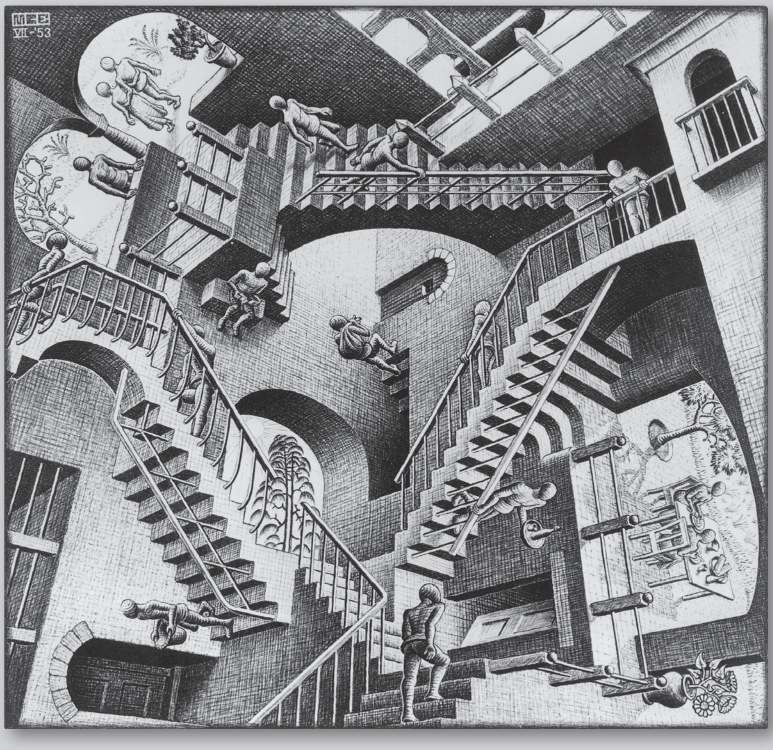
THE ROAD TO INTEGRATION



A GUIDE TO APPLYING THE ISA-95 STANDARD IN MANUFACTURING

BIANCA SCHOLTEN

ISA

Setting the Standard for Automation™

The Road to Integration
A Guide to Applying the ISA-95 Standard in Manufacturing

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ISA™

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Chapter 1: Getting Acquainted with ISA-95

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Figure 1: Pieter Brueghel the Elder (circa 1525–1569), *The "Little" Tower of Babel* (1563), oil on panel, 60 x 74.5 cm, collection of the Boymans-Van Beuningen Museum, Rotterdam, the Netherlands

This painting by Pieter Breughel (ca. 1525–1569) hangs in the Boymans-van Beuningen Museum in Rotterdam. It portrays the Tower of Babel. Brueghel used the Colosseum in Rome as his model for the giant tower. The biblical story painted by Brueghel tells how the builders, when they began this project, all spoke the same language and understood one another. They had to abandon their vain plans, however, when God punished the people. Suddenly they spoke different languages and no longer understood each other. A chaotic situation arose, a "Babylonian confusion of tongues" (Genesis 11:1–9).

We're all well aware that the success of a project stands or falls with speaking the same language and understanding our partners in conversation. But that isn't so easy to accomplish. How do you make sure that you understand each other better, so that breakdowns in communication occur less often, thus ensuring that fewer mistakes are made and that you produce more successful project results faster?

1.1 Introduction

This chapter answers the following questions:

- What issues within the industrial automation field gave rise to the idea for ISA-95?
- Is ISA-95 a software package? Is it a system? Is it a methodology?
- Broadly speaking, what do Parts 1, 2, 3, 4, and 5 cover?
- How can ISA-95 be applied in practice?
- What advantages can applying ISA-95 produce?
- What will new parts of the standard focus on?
- How long will the ISA-95 principles remain usable?

1.2 History of the Development of ISA-95

In recent decades, industrial companies have invested heavily in ERP systems. Much time and money has also been invested in automation of the process control (PCS) layer. Now that we want to reap the rewards of all these investments, the gap between business automation and process automation is becoming painfully obvious.

ERP systems are only valuable if you supply them with current data, and these data originate largely from the PCS layer. Many companies are still in a stage where employees manually exchange and process the necessary information between the ERP and PCS systems. Users of ERP systems think: “Boy, the system really produces terrific reports,” but they don’t realize their colleagues at the “bottom” are busy entering all these data by hand. We all realize that automating information flows offers important advantages, such as reducing the number of errors and saving time. After all, forms no longer lie in a pile on someone’s desk, waiting to be processed. You can dramatically shorten the time between a client’s placing an order and product delivery by having the right information available at the right time in the right place at every step along the supply chain. Even more advantages can be realized when automation not only handles the exchange of information, but also allows the steps in enterprise processes and production processes (workflow) to better mesh. In short: the integration of ERP systems and control systems produces important strategic advantages.

Application integration is no silver bullet, however. In many industrial companies, decisions about software are made on the departmental level rather than centrally, with the result that the company invests in products from different manufacturers, based on different technologies. Acquisitions have also led to a great diversity in systems. Both IT departments and engineering departments must be able to handle a high degree of heterogeneity. They are confronted with differences in technology, metadata, programming languages, user interfaces, and more. The fact that technical automation is often performed by a department other than the IT department doesn’t make it any easier. Especially when it concerns the exchange of information between different, independently operating systems within the manufacturing company, good communication between these departments is very important. *And that's just when the Babylonian confusion begins!* Control system engineers and IT staff usually don't have a good understanding of each others' fields of work, which means a lot of time is spent on communication and - worse still - which can lead to expensive errors. Let's not forget, moreover, that automation has a supporting role within the company; it is not a goal in itself. In production automation projects, good communication with the system's end user is essential. In projects focused on integrating ERP and PCS systems, a large number of departments is usually involved, such as production, maintenance, the lab, and the office. Try speaking the same language then! The above indicates that in recent decades, companies have been confronted with a gap between the ERP and PCS layers, and when trying to bridge this gap, problems have arisen in communication between people, and also between systems.

Against this backdrop, ISA decided in the 1990s to develop a standard for integrating enterprise and control systems in order to reduce the risks, costs, and errors that go hand in hand with implementing interfaces between such systems. ISA is a global non-profit organization. Originally, ISA stood for *Instrument Society of America*, but this was changed to *Instrumentation, Systems, and Automation Society* in 2000. Since the end of 2005, ISA has employed the slogan "Setting the Standard for Automation." ISA defines its key activities as standardization, certification, education and training, publications, conferences, and exhibitions in the field of industrial automation. Examples of familiar and popular ISA standards are ISA-84 (*Functional Safety: Safety Instrumented Systems for the Process Industry Sector*), ISA-88 (*Batch Control*), and ISA-99 (*Manufacturing and Control Systems Security*). The subject of this book, ISA-95, is ISA's ninety-fifth standard and bears the title *Enterprise-Control System Integration.*

1.3 Objective and Content of ISA-95

ISA-95 is not an automation system, but a method, a way of working, thinking, and communicating. The method is described in several documents, each around a hundred pages. These contain models (figures) and terminology you can use to analyze an individual manufacturing company. Each of the models focuses on specific integration aspects; they each illuminate the issue from a different perspective. What is the value of these models? In his book *Information Systems*,[a] Steven Alter gives the following explanation of the use of models:

> A model [is] a useful representation of a specific situation or thing. Models are useful because they describe or mimic reality without dealing with every detail of it. They typically help people analyze a situation by combining a framework's ideas with information about the specific situation being studied. . . . [T]hey help us make sense of the world's complexity.

