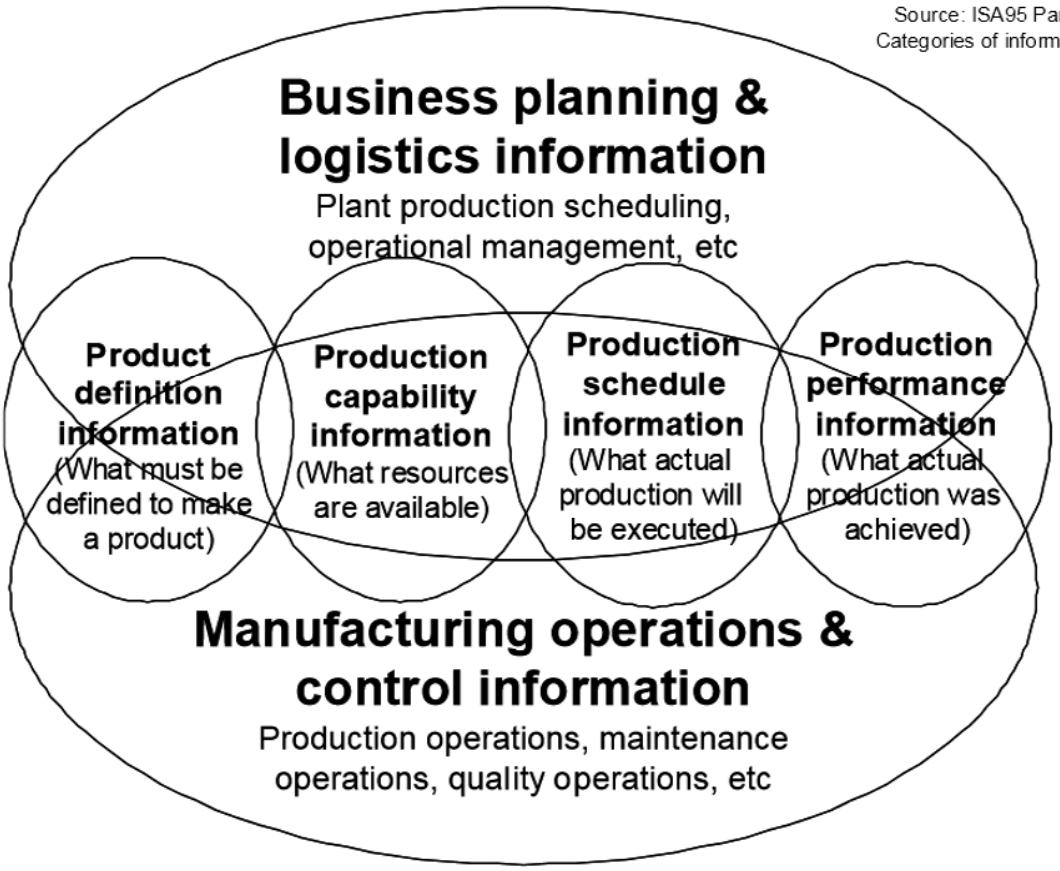


Figure 11 — ISA-95 Categories of information exchanged

ISA-95 Production Capability Information

- Information about plant resource (equipment, personnel, material)
- In ISA-88 terms
  - Equipment:
    - Capabilities of equipment entities as described by attributes in an information model
    - The master recipes this equipment is capable of running
    - Equipment status to be used to determine availability
  - Material
    - ISA-88 does not address this
  - Personnel
    - ISA-88 does not address this

ISA-95 Production Schedule Information

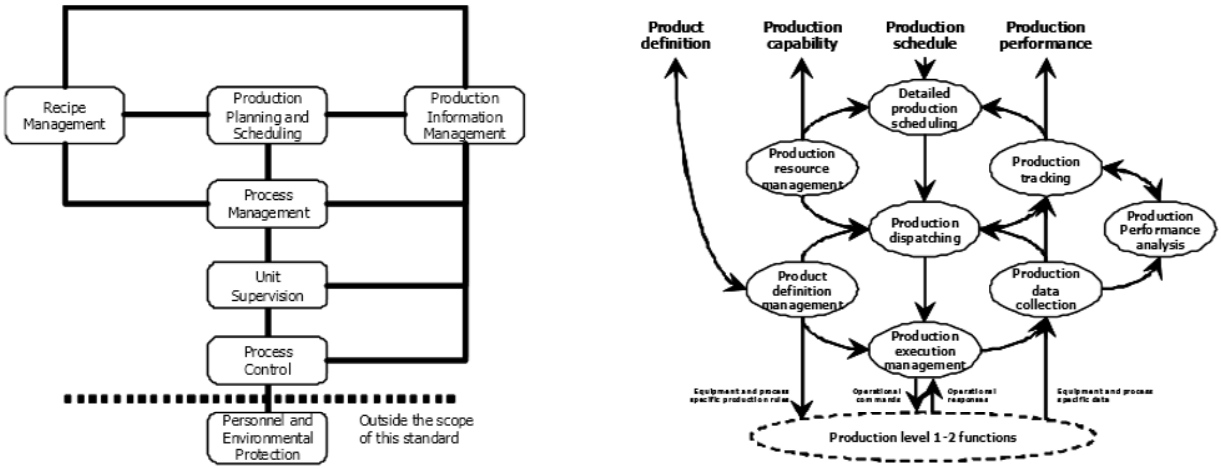
- The ISA-88 batch schedule corresponds to the ISA-95 dispatch list; this is a lower level scheduling object as it is derived from the ISA-95 detailed production schedule
  - ISA-88 does not address scheduling functions/activities above the ISA-95 dispatch list
- ISA-95 detailed production schedules and dispatch lists may contain data that is placed in a control recipe

- What equipment to use or can be used (deferring to recipe execution to decide from a set of equipment)
- Formula data used to customize a control recipe
  - May be used for different reasons such as amount of material used, messages to personnel, etc.

ISA-95 Production Performance Information

- ISA-88 batch history, production information and batch production records map to ISA-95 level 3 activities (production data collection, production performance analysis, production tracking) which are used to produce the production performance information sent to level 4 as well as provide more immediate feedback to the ISA-95 level 3 scheduling activities and flowing through production dispatching to production execution.
- ISA-88 uses many different names for production data
  - Batch history
  - Production information (part 2)
  - ISA 88 Part 4 calls it Batch Production Record
  - Process management activity model calls it Batch and Process Cell Information
  - Unit supervision activity model calls it Batch and Unit Information
  - Process control activity model calls it Data

5 ISA-88 Control Activity Model and the ISA-95 Production Operations Management Model



Source: ISA88 Part 1 Figure 19 - Control activity model – no changes to original 88 model
ISA95 Part 3 Figure 9 – Activity model of production operations management – no changes to original 95 model