Communicating about a system can be difficult, because different people in the same conversation often assign different meanings to general terms. ISA-95 defines words that relate to integrating enterprise and control systems. ISA-95 places this terminology within models, which make clear the relationships among the various terms. You can compare this principle with drawing a blueprint for a house. A blueprint depicts what the house will look like, with symbols for windows, doors, walls, and roofs. The words *window, door, wall*, and *roof* are familiar to all of us, and we use them to talk to each other about the house. Every house is different, and still we can depict and describe every house with the same symbols and words for doors, roofs, walls, and windows. The same applies to ISA-95. No two manufacturing companies are alike, and yet you can use the ISA-95 models and terminology to talk with others about the company's functions, activities, responsibilities, information flows, and so on. Moreover, ISA-95 standardizes the information to be exchanged, which has led to ERP and MES software now offering an ISA-95 interface definition instead of the traditional vendor-specific interface definition. As a result, it has become easier not only on the level of human communication, but also on the technical level, to integrate systems from different vendors.

The objective of the ISA-95 standard is to "reduce the cost, risk, and errors associated with implementing" interfaces between enterprise and control systems.[b] The standard can be used to simplify the implementation of new software products and to ultimately have enterprise and control systems that interoperate and easily integrate. ISA-95 itself defines a number of potential advantages. For example, the standard makes it possible for software vendors to offer appropriate tools for integrating enterprise and control systems. The standard also makes it easier for end users to map out their requirements and their nice-to-haves. Other potential advantages concern integration in general, such as lowering the cost of production processes and optimizing the supply chain. ISA-95 comprises several parts, each of which concentrates on specific aspects of the integration issue. Some parts are still in development and it is not unthinkable that in the future, new - currently unforeseen - parts will be developed. These new parts will focus on yet other aspects of integration. This book covers exclusively the parts known at the time of writing: parts 1, 2, 3, and 5 (part 4 is still being developed). Visit *www.isa.org* for the most current state of affairs.

1.3.1 Part 1

Part 1 of ISA-95 is titled *Enterprise-Control System Integration Part 1: Models and Terminology*. Part 1 presents various models and terminology you can use in preparing and executing projects where the automation of information exchange between ERP and MES systems is central. The most important models in Part 1 are the Functional Hierarchy Model, the Equipment Hierarchy Model, the Functional Enterprise-Control Model, the Object Models, and the Categories of Information Exchange Model. Subsequent chapters will discuss in detail the practical application of the models. To be able to apply the models in practice, it's essential to understand them well. This chapter therefore explains the most important models.

1.3.1.1 The Functional Hierarchy Model

Figure [2] depicts the different levels of a functional hierarchy model: business planning & logistics, manufacturing operations & control, and batch, continuous, or discrete control. [c]

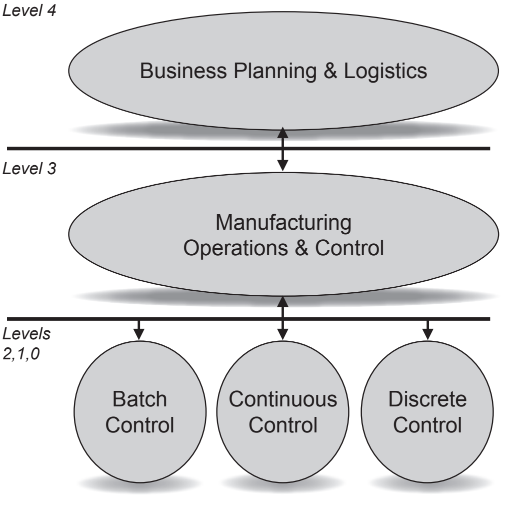

Figure 2: ISA-95 The Functional Hierarchy model (simplified)

What ISA-95 calls *integration of enterprise and control systems* in practice boils down to automating the MES layer plus interfacing the MES system with an ERP system. What is *MES* and what is *ERP*? Though the ISA-95 standard nowhere uses the terms MES and ERP, it does make clear the difference between the two using the **Functional Hierarchy Model** (see figure 2 above). ISA-95 distinguishes two domains within a manufacturing company: the Enterprise Domain (**Level 4**) and the Control Domain (**Levels 3** and lower). The term **Enterprise Domain** correlates more or less to the much-used acronym ERP. Within the Enterprise Domain, processes with time horizons of years, months, weeks, and days take place, in which the scope extends beyond the walls of the factory. The term **Control Domain** stands for a combination of what we popularly call the MES layer (**Level 3**) and the PCS layer (**Levels 2** and **1**), in which the scope remains within the factory walls. **Level 0** represents the process itself. In the MES layer, activities with time horizons of days, hours, minutes, and seconds take place; the PCS layer has time horizons of hours, minutes, seconds, and even more finely grained. Now the different levels have been introduced, we'll dispense with the interpretation-sensitive acronyms ERP and

MES. From now on, we'll talk about the ISA-95 terms level 4, 3, 2, 1, and 0. The first part of ISA-95 focuses on the information exchange between Level 4 and Level 3. For example, Level 4 may send orders to Level 3, and Level 3 may send information about actual quantities produced back to Level 4. Part 1 of ISA-95 defines the content of these and many more information flows between the manufacturing and enterprise functions; in other words, between Level 3 and Level 4.

1.3.1.2 The Equipment Hierarchy Model

> The physical assets of an enterprise involved in manufacturing are usually organized in a hierarchical fashion as described in figure [3]. . . . This model defines the areas of responsibility for the different function levels defined in the [functional hierarchy] model. The equipment hierarchy model additionally defines some of the objects utilized in information exchange between functions.[d]

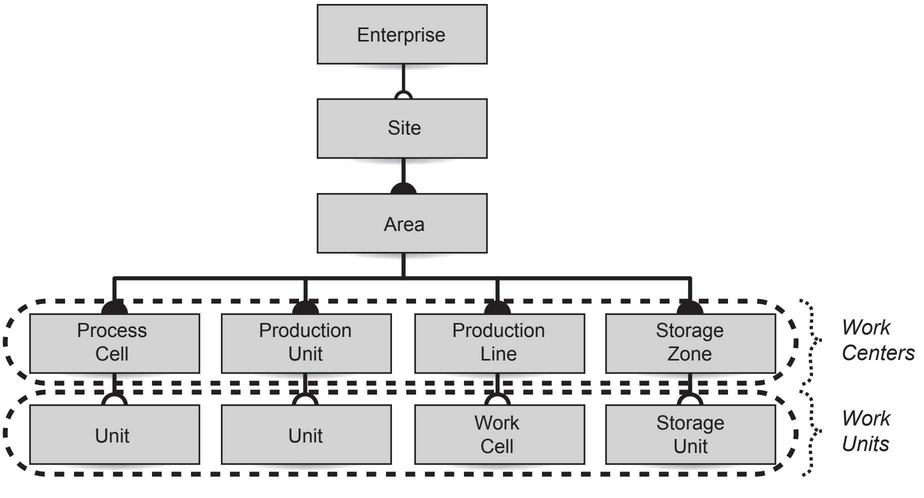

Figure 3: ISA-95 The expanded Equipment Hierarchy model (simplified)

If you're familiar with Part 1 of ISA-95, you'll notice that the model given here is not exactly the same as the model in Part 1. That model has since been superseded by the more extensive model in Part 3 (see figure 3).
This **Equipment Hierarchy Model** makes clear that the physical assets of manufacturing companies can be divided into different levels. At the **Enterprise** level, we have the company name, such as Johnson and Johnson. The Enterprise can comprise one or more **Sites**, such as the Johnson and Johnson Sites in Geel, Belgium; Schaffhausen, Switzerland; and Cork, Ireland. We typically indicate Sites using the name of the city. A Site can further contain one or more **Areas**, which you can interpret as *manufacturing departments*. For example, Philip

Morris (Enterprise) in Bergen op Zoom, the Netherlands (Site) can be divided into two Areas: the *primary* (tobacco processing) and the *secondary* (cigarette manufacture and packaging). Companies often group Areas according to specific product groups, such as the liquids department and the powders production department. Each Area can contain a combination of one or more **Work Centers**. This is a general term for Process Cells, Production Units, Production Lines, and Storage Zones. Whether the term Process Cell, Production Unit, Production Line, or Storage Zone applies depends on whether we are talking about a Batch Process, a Continuous Process, a Discrete Process, or Storage. The distinction among the different process types is easiest to make by determining how the result of the process is measured. For **Batch Processes**, the quantity can never exceed the volume of the reactor (or tank, bin, mixer, etc.) in which the batch is manufactured. This limitation, enforced by the maximum capacity of the equipment, is characteristic of Batch Processes. Quantities are thus expressed in kilos or liters, for example. The food industry and the pharmaceuticals industry in particular often employ batch processing.

When a company manufactures products in a continuous stream at a particular speed, such as number of liters per second, it is using a **Continuous Process** (e.g., water purification, water distribution, gas extraction). In the case of **Discrete Processes**, the final result of the process can be measured by the number of countable products (such as cars, televisions, and electric shavers).

A **Process Cell** is an example of a Work Center. Batch Processes take place within a Process Cell. A Process Cell can be further subdivided into **Units**, such as weighers, mixers, reactors, bins, and tanks. On yet a lower level than that of Units, the ISA-88 standard[e] defines *equipment modules* and *control modules*: valves, pumps, motors, sensors, actuators, and so forth. ISA-95 ignores those levels, however, as they are too detailed for the (integration) problem ISA-95 targets. In addition to Process Cells, an Area can also contain **Production Units**, which are also made up of Units. Within a Production Unit, a Continuous Process takes place, such as water distribution. The supply area for a water distribution company is an example of a Production Unit. This Production Unit can be further subdivided into Units, such as reservoirs. An Area can also consist of **Production Lines**, which in turn contain **Work Cells**. Within Production Lines, Discrete Processes take place, such as in a Production Line for electric shavers. The Work Cells within a Production Line produce one part of the product, such as the shaving heads for the electric shavers. Finally, in Areas we also encounter **Storage Zones** (such as silo parks and warehouses) and **Storage Units** (e.g., silos, bins, racks, pallets).

On the Site and Enterprise levels, we encounter the enterprise automation systems that must exchange information with the production systems located on the level of the Area and lower. Parts 1 and 2 of ISA-95 specify the content of the information that flows between the Site level (Level 4) and the Area level (Level 3). (Note that Level 3 activities can also target a *group* of Areas within the Site.)

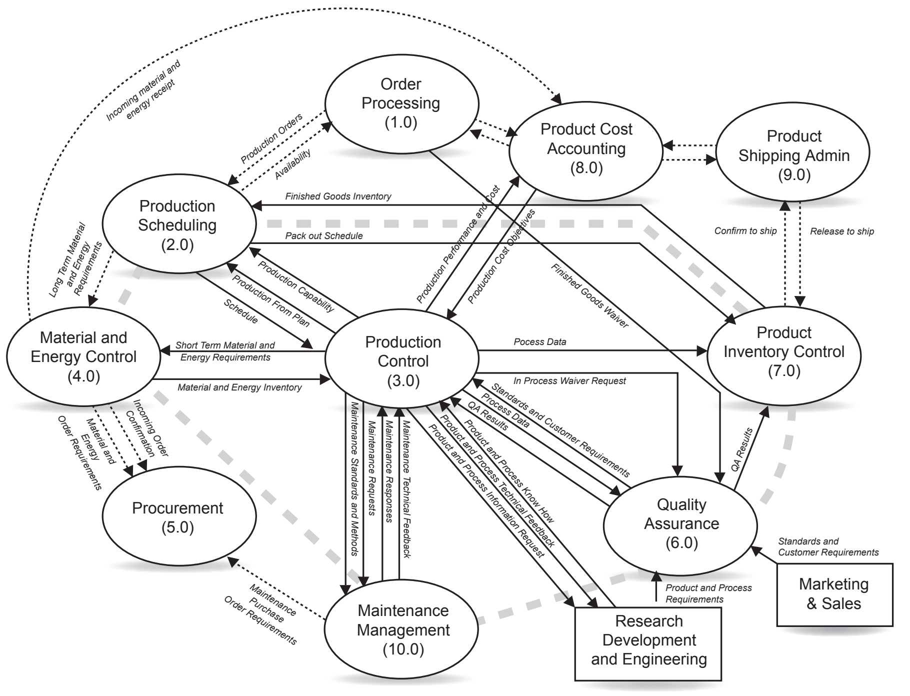

Figure 4: ISA-95 The Functional Enterprise-Control model

1.3.1.3 The Functional Enterprise-Control Model

> The functional model is depicted in figure [4]. The wide dotted line illustrates the boundary of the enterprise-control interface. The line is equivalent to the level 3-level 4 interface . . . . The labeled lines indicate information flows of importance to manufacturing control. The wide dotted line intersects functions that have sub-functions that may fall into the control domain, or fall into the enterprise domain, depending on organizational policies.[f]

The **Functional Enterprise-Control Model** (see figure 4) makes clear that manufacturing companies carry out twelve different functions. The standard describes point by point the tasks of each function. Every company will have a different name for these functions. Some companies have divided the tasks for a single function over two or more departments, while other companies have assigned responsibility for two or more functions to a single department. A function may be very important in one company, but merit little attention in another. For example, material control for automobile production is a very complex matter, while it is fairly simple in a water distribution company. We aren’t meant to use this model to reorganize a company. The model is a kind of measuring stick, along which you can lay the characteristics of a specific company to gain insight into the range of departments and applications and into the division of responsibilities. You can also use the model to determine what does and does not fall within the scope of the project.