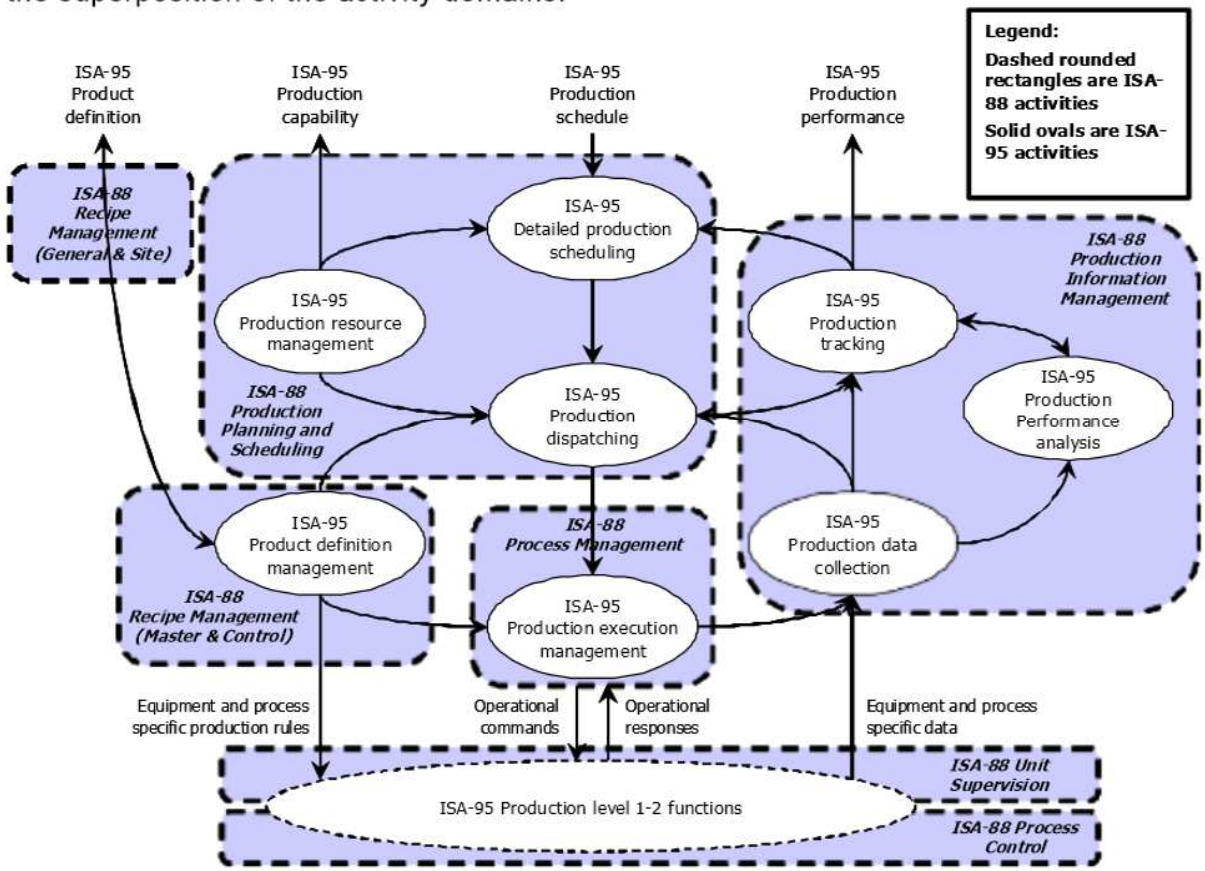
Figure 12 — ISA-88 Control Activity Model and ISA-95 Production Operations Management Model

5.1 Mapping activity models

The ISA-88 control activity model and the ISA-95 production operations management model are depicted in Figure 12. Each defines a set of activities. The control activity model defines activities commonly performed in batch process cells. The ISA-95 production operations management model defines activities commonly performed in a production environment, this model is intended to fit batch, continuous and discrete processes, so it shows a wider scope than the ISA-88 control activity model.

The ISA-88 control activities can be mapped onto the ISA-95 process operations management model as shown in Figure 13 and listed in the table below. In the figure the rounded rectangles and italicized labels represent ISA-88 control activities and their positioning shows how they

relate to the ISA-95 activities. The size of the rounded rectangles has no meaning except to show the superposition of the activity domains.



Source: ISA-95 Part 3 Figure 9 – Activity model of production operations management – objects spread out and relabeled, ISA-88 Part 1 Figure 19 – Control activity model resized and rearranged to map onto the ISA-95 figure

Figure 13 — ISA-88 Control Activity Model mapped onto ISA-95 Part 3 Figure 9 – Production Operations Management

NOTE: This Technical Report uses comparison tables to list the major activities defined in ANSI/ISA-95.00.03 Production Operations Management and explains how each activity is either addressed or not addressed in ISA-88.00.01.

Table 2 — Comparison Table: ISA-95 Production Operations Management Activities in relation to ISA-88. Batch Control Activities

ISA-95 Production Operations Management Activities	ISA-88 Batch Control Activities
Level 4 Product Definition (not in scope)	Recipe Management (General and Site)
Product Definition Management	Recipe Management (Site and Master)
Detailed Production Scheduling	Production Planning and Scheduling
Production Dispatching	
Production Resource Management	
Production Execution Management	Process Management
Production Tracking	Production Information Management

ISA-95 Production Operations Management Activities	ISA-88 Batch Control Activities
Production Performance Analysis	
Production Data Collection	
Level 0-1-2 Process Control (not in scope)	Unit Supervision
	Process Control

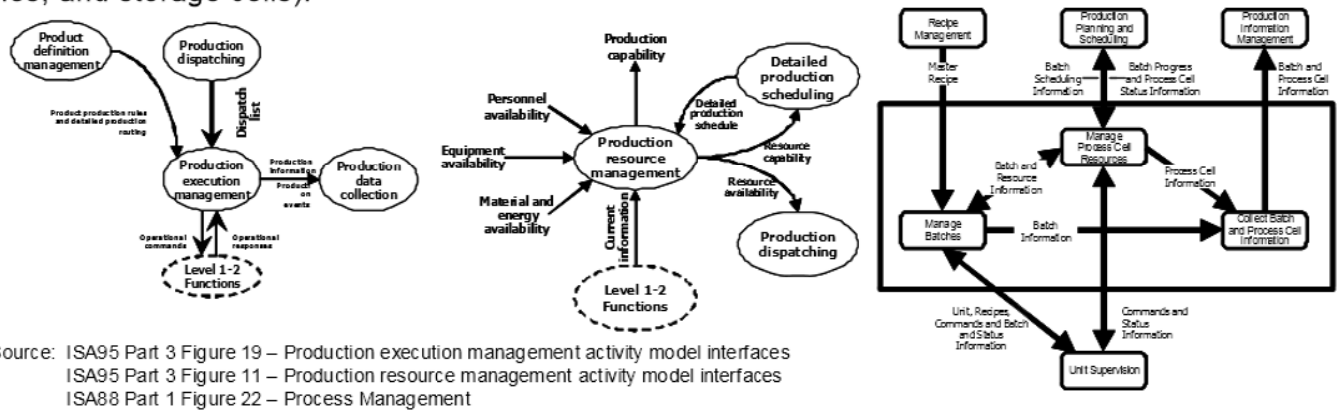
This mapping shows the coarse relationship between ISA-88 and ISA-95 activities; however a more detailed mapping reveals that there is not a one to one mapping. The subsections below provide more information on the detailed mappings for the ISA-88 and ISA-95 activities. A noteworthy example detailed in the following subsection is the weak mapping between ISA-88 Process Management and ISA-95 Resource Management.

The lines in the ISA-88 control activity model show relationships between activities, not data flows. The above mapping of the ISA-88 control activities to the ISA-95 production operations management model reveals that the ISA-95 information flows are applicable to ISA-88 control activities, at least on a coarse level.

5.2 Alignment of ISA-88 Process Management and ISA-95 Production Resource/Execution Management Activities

ISA-95 part 3 focuses on work center, area and site levels, but ISA-88 deals only with a process cell and the lower equipment entities it contains.

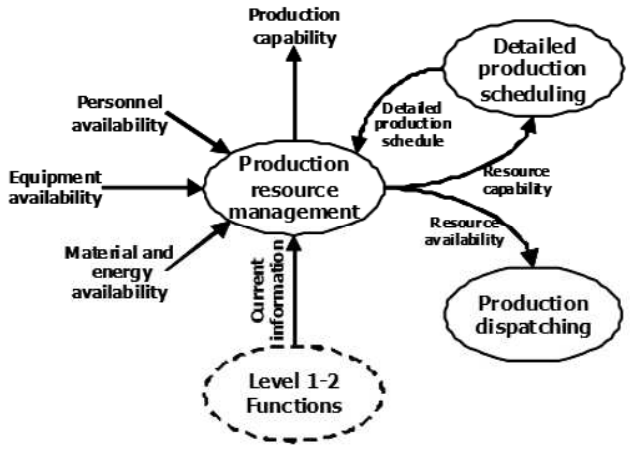
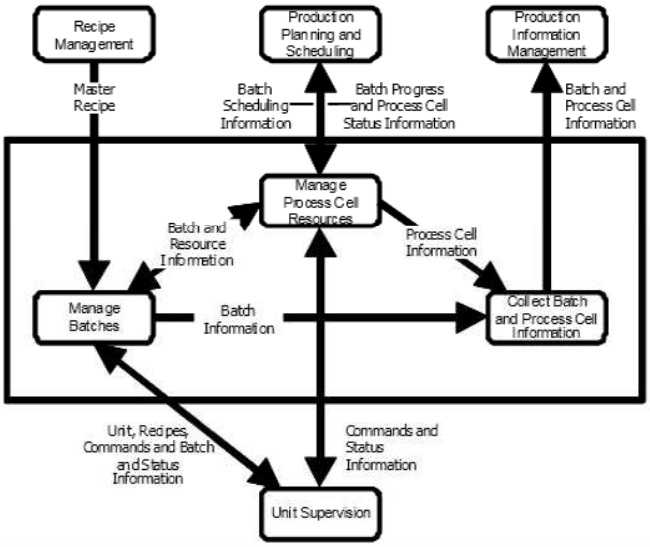
There is overlap with ISA-88 Process Management in the process cell as is illustrated in Figure 14. When this occurs remember that any ISA88-controlled batch is constrained to a single process cell; however, ISA-95 Production Execution Management and Production Resource Management may span multiple work centers (i.e. process cells, production units, production lines, and storage cells).