The model contains twelve functions, each with a serial number. Most of the functions are enclosed in an oval. The functions Research, Development and Engineering, and Marketing and Sales are enclosed in rectangles, however, which indicates that they are *external entities*. These are components outside the boundaries of the model that send data to and receive data from the functions. Don't spend too much time thinking about this! In Part 3, these two functions are also enclosed in ovals, and in integration projects the chance is great that you will interact with them in the same way you interact with the other functions.

The wide dotted line in the model depicts the boundary between the Enterprise Domain (Level 4) and the Control Domain (Levels 3 and lower). Everything that lies outside the dotted line belongs on Level 4, and everything that lies inside the dotted line belongs on Level 3.

Order Processing, Procurement, R&D and Engineering, Marketing and Sales, Product Shipping Administration, and Product Cost Accounting are thus all Enterprise Domain (Level 4) functions. The function Production Control is a pure Control Domain function, with tasks on Levels 3, 2, and 1. Conspicuous about the functions Production Scheduling, Material and Energy Control, Maintenance Management, Quality Assurance, and Product Inventory Control is that they do not clearly fall inside or outside the boundary. And rightly so, for they carry out tasks partly on Level 4 and partly on Levels 3 and lower. An example: Level 4 Production Scheduling generates Production Schedules with a time horizon of months and weeks. It typically provides a schedule at the weekly level (the *master production schedule*) to Level 3. On Level 3, Detailed Scheduling takes place, which converts the weekly schedule to an optimal production schedule based on days or hours, taking into account the limited capacity of production lines and focusing on the efficiency of the production process. The functions work together by exchanging information.

ISA-95 groups this information into thirty-one information flows, each with its own name and content, such as Schedule, Production Performance and Cost, Process Data, QA Results, and Material and Energy Inventory (see figure 4). ISA-95 gives a short textual description of the content for each information flow. In practice, every company uses its own terminology for the ISA-95 information flows. For example, the ISA-95 information flow Schedule might be called a *prognosis* by a particular waterworks company, while a vitamin supplement manufacturer may use the word *production plan*. In this context, ISA-95 can be compared to the English language. A Dutchman and a Dane, neither of whom speaks the other's language but both of whom speak English, can use English as a kind of "standard language," allowing them to understand one another.

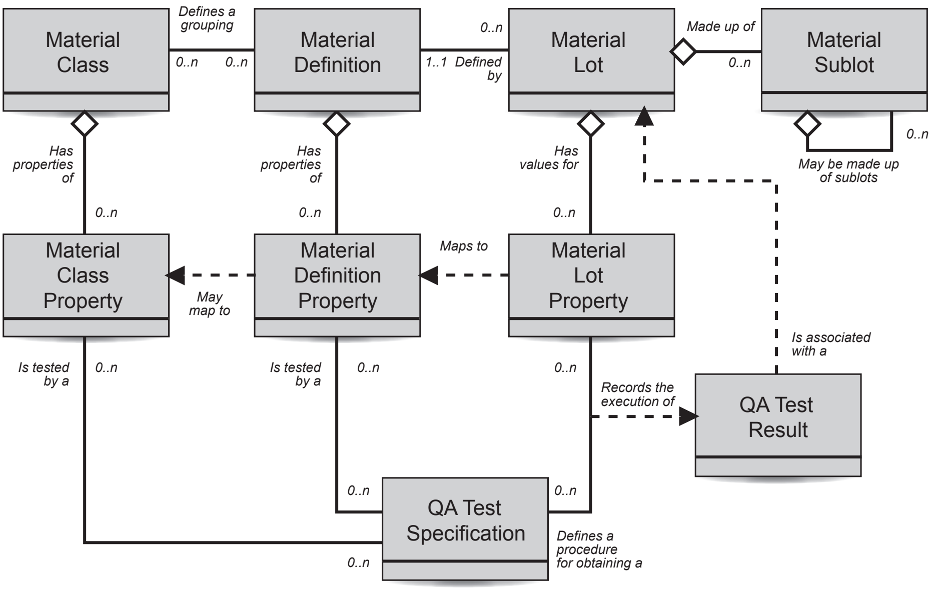

Figure 5: ISA-95 The Material model

1.3.1.4 Object Models

> The material model defines the actual materials, material definitions, and information about classes of material definitions. Material information includes the inventory of raw, finished, and intermediate materials. The current material information is contained in the material lot and material sublot information. Material classes are defined to organize materials.[g]

If you compare the information in the different information flows, you encounter a lot of overlap. For example, both recipes and production schedules contain information about materials. In order to standardize the large amount of information to be exchanged, it is necessary to first carry out a normalization process. That is: an analysis of the information flows to determine what the fundamental data are, so we can develop standard models for information exchange, in which data appear only once. Fortunately, the SP95 committee has already done this normalization, which saves us a lot of time. ISA-95 defines the following basic data: Equipment, Material, and Personnel. These are the Lego blocks, as it were, with which you construct information flows. You could also compare it to the words you use to write a text. The information flow Production Performance and Cost, for example, contains information about the equipment used, the materials produced, and the ingredients consumed, among other things. In addition to the basic building blocks Personnel, Equipment, and Material, ISA-95 introduces the concept Process Segment. A **Process Segment** is a logical group of Equipment, Personnel, and Material required to carry out a specific part of a process. Examples of Process Segments are *Mixing*, *Sawing*, and

Painting. To mix, you need an operator (Personnel), a mixer (Equipment), and raw ingredients (Material). For the Process Segment *Sawing*, you need a saw (Equipment), wood (Material), and an employee (Personnel). And to paint, you need paint (Material), a painter (Personnel), and a brush (Equipment). Segments don't have to include Equipment, Material, and Personnel by definition. For the Process Segment *Inspection*, for example, you only need an inspector.
For each basic building block with which you can compose information flows (Personnel, Material, Equipment, and Process Segments), ISA-95 defines a UML model (see figure 5). The models are collectively termed the Resource Models. They clarify the meaning of data that apply to the resources Personnel, Material, Equipment, and Process Segments. They also specify the relationships among the data. For example, the Material model makes clear that there are various data that say something about the subject *material*, such as **Material Definition** (name, description), **Material Class** (category), and **Material Lot** (measurable quantity of material). The model also depicts the relationships between these data, such as: a Material Lot is defined by just one Material Definition.

1.3.1.5 The Categories of Information Exchange Model and the Information Models

> Some information . . . must be shared between the manufacturing control systems and the other business systems, as illustrated in figure [6].[h]

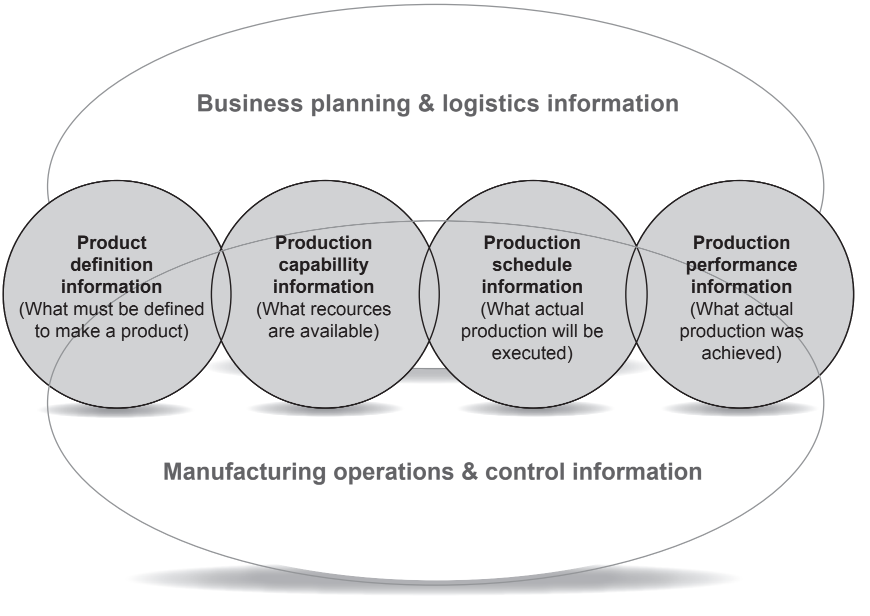

Figure 6: ISA-95 The Categories of Information Exchange model (simplified)

In order to standardize the information flows, ISA-95 groups all information to be exchanged into four categories: Production Capability Information, Product Definition Information, Production Schedule Information, and Production Performance Information. The resource models for Equipment, Personnel, Material, and Process Segments form the basic building blocks for each category.
Production Capability Information is information about the availability of production resources, such as machines, tools, operators, temporary workers, ingredients, and energy. **Product Definition Information** is the collection of information that describes how to make a product, such as recipes, SOPs, bills of materials, and assembly instructions. **Production Schedule Information** is information about what you need to produce and when you're going to produce it, such as a production plan or a prognosis. And **Production Performance Information** is information about what and how much has been produced and which people and resources have been used to do so, such as a report.
The Categories model is primarily intended to explain the object models that follow it. In practice, you'll use it - in my experience - only to explain to others what information Level 4 and Level 3 share with each other.

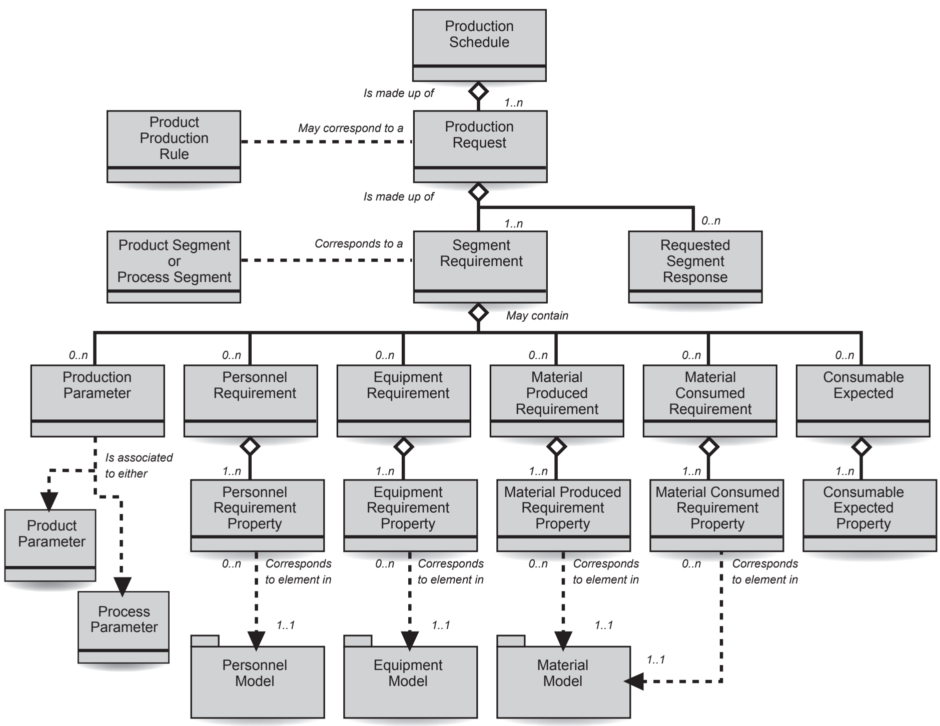

Figure 7: ISA-95 The Production Schedule model

All thirty-one information flows can be placed in one of these categories.[i] The resource models described above (Equipment, Personnel, and Material) are the basic building blocks for these categories, as you can see in the example (figure 7). ISA-95 Part 1 concludes with UML models for these four information categories: Production Capability, Product Definition Information, Production Schedule, and Production Performance. The UML models make clear which building blocks the information category contains and what the internal relationship is between the building blocks. A Schedule, for example, consists of one or more Production Requests, all of which are related to a Product Production Rule (product ID). At the bottom of the Production Schedule model, you see the basic building blocks Personnel, Equipment, and Material.[j]

1.3.2 Part 2

The second part of ISA-95 came out in 2001. The title of Part 2 of ISA-95 is *Enterprise-Control System Integration Part 2: Object Model Attributes*. This part also contains roughly a hundred pages and it targets the same area as Part 1. If you want to apply ISA-95 to create standardized interfaces between ERP and control systems, you can't do without Part 2. Part 2 expands on the information model in Part 1. It gives a detailed description of the information, in the form of **Attributes**. For each Object in Part 1, ISA-95 Part 2 provides a table with the standard Attributes of the Object.

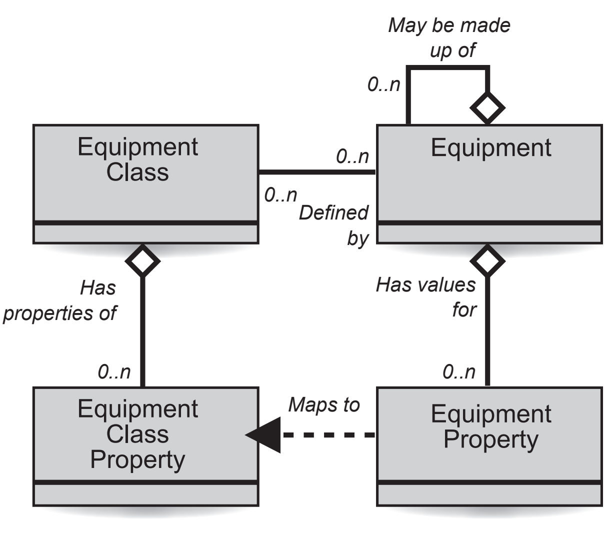

Figure 8: Part of the ISA-95 Equipment model

For example, the Object Equipment comprises the standard Attributes ID and Description, and the Object Equipment Class also comprises the standard Attributes ID and Description. Take, for example, the hydraulic pump P105 (see tables 1.1 and 1.2). *P105* is in this case the Equipment ID, while *Hydraulic pump with tag number P105* is the Description for pump P105. Pump P105 belongs to the Equipment Class of hydraulic pumps. *Hydraulic pumps* is the Description of the class, and the class has the unique ID *Equipment class no. 5*.