Source: ISA95 Part 3 Figure 19 – Production execution management activity model interfaces
ISA95 Part 3 Figure 11 – Production resource management activity model interfaces
ISA88 Part 1 Figure 22 – Process Management

Figure 14 — ISA-95 Production Resource/Execution Management and ISA-88 Process Management Activities

Table 3 — Comparison Table: ISA-95 Part 3 Production Resource/Execution Management in relation to ISA-88 Process Management Activities

ISA-95 Part 3 Production Resource & Execution Management	How it applies to ISA-88 Process Management
	
ISA-95 Part 3 section 6.5 Production resource management – see section 6.4 of this technical report for relationships of other aspects to ISA-88 Planning and Scheduling	
	The following recommendation to revise ISA-88 part 1 has been submitted to the ISA88 committee: Both ISA-95 and ISA-88 contain functions called resource management. While they might look like overlap, they are not. Resource management as described in ISA-95 is strategic and sometimes tactical, but essentially always forward-looking. Resource management as described in ISA-88 Process Cell Management is, in reality, resource tracking and execution related allocation. Revising the language to emphasize that the two functions are, indeed, different and complimentary rather than overlapping will make the joint use of the two standards less confusing. Refer to Annex B for specific recommended revision to ISA-88 part 1, section 6.5.2.
Production resource management shall be defined as the collection of activities that manage the information about resources required by production operations. The resources include machines, tools, labor (with specific skill sets), materials, and energy, as defined in the Part 1 object models.	ISA-88 process management deals with this in a process cell but is constrained by the batch schedule (= ISA-95 dispatch list). The batch schedule is limited to the process cell boundary.

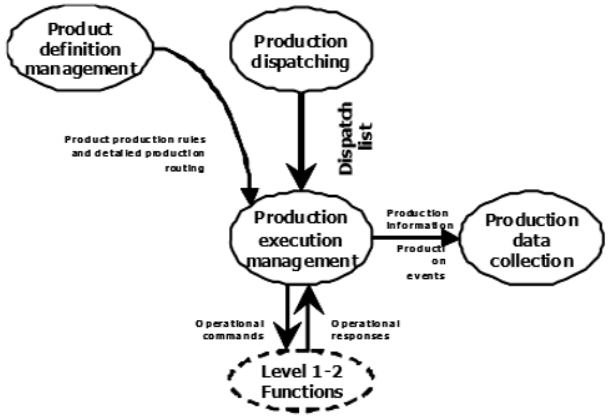
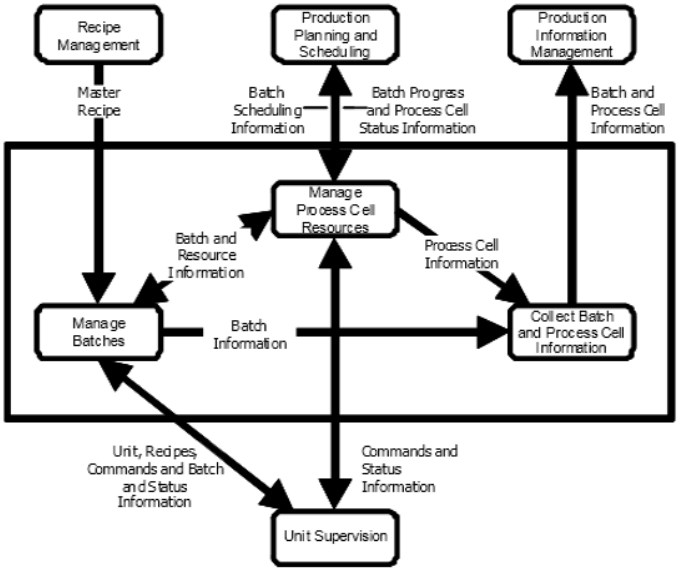
ISA-95 Part 3 Production Resource & Execution Management	How it applies to ISA-88 Process Management
Direct control of these resources in order to meet production requirements is performed in other activities, such as production dispatching and production execution management.	ISA-88 process management is responsible for reservation, arbitration, assignment, and allocation of resources, primarily equipment resources.
Management of information about segments of production is also an activity in resource management.	Segments of production are unit recipes/procedures, etc.
Management of the resource information may be handled by computer systems, but it may be partly or entirely handled by manual processes.	ISA-88 is intended to apply to manual as well as automated processes.
Management of the resources may include local resource reservation systems to manage information about future availability. There may be separate reservation systems for each managed critical resource. There may be separate activities for each type of resource, or combined activities for sets of resources.	Process management does not deal with future availability. Scheduling does this. Local reservation is assumed to be within the process cell. It is acceptable to have a separate reservation system for each managed resource.
Information about resources needed for a segment of production must be maintained and provided on the available, committed, and unattainable capacity for specific periods of time of specified resources as defined in Part 1.	Other than current production status origination of this information is outside the scope of ISA-88 ISA-88 process mgt assigns resources so it has input to resource available and committed status but it does not collect unattainable status.
ISA-95 Part 3 section 6.5.3 Tasks in production resource management	
Production resource management tasks may include:	
a) Providing personnel, material, and equipment resource definitions. The information may be provided on demand or on a defined schedule, and may be provided to people, to applications, or to other activities.	Beyond scope of ISA-88. ISA-88 activities may use the definitions but they do not provide them.

ISA-95 Part 3 Production Resource & Execution Management	How it applies to ISA-88 Process Management
b) Providing information on resource (material, equipment, or personnel) capability (committed, available, or unattainable). The information is based on the current statuses, future reservations, and future needs (as identified in the production plan and detailed production schedule) and is specific for resources, for defined time spans and process segments. It may include information on current balance and losses to product cost accounting and may be provided on demand or on a defined schedule, and may be provided to people, to applications, or to other activities.	ISA-88 process management does some of this, specifically dealing with current status information within the scope of the batch schedule (ISA-95 dispatch list).
c) Ensuring that requests for acquisition of resources to meet future operational capabilities are initiated.	ISA-88 does not generally initiate requests for future operational capabilities. It does deal with short time horizon issues such as arbitration, allocation, reservation within the scope of the batch schedule.
d) Ensuring that equipment is available for the assigned tasks, and that job titles are correct and training is current for personnel assigned to tasks. EXAMPLE: Checking that an equipment sterilization status is correct ("Clean") before it is assigned to a production operation.	Batch control systems are often programmed to check personnel, material and equipment qualification checks, but the ISA-88 standard does not address this.
e) Providing information on the location of resources and assignment of resources to areas of production. EXAMPLE: Providing a location for a mobile inspection machine that can be used in multiple locations.	Within a process cell for material and equipment. ISA-88 Part 1 6.5.2 Manage Process Cell Resources: "Process cell resource management must know which materials are in the process cell, their location, and their disposition."
f) Coordinating the management of resources with maintenance resource management and quality resource management.	ISA-88 does not address this.
g) Collecting information on the current state of personnel, equipment, and material resources and on the capacity and capability of the resources. Information may be collected based on events, on demand and/or on a defined schedule, and may be collected from equipment, people, and/or applications.	6.5.3 Collect batch and process cell information addresses this.

ISA-95 Part 3 Production Resource & Execution Management	How it applies to ISA-88 Process Management
h) Collecting future needs such as from the production plan, current production, maintenance schedules, or vacation schedules.	Batch control systems are often programmed to do this but ISA-88 does not address this.
i) Maintaining personnel qualification test result information.	Batch control systems are often programmed to do this but ISA-88 does not address this.
j) Maintaining equipment capability test result information.	Batch control systems are often programmed to do this but ISA-88 does not address this.
k) Managing reservations for future use of resources.	Batch control systems are often programmed to do this but ISA-88 does not address this.
ISA-95 Part 3 section 6.5.4 Resource availablity	
Resource availability provides time-specific definitions needed for scheduling and reporting on a resource. The resource availability must take into account elements such as working hours, labor regulations, holiday calendar, breaks, plant shutdowns, and shift schedules. EXAMPLE: The available time can be a fixed time or a flexible time. For example, in personnel resource management the time for lunch may be flexible between 11:00 AM and 2:00 PM, or a machine may be unavailable for 8 hours within a 16-hour period. Personnel availability may define working days and days off; Monday to Friday are available for work, Saturday and Sunday are unavailable for work, or available for 2 days early shift, 2 days late shift, 2 days night shift, and 3 days off. ISA 95 Part 3 Figure 12 illustrates the types of information about the capacity of a single resource that may be provided by resource management.	ISA-88 production planning and scheduling would address this or use the data obtained from a source outside the scope of ISA-88.
ISA-95 Part 3 section 6.5.5 Collecting future committed resource information	
Production resource management manages committed resource availability based on the detailed production schedule and product requirements. An assigned resource changes from available to committed for the period of time defined by the production plan, or until the completion of the scheduled task.	ISA-88 production planning and scheduling would address this or use the data obtained from a source outside the scope of ISA-88.