Table 1.1 Equipment Attributes for pump P105

ISA-95 Attribute name	Attribute value
ID	P105
Description	Hydraulic pump with tag number P105

Table 1.2 Equipment Class Attributes for hydraulic pumps

ISA-95 Attribute name	Attribute value
ID	Equipment class no. 5
Description	Hydraulic pumps

On the level of Equipment, Personnel, and Material, ISA-95 defines only a few very basic Attributes, namely ID and Description. Of course, resources have many more Properties. For example, the characteristics of a pump include the capacity, the maximum pressure, and the type (such as centrifugal). Material Attributes could include specific gravity, color, viscosity, and pH value. And finally, examples of Personnel Properties are telephone number, level, certification, and availability for overtime. It's important that every industry, even every individual company, retain the freedom to decide for itself which Attributes are relevant in addition to the standard ISA-95 ID and ISA-95 Description. Many Attributes are, after all, industry- or company-specific. For example, a material's pH value is for a great many industries irrelevant. This is why the committee decided on a flexible method for adding extra Attributes in the form of **Properties**. Users are free to define as many Properties for Material, Personnel, and Equipment as they need. To force structure, Properties also possess several standard ISA-95 Attributes, namely ID, Description, Value and Value Unit of Measure. See the example in the following tables.[k]

Table 1.3 Equipment Property Attributes for pump P105

ISA-95 Attribute name	Attribute value
ID	Pump 105 property 1
Description	Maximum capacity
Value	1,000
Value Unit of Measure	l/h

Table 1.4 Equipment Class Property Attributes for the class of hydraulic pumps

ISA-95 Attribute name	Attribute value
ID	Equipment class no. 5 property 1
Description	Maximum capacity
Value	{100..4,000}
Value Unit of Measure	l/h

The information structure for Production Schedules, Production Capability, Product Definition Information, and Production Performance is, in contrast to the Properties of the resources, fully standardized. On this level, the user no longer has the freedom to add Properties; rather, all characteristics are defined by ISA-95 in the form of standard Attributes.

The ISA-95 information model with its associated Objects, Attributes, and Properties has as its objective standardization of the exchange of information between enterprise and control systems. The standard makes no verdict on the information exchange technology to be used, such as XML or ASCII. Nor does it posit any requirements in terms of data types, such as string or numeric. Thanks to this freedom, ISA-95 can be used in the most diverse situations. A disadvantage is that you'll have to make choices and agreements, which makes the standard less "standard."

Many companies make grateful use of the information model to develop applications and databases. But because ISA-95 was not designed for this purpose, they're confronted with several difficult choices. Chapter 3 will discuss how you can apply the information model to more quickly and easily develop well-structured applications and databases that can more easily exchange information with applications and databases from other vendors.

1.3.3 Part 3

The third part of the ISA-95 standard was published in the summer of 2005 under the title *Enterprise-Control System Integration Part 3: Activity Models of Manufacturing Operations Management*. This part focuses entirely on the MES layer (Level 3) and presents models and terminology you can use to analyze and describe the activities within the MES layer. These emphasize good practices for manufacturing operations and can be used to improve existing production systems. They can be applied in heavily automated companies and in companies that work largely by hand. Part 3 states several potential advantages that accompany the models and terminology. For example, Part 3 can help software vendors develop suitable products. And for end users, Part 3 makes it easier to describe their desires and demands in a uniform and consistent way.

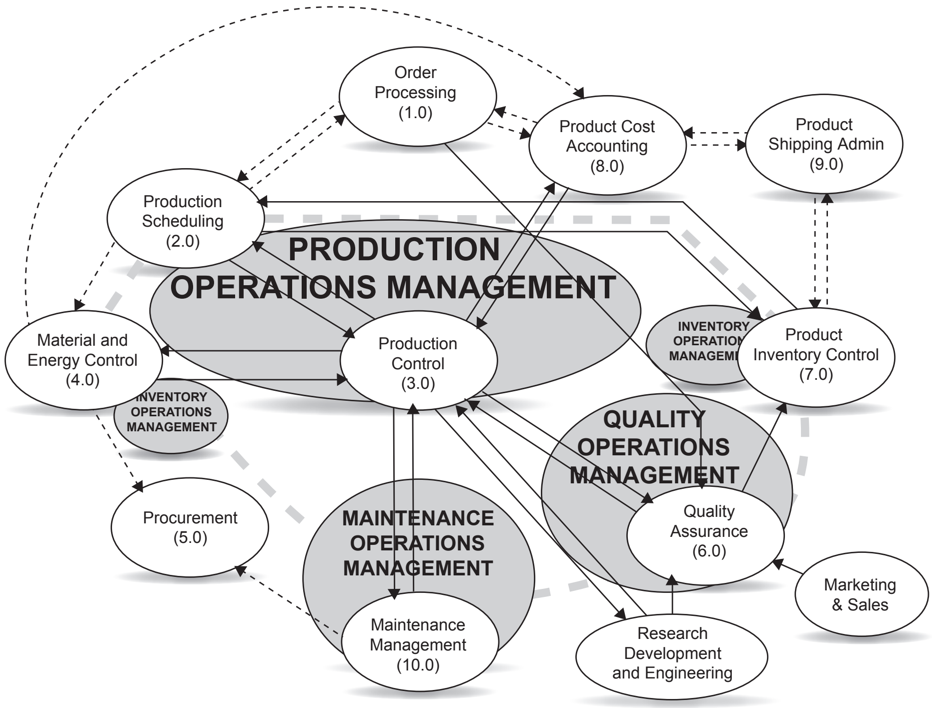

Figure 9: ISA-95 The Manufacturing Operations Management model

Figure 9, the **Manufacturing Operations Model**, makes clear what the focus of Part 3 is in terms of Part 1 of ISA-95: it zooms in on the Control Domain (the area inside the wide dotted line). Within this domain, it recognizes four groups of activities: Production activities, Inventory activities, Maintenance activities, and Quality activities. The ISA-95 committee has developed one generic model as a basis for describing the activities in the areas of production, maintenance, quality testing, and inventory (see figure 10).

This ISA-95 model provides a clear and logical division of all activities within production departments, warehouses, laboratories, and maintenance departments (automated or otherwise). For example, someone will have to keep records on the availability of production personnel, machines, and materials (**Production Resource Management**). It will also be necessary to maintain the recipes and instructions that the operators use (**Product Definition Management**). A detailed schedule (**Detailed Production Scheduling**) is required to optimally combine production orders, taking into account the limited capacities of production lines, changeover time, and cleaning. Next, someone will have to dispatch the orders and assign the tasks to teams (**Production Dispatching**). The **Production Execution Management** function ensures that production personnel really do carry out those tasks, in accordance with the applicable quality standards[i]. Finally, you will need to gather various data during the production process (**Production Data Collection**) and transform those data into information

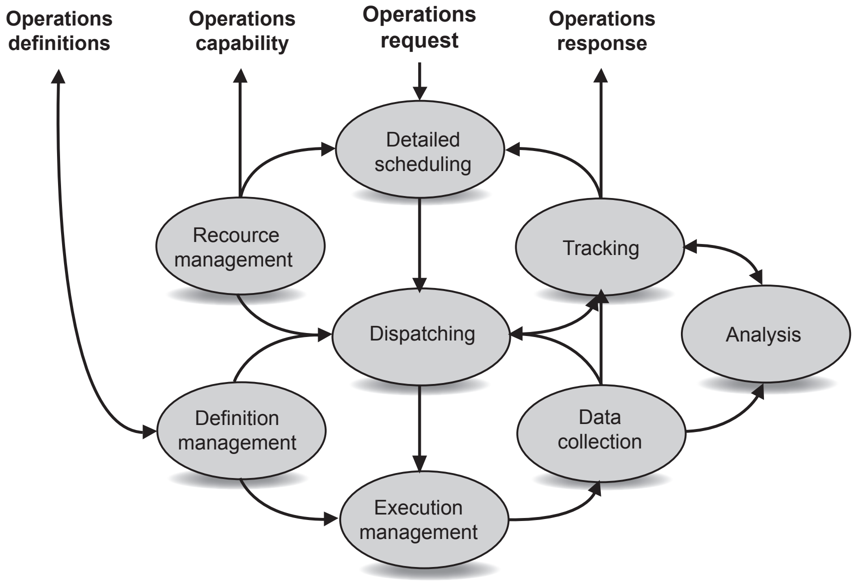

Figure 10: ISA-95 The generic activity model of Manufacturing Operations Management

(**Production Tracking**) to use in analyzing and optimizing the activities of the production department (**Production Analysis**). The same model can be used as a basis for defining the activities of a maintenance department: someone must schedule the mechanics (**Detailed Maintenance Scheduling**). The mechanics use maintenance instructions that must be managed (**Maintenance Definition Management**). Data must be gathered on the maintenance performed (**Maintenance Data Collection**) in order to put together a report (**Maintenance Tracking**). Activities within the lab and activities within the warehouse can also be categorized in this way. The basic activity model in ISA-95 Part 3 displays some similarity to the MESA model. This is because the ISA-95 committee selected the MESA model as its starting point. But the MESA model

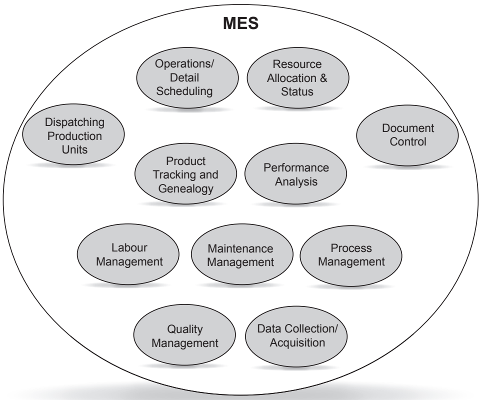

Figure 11: The eleven MESA activities

has not been indiscriminately adopted. The ISA-95 model is clearer and more logical; it gives a detailed description of the activities that take place in every factory (automated or not) and defines their boundaries. It also makes clear the connections among the different activities. Now that there's a better alternative (ISA-95 Part 3), you would be wise to stop making use of the MESA model, because the MESA model is based on functionality offered by MES vendors rather than providing a vendor-independent model. Moreover, the MESA model does not specify the connections among the various activities, nor does it cover the information flows. It also lacks an extensive textual explanation of the eleven MES activities that MESA defines. The generic model in ISA-95 Part 3 makes clear which activities occur on Level 3, the level popularly termed the *MES layer*. Originally, the acronym *MES* stood for *manufacturing execution systems*. It is striking that the term *execution* is used in the ISA-95 model only at the very bottom, in the activity Execution Management. And even then, it doesn't concern the actual execution of the manufacturing process, but rather the management of this process. *Execution* belongs - strangely enough - not in the MES layer, but in the process control layer. And so a new interpretation of the acronym *MES* has arisen, namely *manufacturing enterprise solutions*.
People often ask me if there's an MES vendor that supports all the activities in the ISA-95 Level 3 activities model. Naturally, the answer is "yes, there is." It's called Microsoft, and the software is called Excel. But don't tell that to IT managers, for it will give them - or already has given them - nightmares!
Part 3 provides four specific models based on the generic model (figure 10), namely the Production Operations Management Activity Model, the Maintenance Operations Management Activity Model, the Quality Test Operations

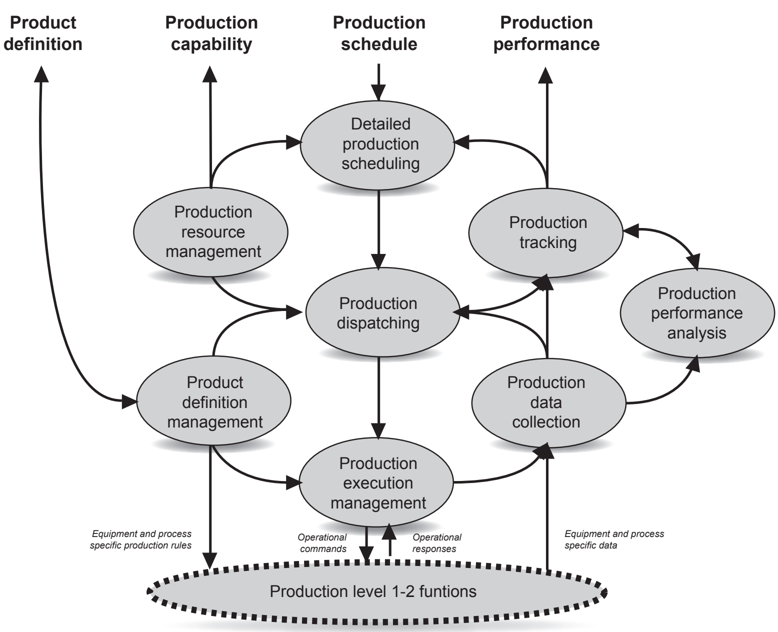

Figure 12: ISA-95 The activity model of Production Operations Management

Management Activity Model, and the Inventory Operations Management Activity Model (see the production example in figure 12).
For each activity, a detailed textual description has been included.
Moreover, detail figures are included for all production activities, which define the information that the individual activities exchange with one another. Take, for example, figure 13, *Detailed production scheduling activity model interfaces*.