ISA-95 Part 3 Production Resource & Execution Management	How it applies to ISA-88 Process Management
NOTE: Once the schedule window requiring the resource is completed, the resource is typically taken back to the available state, unless it was already dispatched for a new assignment. In the most basic systems, the end of the planned schedule window triggers this ending of committed time window. But for more sophisticated systems, it may be triggered by production tracking that relays the actual time the work is completed to production resource management.	ISA-88 production planning and scheduling addresses this. In ISA-88 resource reservation and allocation are addressed at the execution level – not at this planning and scheduling level.
ISA-95 Part 3 section 6.5.6 Collecting resource definition changes	
The production resource management activity includes collecting information about new, modified, or deleted resource definitions, classes, and instances. This includes information on resource property definitions.	ISA-88 uses the resource definition changes but does not manage this data.
ISA-95 Part 3 section 6.5.7 Personnel resource information management	
Management of information about personnel resources and future personnel availability is part of resource management. EXAMPLE: If an individual has vacation planned or is known sick for a certain period of time, then a business-level Human Resource (HR) function may report this situation to production resource management. This prevents production from assigning the resource within this period of time. As an extension, the whole working schedule of the personnel must be known by production in order to make the right allocation decisions. This may include information such as levels of certification, tracking of time spent for specific tasks, and managing availability of personnel resources. In some cases this information is maintained and managed in corporate HR (Human Resource) systems, but must be available to manufacturing. Often the level of detail required for manufacturing, such as certification expiration dates and union line of seniority, is not maintained in the HR systems. In these cases labor management can be considered part of the manufacturing operations activities. The production resource management activity also has to address skill levels. Each member	ISA-88 does not directly address this, but such issues as operator qualifications can be address in the ISA-88 recipe structures or as part of the batch schedule.

ISA-95 Part 3 Production Resource & Execution Management	How it applies to ISA-88 Process Management
of the personnel may have recognized skills through qualification tests results. This defines a skill profile utilized by production resource management to allow the dispatch of the qualified personnel to each specific production activity.	
ISA-95 Part 3 section 6.5.8 Equipment resource information management	
Management of information about equipment resources and future equipment availability is part of resource management. Maintenance operations often have a major impact on resource utilization. Periods of future unavailability, based on yet unscheduled maintenance requirements, also affect utilization. EXAMPLE: When a piece of equipment is reported defective, a maintenance task request could request the equipment to be classified as unavailable. The equipment would be also classified as unavailable if preventive maintenance is scheduled for this equipment. When the equipment is repaired or the preventive maintenance activity is over, the maintenance task would request that the equipment is to be taken back to its available status. Selected equipment may be submitted to an equipment capability test as defined in the Part 1 standard. This test result determines if specific equipment may be assigned for a specific task in a specific process segment.	ISA-88 does not address future availability; it does some management of current equipment status.
ISA-95 Part 3 section 6.5.9 Material resource information management	
Management of information about material and energy resources and future material and energy availability is part of resource management. Production resource management is informed as material is received or energy is made available. Future availability is also maintained to provide information for production scheduling. Production resource management includes managing information about changes in material conditions, such as when material lot/sub lot or energy source is found to have changed its specification. Changes are often indicated from QA test results. EXAMPLE: A material lot may change from	ISA-88 states this is done for current status, but it doesn't say how. Future availability is not addressed. ISA-88 Part 1 6.5.2 Manage Process Cell Resources: "Process cell resource management must know which materials are in the process cell, their location, and their disposition."

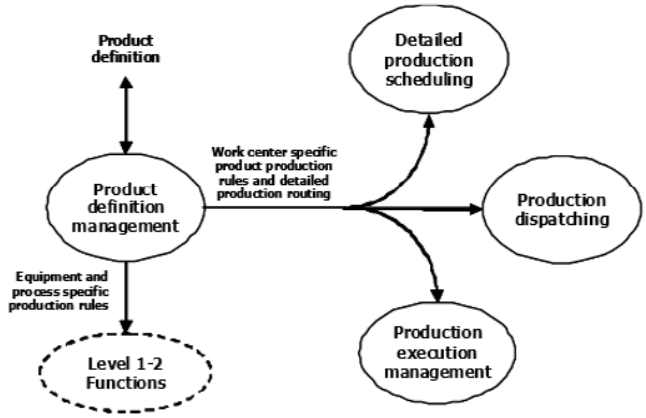
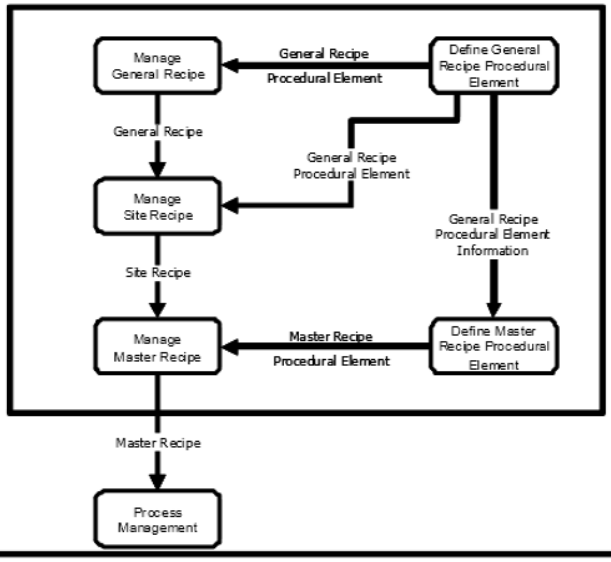
ISA-95 Part 3 Production Resource & Execution Management	How it applies to ISA-88 Process Management
"dry" to "wet," a pH may change from 7.0 to 7.1, or available electrical power may change from 300 kW to 280 kW.	
ISA-95 Part 3 section 6.8 Production execution management ISA-95 Part 3 section 6.8.1 Activity definition	
Production execution management shall be defined as the collection of activities that direct the performance of work, as specified by the contents of the production dispatch list elements.	
	
The production execution management activity includes selecting, starting and moving those units of work (for example lots, sublots, or batches) through the appropriate sequence of operations to physically produce the product. The actual work (manual or automatic) is part of the Level 2 functions.	In ISA-88 the units of work are batches. The appropriate sequence is a recipe procedure. Work is done at lower procedural levels such as unit recipes, operations, and phases in unit supervision which maps to ISA-95 level 2.
NOTE: The definition of a sequence may take the form of a detailed production route specific for a particular produced item. Production execution transacts the individual units of work from one operation or step to the next, collecting and accounting for such things as actual materials consumed, labor hours used, yields and scrap at each step or operation. This provides visibility into the status and location of each lot or unit of work or production order at any moment in the plant, and offers a way to provide external customers with visibility into the status of an order in the plant.	Tracking of labor and material usage can be collected as data in a recipe if needed, but labor data is typically not a concern in the process industries. In ISA-88 sequences map to procedures.

ISA-95 Part 3 Production Resource & Execution Management	How it applies to ISA-88 Process Management
Production execution management may use information from previous production runs, captured in production tracking, in order to perform local optimizations and increase efficiencies.	This is a common practice but the ISA-88 standard does not have a data flow showing this.
ISA-95 Part 3 section 6.8.3 Tasks in production execution management	
The production execution management activities include the coordination of the manual and automated processes in a site or area. This often requires well-defined communication channels to automated control equipment.	ISA-88 process management is the collection of control functions that manage all batches and resources within a process cell. The following request has been submitted to the ISA95 committee: Committee asks ISA95 to modify part 3 to state that production execution mgt also includes activities in a process cell, proposed new text is: Production execution management activities include the coordination of the manual and automated processes in a site, or area or work center. NOTE: ISA-95 level 3 and ISA-88 overlap at the process cell level. Level 3 functions as defined in ISA-95 will not typically cover units. Figure 10 is primarily for use with batch processes – the difference is that there is a batch standard defining ISA-95 level 3, 2 and 1 activities where in continuous and discrete processes there is no lower level standard and in discrete there is a tradition of ERP and MES functions having more interaction with the shop floor than in batch processes.
Production execution management tasks may include the following:	
a) Directing the performance of work and initiating Level 2 activities.	Work as in batches, level 2 activities are unit recipes/procedures.
b) Ensuring that the correct resources (equipment, materials, and personnel) are used in production.	Resources are specified by the recipe and schedule.
c) Confirming that the work is performed according to the accepted quality standards. This may involve receiving information from quality activities.	This also applies in ISA-88, but how it is done is recipe and equipment specific. ISA-88 does not address quality as a separate topic as ISA-95 part 3 does.

ISA-95 Part 3 Production Resource & Execution Management	How it applies to ISA-88 Process Management
d) Ensuring that resources are valid for the assigned tasks. EXAMPLE: This may be ensuring that equipment sterilization status is correct for the assigned operation (e.g., a vessel is "Clean" before use in production). EXAMPLE: Equipment certifications are current, personnel qualifications are up to date, and materials are released for use.	Typically done in a recipe or in control logic, equipment class definition, equipment status, or equipment logic. Material release is outside the scope of ISA-88, it is assumed that information is available to scheduling or embedded in phase logic.
e) Assigning resources under local run time control. EXAMPLE: The assignment of units to a batch, if the detailed production schedule does not define unit allocation.	This applies directly in ISA-88.
f) Informing other activities when unanticipated events result in the inability to meet the work requirements.	This is a function of production information management. It is also a function of process control and unit supervision. For example: propagate a state from the lower level of a recipe to a higher level and then, putting parts of the recipe on hold or in manual mode.
g) Receiving information from production resource management about unanticipated future resource availability.	ISA-88 process management does not perform resource prediction; it presumes this is handled outside the process management activity. The data can be sent to process management via Production Planning and Scheduling. Production Planning and Scheduling is responsible for "determining the availability of resources as an input to the scheduling process."
h) Providing production information and events on production execution management, such as timing, yields, labor and material used, start of runs, and completion of runs.	Some of this is done by Collect Batch and Process Cell Information. Some information is collected by Production Information Management directly from Unit Supervision.

5.3 Alignment of ISA-88 Recipe Management and ISA-95 Product Definition Management Activities

Table 4 — Comparison Table: ISA-95 Part 3 Product Definition Management activities in Relation to the ISA-88 Recipe Management Activity

ISA-95 Part 3 Product Definition Management	How it applies to ISA-88 Recipe Management
	
ISA-95 Part 3 section **6.4.1 Activity definition**	
Product definition management shall be defined as the collection of activities that manage all of the Level 3 information about the product required for manufacturing, including the product production rules.	ISA-88 defines the Recipe Management activity that is very similar in function to the Product Definition Management activity defined in ISA-95. The ISA-88 activity is a well defined four level hierarchy ranging from the General Recipe that may well exist at ISA-95 level 4 to the Control Recipe that is actually executed in the ISA-88 Process Management and Unit Supervision activities. The ISA-95 Product Definition Management activity is focused primarily on the Master Recipe.
Product definition information is shared between product production rules, bill of material, and bill of resources. The product production rules contain the information used to instruct a manufacturing operation how to produce a product. This may be called a general, site, or master recipe (IEC 61512-1 and ANSI/ISA88.00.01-1995 definition), standard operating procedure (SOP), standard operating conditions (SOC), routing, or assembly steps based on the production strategy used. The product definition information is made available to other Level 3 functions and to Level 2 functions as required.	

ISA-95 Part 3 Product Definition Management	How it applies to ISA-88 Recipe Management
Product definition management includes management of the distribution of product production rules. Some of the product production rules may exist in Level 2 and Level 1 equipment. When that is the case, downloads of this information shall be coordinated with other manufacturing operations management functions to avoid affecting production. This information may be included as part of operational commands when the download is part of a production execution management activity.	In most cases, this line goes through Process Management when the ISA-88 models are used.
ISA-95 Part 3 section 6.4.3 Tasks in product definition management	
Product definition management tasks may include the following:	
a) Managing documents such as manufacturing instructions, recipes, product structure diagrams, manufacturing bills, and product variant definitions.	Applies only to ISA-95.
b) Managing new product definitions.	In ISA-88, this would be a new recipe.
c) Managing changes to product definitions. This may include the ability to route designs and manufacturing bill changes through an appropriate approval process, management of versions, tracking of modifications, and security control of the information.	Applies equally to ISA-88 except that the approval process is not specified in ISA-88.
d) Providing product production rules to personnel or other activities. EXAMPLE: These may take the form of manufacturing steps, master recipes, machine setup rules, and process flowsheets.	This applies equally to ISA-88. Although the form is clearly different, ISA-88 makes no specific distinction between recipes intended for people or automated systems.
e) Maintaining the feasible detailed production routings for products.	ISA-88 recipes contain equipment requirement information which defines which routings within a process cell may be used for a given product.
f) Providing the product segment route to manufacturing operations in the level of detail required by manufacturing operations.	The product segment route in ISA-88 would be very similar to the feasible detailed production routings mentioned in e) above.
g) Managing the exchange of product definition information with Level 4 functions at the level of detail required by the business operations.	ISA-88 defines the General, Site and Master recipes as three levels of detail that can be exchanged with any other function including level 4 functions.
h) Optimizing product production rules based on process analysis and production performance analysis.	This is part of recipe management.

ISA-95 Part 3 Product Definition Management	How it applies to ISA-88 Recipe Management
i) Generating and maintaining local production rule sets indirectly related to products, such as for cleaning, startup, and shutdown.	ISA-88 anticipates that these activities are directed by a recipe – either as part of a product recipe or as a separate recipe for the activity. EXAMPLE: Cleaning recipe.
j) Managing the Key Performance Indicator (KPI) definitions associated with products and production.	Could be embedded within the ISA-88 recipe.
NOTE: There are a number of tools to assist in the product definition management activity, including mechanical and electronic computer-aided design (CAD), Computer-Aided Engineering (CAE), and Computer-Aided Software Engineering (CASE), recipe management systems, Computer-Aided Process Engineering (CAPE), and Electronic Work Instructions (EWIs).	ISA-88 is more specific about the form and function of the recipe, which defines the batch product.
ISA-95 Part 3 section 6.4.4 Product definition rule information	
Product definition is the information exchanged with engineering, R&D and others to develop the site specific product production rules. This information may include R&D manufacturing definitions that are translated and extended by product definition management into site-specific definitions using local material, equipment, and personnel. This may also involve translation to elements of a work order. EXAMPLE: Translation to master recipes, machine setup rules, and process flow diagrams. Product definition management may also include managing other product information in conjunction with manufacturing information. This may include: • Customer requirements, product design, and test specifications. • Process design and simulation • Technical publications and service materials. • Regulatory filings requirement information.	The equivalent information in ISA-88 would come from a Site Recipe or a General Recipe if no Site Recipe is required. The creation of a General Recipe is not in the scope of ISA-95.

ISA-95 Part 3 Product Definition Management	How it applies to ISA-88 Recipe Management
The product definition management activity interacts with production dispatching and production execution management to get the work done and interacts with research development and engineering to obtain the product production rules for executing the work. EXAMPLE: Production dispatching activities may need to refer to production dependencies to identify when a specific resource will be required.	This is similar to ISA-88 Functionality.
The product production rule identifies elements of a work order and establishes relationships between them. Each element can contain information regarding personnel, equipment, material, and product parameters. To perform these functions, product definition management may need to exchange information with resource management.	This type of information is essential to the creation of any level of ISA-88 recipe.
ISA-95 Part 3 section 6.4.5 Detailed production routing	
The product definition information includes dependencies of work order elements. Detailed work order element routing may contain a finer granularity of definition than is visible to business systems, but is required for detailed routing of work between work centers (process cells, production lines, and production units). Detailed work order element routing is organized by the physical production process. NOTE: A detailed production routing is sometimes called a production route, master business system route, master route, or business route.	In an ISA-88 implementation, the routing described in ISA-95 typically defines the order in which a specified sequence of recipes is to be executed in a specified sequence of process cells.

5.4 Alignment of ISA-88 Planning and Scheduling and ISA-95 Dispatching and Detailed Scheduling Activities

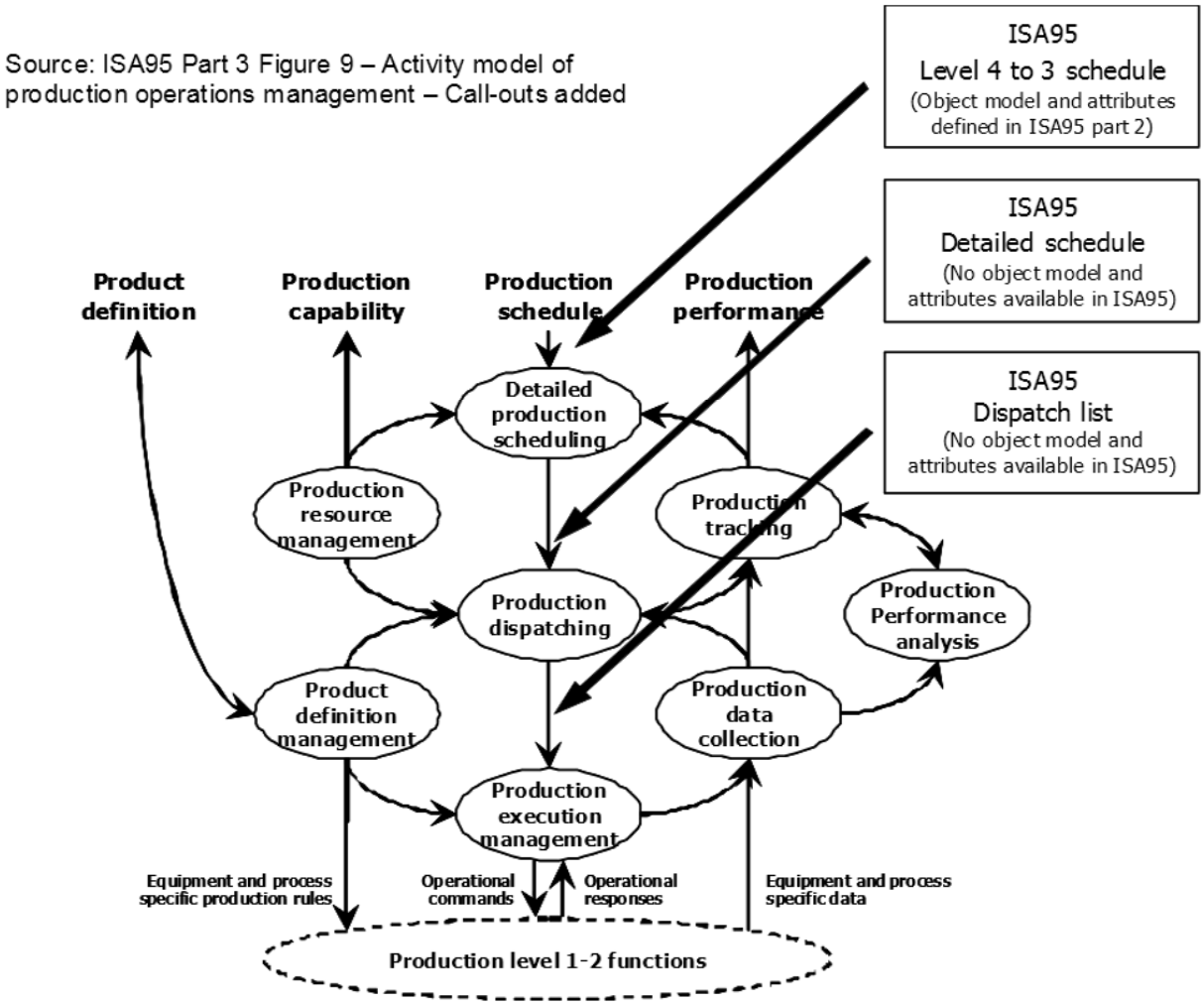
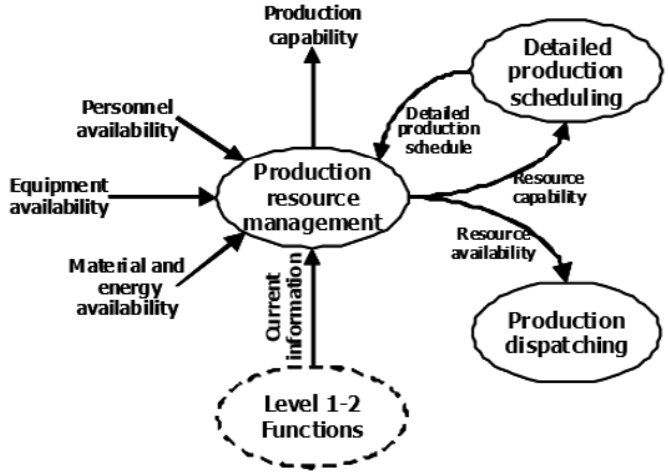
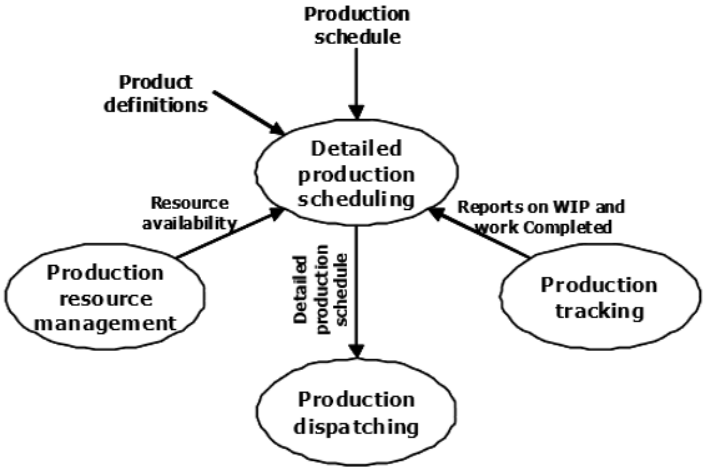
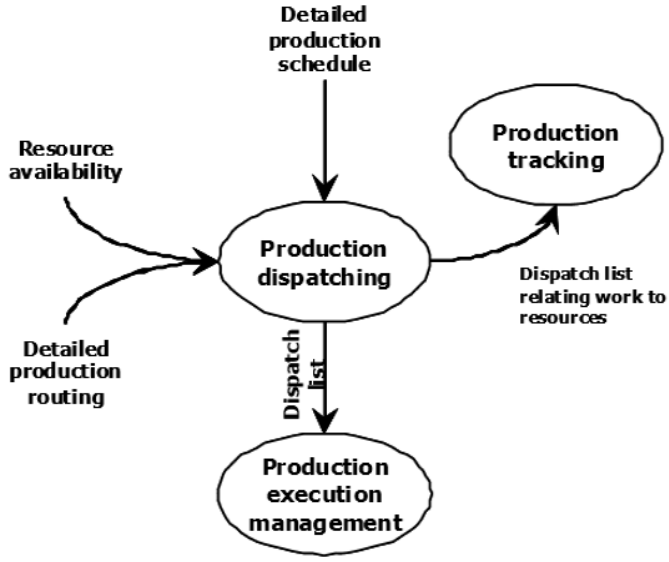


Figure 15 — ISA-95 Dispatching and Detailed Scheduling Activities

Table 5 — Comparison Table: ISA-95 Part 3 Dispatching and Detailed Scheduling in Relation to ISA-88 Planning and Scheduling Activities

ISA-95 Part 3 Dispatching and Detailed Scheduling	How it applies to ISA-88 Planning and Scheduling
	
ISA-95 Part 3 section 6.5 Production resource management – see section 5.2 of this technical report for relationships of other aspects to ISA-88 Process Management	
NOTE: Once the schedule window requiring the resource is completed, the resource is typically taken back to the available state, unless it was already dispatched for a new assignment. In the most basic systems, the end of the planned schedule window triggers this ending of committed time window. But for more sophisticated systems, it may be triggered by production tracking that relays the actual time the work is completed to production resource management.	
ISA-95 Part 3 Section 6.6 Detailed production scheduling **ISA-95 Part 3 section 6.6.1 Activity definition**	
Detailed production scheduling shall be defined as the collection of activities that take the production schedule and determine the optimal use of local resources to meet the production schedule	The ISA-95 detailed production scheduling activity is part of the ISA-88 production planning and scheduling activity.

ISA-95 Part 3 Dispatching and Detailed Scheduling	How it applies to ISA-88 Planning and Scheduling
requirements. This may include ordering the requests for minimal equipment setup or cleaning, merging requests for optimal use of equipment, and splitting requests when required because of batch sizes or limited production rates. Detailed production scheduling takes into account local situations and resource availability. NOTE: Enterprise-level planning systems often do not have the detailed information required to schedule specific work centers, work center elements, or personnel.	
ISA-95 Part 3 section 6.6.2 Activity model	
ISA 95 Part 3 Figure 13 illustrates some of the interfaces to detailed production scheduling  ISA 95 Part 3 Figure 13 – Detailed production scheduling activity model interfaces	ISA-88 does not define detail for this activity, it does focus on activities involving the receipt and processing of schedules (dispatch lists in ISA-95 terminology). For this reason there is no conflict between ISA-88 Part 1 and ISA-95. Therefore for detailed guidance, a practitioner should rely on ANSI/ISA95.00.03.
ISA-95 Part 3 Section 6.7 Production dispatching **ISA-95 Part 3 Section 6.7.1 Activity definition**	
Production dispatching shall be defined as the collection of activities that manage the flow of production by dispatching production to equipment and personnel. This may involve: a) Scheduling batches to start in a batch control system. b) Scheduling production runs to start in production lines. c) Specifying standard operating condition targets in production units. d) Sending work orders to work centers.	The ISA-95 production dispatching activity is part of the ISA-88 production planning and scheduling activity.

ISA-95 Part 3 Dispatching and Detailed Scheduling	How it applies to ISA-88 Planning and Scheduling
e) Issuing work orders for manual operations. EXAMPLE: Dispatched work may be machine setup, grade change switchovers, equipment cleaning, run rate setup, or production flow setup.	
ISA-95 Part 3 Section 6.7.2 Activity model	
ISA 95 part 3 Figure 16 shown below illustrates some of the interfaces to production dispatching  ISA 95 part 3 Figure 16 – Production dispatching activity model interfaces	ISA-95 defines production dispatching as the source of dispatch lists. The ISA-95 dispatch list is the equivalent of the ISA-88 batch scheduling information referenced in ISA-88 Part 1, Figure 22, as an input to process management from production planning and scheduling. This is the common point between the two standards. The details of the ISA-95 production dispatching activity are only covered very briefly in ISA-88 Part 1, section 6.3 Production planning and scheduling. For this reason there is no conflict between ISA-95 and ISA-88 Part 1. Therefore, for detailed guidance, a practitioner should rely on ANSI/ISA-95.00.03.

5.4.1 Comparison of ISA-88 Planning and Scheduling and ISA-95 Dispatching/Detailed Scheduling Activities by Physical Hierarchy and Functional Levels

ISA-95 acknowledges different levels of planning and scheduling. The higher levels are more or less out of scope of ISA-95 (e.g., development of a business plan and development of a demand plan). That is because ISA-95 focuses on the integration of enterprise and control systems. The development of a schedule and the flow of this information to level 3 is within scope of enterprise-control system integration. ISA-95 also explains which scheduling activities (detailed production scheduling and dispatching) and supporting activities (resource management) take place within level 3. ISA-95 mentions the development of a batch list as part of the responsibility of the Production Dispatching activity.

ISA-88 focuses on batch control within the Process Cell. In its Activity model, ISA-88 makes clear that, before, during and after the execution of batch processes, several activities take place. These include production planning and scheduling activities. From the ISA-88 perspective this is a high level control activity that ISA-88 considers to be out of scope. Planning and scheduling functions described in the two standards is illustrated in Figure 15 and by level in Table 7 below.

Table 6 — Comparison ISA-95 Schedule model versus ISA-88 Procedural elements

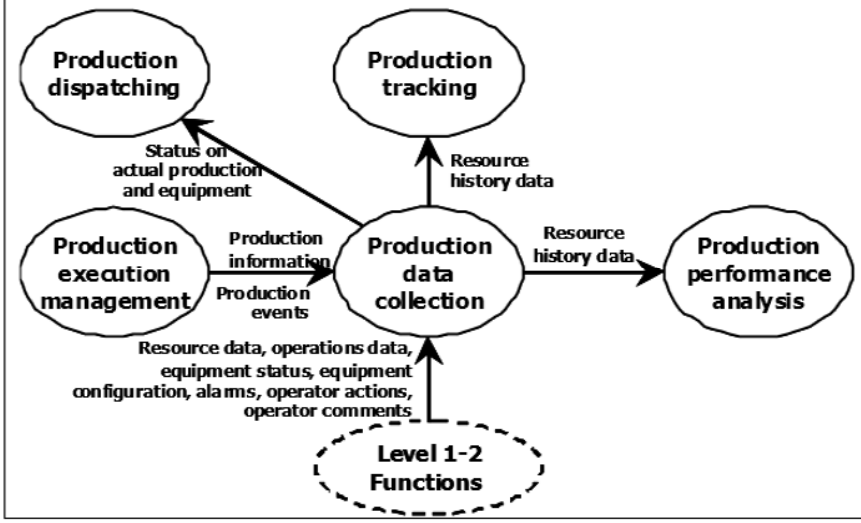
Level	Physical model	Level of detail	ISA-95	ISA-88 Control Recipe Level	EXAMPLE
4 (aims at level 3)	Enterprise / Site	Production of several products, or intermediates	Production schedule (Contains several level 4 production orders)	NA. at this level	Schedule 2006-week 20-v1
3 (aims at areas and work centres)	Area(s)	Production of a product, or an intermediate	Production request (Contains one level 4 production order. May contain several segments which need to be executed in sequence, or parallel, in order to produced the requested product or intermediate)	NA. at this level	Request 1: Produce x boxes with six packs of bounties Request 2: Produce x boxes with six packs of milky ways.
3 (aims at area and work centres)	Area	Production of a product, or an intermediate	Production segment requirement (The (production)order to execute one product or process segment, usually an intermediate)	NA. at this level	Segment 1: Produce x bounties Segment 2: Package x bounties
3	Process cell	Production of one or more batches	Production segment requirement (within the upper segment)	Procedure	Segment 1: Produce x litres of chocolate Segment 2: Produce coconut mixture
2	Unit	Execution of a unit procedure to produce a batch	Production segment requirement (within the upper segment)	Unit procedure	Segment 1: Prepare cocoa butter in Reactor *
2	Unit	Execution of an operation as part of the execution of a unit procedure	Production segment requirement (within the upper segment)	Operation	Segment 1: Charge ingredients Segment 2: Mix ingredients

NOTE: Often this level of detail will not be the concern of the production schedule that level 4 sends to level 3. But, it may be part of the detailed production schedule that defines the desired sequencing of work orders.

5.5 Alignment of ISA-88 Production Information Management and ISA-95 Data Collection, Analysis and Tracking Activities

This section of the technical report deals with the corresponding topics of ISA-88 Production Information Management and ISA-95 (Work) Data Collection, Performance Analysis and Tracking. The main ISA-95 work activity to be considered in this section is Production operations management; however, it should be noted that similar topics for the other operations management categories (maintenance, quality and inventory) are also partly considered.

Table 7 — ISA-95 Part 3 Production Data collection, Production Performance Analysis, Production Tracking in relation to ISA-88 Production Information Management activities

ISA-95 Part 3 Production Data collection, Production Performance Analysis, Production Tracking	How it applies to ISA-88 Production Information Management
	Typically all of these functions are included in the ISA-88 Production Information Management activity. However, they are not detailed in that standard. The discussion of these functions is much richer and much more detailed in the ISA-95 standard and is a better reference for that kind of information.

Annex A - Relationship of Activities and Terminology Between the Two Standards

A.1 How do the ANSI/ISA-88 and ANSI/ISA-95 standards relate?

Table 8 — Listing Overlapping Terminology

Grouping	ISA-88 Term	Ref	ISA-95	Ref	Comment
Materials	Batch		Material Lot		A batch is distinguishable from a material lot only in that a batch is associated with the production of the material by an ISA-88 recipe; for example, a lot of raw material is not a batch although an input intermediate could be material from a batch of another batch process.
Materials	NA		Material sublot		A uniquely identifiable subset of a material lot, but not addressed directly in ISA-88
Materials	Lot		Material Lot		The terms are essentially the same
Models	Area		Area		The terms are essentially the same
Models	Site	4.2.2	Site		The terms are essentially the same except: - In ISA-88 site is an optional element. - In ISA-95 at least one site must exist.
Models	Process cell	4.2.4	Process cell		Identical - ISA-95 actually references the ISA-88 standard
Models	Unit		Unit		Identical - ISA-95 actually references the ISA-88 standard
Models	Enterprise	3.13, 4.2.1	Enterprise	3.10, 5.2.1	The terms are essentially the same
Scheduling	Reservation	5.6.2	Resource allocation	5.1.2 .1	Allocation as used in the context of ISA-95 really maps to reservation of equipment in ISA-88 (see also ISA-88 allocation)
Scheduling	Batch schedule Batch list (Part 2)	I: 6.3, 5.4 II: 2.0	Dispatch List (Part 3)	6.7.4	In ISA-88 a batch schedule includes identity, resource and parameter information sufficient to define a control recipe for one or more batches in a specific process cell from the master recipe specified. This is the equivalent of a dispatch list derived from an ISA-95 detailed production schedule.

Grouping	ISA-88 Term	Ref	ISA-95	Ref	Comment
Scheduling			Committed		In ISA-95 this is a scheduling related term indicating that something is scheduled to be used but may not yet been used. ISA-88 does not use or define this term.
Scheduling	Batch schedule	6.3, 5.4	Production Schedule		In ISA-88 a batch schedule includes identity, resource and parameter information sufficient to define a control recipe for one or more batches, in a specific process cell, from the master recipe specified. In ISA-95 a production schedule is a collection of production work orders and their sequencing involved in production of one or more products, at the level of detail required for manufacturing. The primary difference is that whilst an ISA-88 batch schedule is for a specific process cell, in ISA-95 a schedule may span multiple work centers/products.
Scheduling	Plan		Plan		The terms are essentially the same
Scheduling	Allocation				Allocation in ISA-88 uses reserved or otherwise available equipment, via arbitration rules, to dedicate equipment to a specific batch. Unless explicitly shared, an allocated unit in ISA-88 is subsequently not available to anything else until released.
Models	Level	3 4.2 ...	Level		In ISA-88 a level is a simply a reference to a position in a hierarchical model. In ISA-95 levels are generally used to represent the position of an activity against the functional levels derived from the Purdue Reference Model (PRM) as discussed elsewhere in this report.
	Resource			3.27	Defined in ISA-95 part one to be constrained to be a collection of people, equipment and materials. ISA-88 resources are equivalent to ISA-95 equipment resources. IEC 62264-1 Section 3.30 defines resource as "enterprise entity that provides some or all of the capabilities required by the execution of an enterprise activity and/or business process (in the context of this standard, a collection of personnel, equipment, and/or material)"

Grouping	ISA-88 Term	Ref	ISA-95	Ref	Comment
ISA-88 Only Terms	Common resource	3.10		5.1.2 .1	Typically refers to an equipment entity such as a control module or equipment module that is not permanently configured as part of a unit but may be acquired by or used by two or more units.
	Equipment module Control module	3.16 3.10			The ISA-95 equipment hierarchy model purposely did not go lower than the unit. This was done to defer to the ISA-88 definition of all lower level equipment resource definition.
	Formula	3.23	BOM etc		ISA-95: Material Specification, Material Requirement, Product Parameter, Process Parameter The ISA-88 formula consists of Process Inputs, Process Outputs and Process Parameters. The Formula of an ISA-88 master recipe is equivalents to some of the objects in the ISA-95 Product Definition Information Model. ISA-88 Process Input = ISA-95 Material Specification (Material Consumed) in a single process cell. ISA-88 Process Output = ISA-95 Material Specification (Material Produced) in a single process cell. ISA-88 Process Parameter = ISA-95 Product Parameter. The same comparison may be made between the formula within a control recipe and the material and parameter objects within an ISA-95 Production Schedule.
	Recipe		Recipe		The meaning in both standards is essentially the same.
	Phase	3.34	Lifecycle Phase		ISA-88 defines a Phase as a procedural element that is part of an Operation and can call for or carry out a process oriented task. This is different in meaning from the use in ISA-95 where a Phase is a portion of an entire lifecycle.
	Process control	3.41	Process control		The terms are essentially the same
	Shared use	3.54			In ISA 88 the term refers to equipment that may be shared between two of more units simultaneously. ISA-95 does not address this.
	Unit supervision	3.63			In ISA 88 the term refers specifically to the control activity that is specific to the grouping of equipment defined as a Unit. ISA-95 does not address this specific function.

Grouping	ISA-88 Term	Ref	ISA-95	Ref	Comment
	Process Management	3.43	Production Execution Management	6.8.1	Essentially identical functions.
	Coordination Control	4.5.1			In ISA 88 coordination control is a specific and defined type of control that is required to allow procedural control to function properly. In ISA-95, the term is used in its common and accepted definition.

NOTE: Terminology Table

1. In the physical models, the ISA-88 hierarchy is presented with a batch focus; in ISA-95 the scope includes batch, continuous, discrete and storage work centers.
2. The ISA-95 activity model that is aligned with ISA-88 is the production activity model. The quality, maintenance and inventory models are not discussed here.

Annex B - Recommended Changes to ISA88.00.01 and Related Documents

B.1 Change ISA-88.00.01 6.5.2 Manage process cell resources:

Both ISA-95 and ISA-88 contain functions called resource management. While they might look like overlap, they are not. Resource management as described in ISA-95 is strategic and sometimes tactical, but essentially always forward-looking. Resource management as described in ISA-88 Process Cell Management is, in reality, resource tracking and execution related allocation. Revising the language to emphasize that the two functions are, indeed, different and complementary rather than overlapping will make the joint use of the two standards less confusing. Specific recommended revision to ISA-88, Part 1, Section 6.5.2 is included below. Refer to section 5.2 for further detail.

ISA-88.00.01, Section 6.5.2 - Track and allocate process cell resources

This is an execution related control function in which process cell resources are made available for execution by allocating and reserving units and other equipment, by arbitrating multiple requests for the same equipment, and by providing a mechanism for tracking unallocated equipment. Process cell resources also include the materials within the process cell. Process cell resource tracking and allocation must keep track of which materials are in the process cell, which are pre-allocated by the batch schedule, the materials that are available for allocation during recipe execution, the units that contain them, and their disposition.

An assignment of resources at the process cell or unit level (resource allocation) needs to be provided in order for Process Cell Management to be able to assign the equipment or equipment options according to active recipes being executed and the batch schedule. Although limited in function to execution time allocations, limited equipment reassignment and generation of a new resource allocation at the process cell or unit level may also be needed by an operator. This new resource allocation may be necessary because of such variables as an execution-time malfunction in equipment or availability of raw materials that could not be anticipated by production planning and scheduling. Production Planning and Scheduling may require notification of this new resource allocation to allow for assessment of impact.

The following capabilities are typically included in this control function:

— Obtaining scheduling information from Production Planning and Scheduling and providing this information to the *manage batches* control function

— Allocating or reserving equipment as requested by the *manage batches* control function. Within a process cell, batches may move from unit to unit. In each unit a portion of the control recipe, corresponding to the unit procedure, is executed. The control of what equipment to allocate to the different batches, and when transfers can take place may require control at the process cell level. Some examples of how this allocation may be done are

a) according to a batch schedule designating each individual unit allocation; or

b) according to a strategy defined at the process cell level combining the equipment requirements of the control recipe and the availability and capabilities of equipment at the time of execution.

— Arbitrating, as required, multiple requests for reservation or allocation of the same equipment during control recipe execution. The rules for arbitration may be simple or complex, depending on the application. Examples of arbitration rule sets include the following:

a) Order of request (FIFO)

b) Timed requests (such as by reserving the equipment)

c) Priority of batch

d) Maximizing equipment utilization (such as by minimizing cleaning requirements, minimizing energy consumption, or maximizing throughput)

e) Operator judgment

— Keeping track of unallocated equipment within the process cell

— Receiving status information sent by Unit Supervision and/or status information sent by Process Control related to unallocated equipment within the process cell

— Updating information on all process cell resources to the *collect batch and process cell information* control function

— Updating Production Planning and Scheduling with batch progress information, such as

a) batch ID;

b) batch state change events;

c) actual quantities of raw materials, products, and utilities;

d) equipment assignments; and

e) projected and actual allocation and de-allocation times of process cell resources.

B.2 Revise ISA-88, Part 1 to include specific categories of resources

ISA-95 defines specific categories of resources. ISA-88 does not specifically do so for personnel or material.

ISA-88 should be revised to reflect the ISA-95 resources (equipment, personnel, material). Refer to section 5.4 for further detail.

Annex C- Recommended Changes to ANSI/ISA95.00.03 and Related Documents

The ISA 88-95 working group has requested that the following issues be sent to the ISA95 committee with request for guidance

The working group asks ISA95 to modify Part 3 to state that production execution management also includes activities in a process cell. The proposed new text is:

“The production execution management activities include the coordination of manual and automated processes in a site, area or work center.”

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ISBN: 978-1-934394-78-6