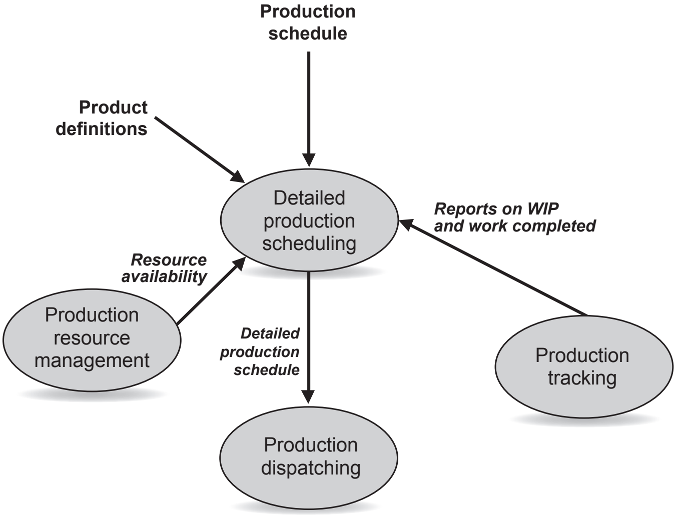

Figure 13: ISA-95 Detailed Production Scheduling activity model interfaces

This model provides insight into the fact that the Level 3 activity Detailed Production Scheduling must receive information from Level 4, namely a Production Schedule (in the form of a *master production schedule*, for example) and Product Definitions (such as a Manufacturing Bill). Moreover, Detailed Production Scheduling needs information about the availability of Personnel, Equipment, and Materials. After all, people who are sick or on vacation can't be scheduled, and machines undergoing maintenance are not available for production. Detailed Production Scheduling receives information about the availability of resources from the activity Production Resource Management. The scheduler must also take into account the current status of orders and any setbacks in production when creating a schedule. This information is provided by Production Tracking. Based on all this information, Detailed Production Scheduling creates a Detailed Production Schedule and sends this information to Production Dispatching.
It is beyond the scope of this book to discuss all the models in Part 3. The standard itself gives an extensive, detailed explanation of all activities and the accompanying information flows. In chapter 2, we'll see how you can use these models in practice to more quickly and accurately form a picture of how a particular company has apportioned tasks (or is going to apportion tasks) among applications and departments. We'll also discuss how, based on the models, you can determine ways for the company to work more efficiently and deliver results

more quickly, for example.

Besides activities in the areas of production, maintenance, quality tests, and inventory, Level 3 is also home to activities in the areas of Security Management, Information Management, Configuration Management, Documentation Management, Management of Regulatory Compliance, and Management of Incidents and Deviations. These are, however, not unique to Level 3, but occur on all levels. They are moreover not independent of the Level 3 activities already named; they are interwoven with these activities. A short textual description of these activities is also included in Part 3 of the standard.

What is the value of all these models? The models in ISA-95 Part 3 are exceptionally well-suited as a basis for analyses, such as

- Aiding specification of the requirements for a new tracking and tracing system to be purchased.
- Investigating whether SAP offers sufficient functionality for the MES layer in a specific factory.
- Comparing the characteristics of different production areas and sites and comparing software products from different vendors.
- Determining for a particular company how each activity is carried out at present (*as is*) and what the opportunities for optimization are (*to be*).
- Describing a manufacturing company to assist in providing new employees and external parties with information.
- And more.

1.3.4 Part 4

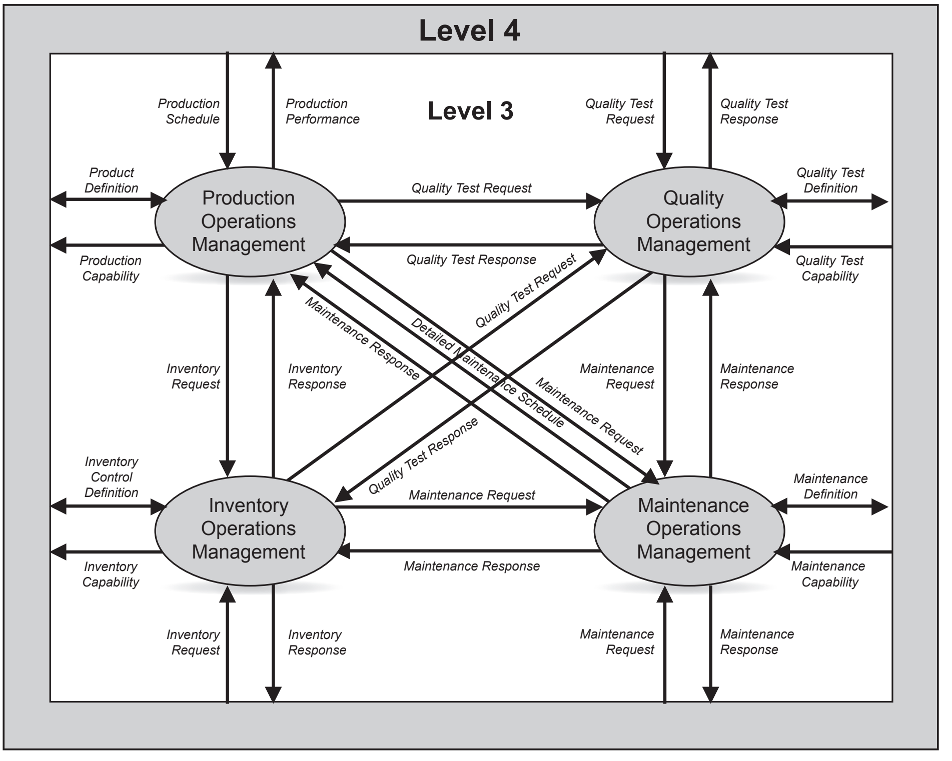

Figure 14: ISA-95 (Part 4, draft 3) Example of information exchanged between Level 3 activity categories

The (preliminary) title of ISA-95 Part 4 is *Enterprise-Control System Integration Part 4: Object Models and Attributes of Manufacturing Operations Management*. Parts 1 and 2 of ISA-95 have already standardized the data flows between ERP and MES systems. But Level 3 also contains systems for maintenance, laboratory information management systems (LIMS), and warehouse management systems (WMS). These systems must also exchange information with ERP systems. Moreover, they must exchange information with each other and with MES systems. Part 4 is currently in development. The SP95 committee is developing formal data models for all these information flows. See *www.isa.org* for the current state of affairs.

1.3.5 Part 5

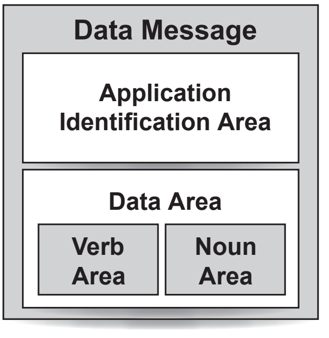

Figure 15: ISA-95 (Part 5, draft 9) Typical set of data exchanged (simplified)

The title of ISA-95 Part 5 is *Enterprise-Control System Integration Part 5: Business to Manufacturing Transactions*. Part 5 elaborates on the information exchange that Parts 1 and 2 describe. Parts 1 and 2 make clear what information ERP and MES systems must exchange with each other, and according to what structure. Parts 1 and 2 have standardized the structure of the Message, but they don't go further into what the receiving system should do with the data. Should it create, alter, or delete the data? The SP95 committee has tackled this issue and developed Part 5 of the standard as a solution. Part 5 specifies how sending and receiving systems should interact with the information in Parts 1 and 2. To that end, Part 5 defines several **Transactions**. ISA-95 Transactions are conversations, as it were, between ERP and MES systems about typical ISA-95 subjects. Transactions are constructed from Messages. If we view the Transaction as a conversation, then an ISA-95 **Message** can be compared with a sentence spoken by one of the systems. The receiving system "hears" that sentence and answers with another sentence. We learned at school that a sentence must in any case always contain a Verb and a Noun. ISA-95 Messages, too, have a prescribed content, of which Verbs and Nouns are a part. ISA-95 Messages comprise by default an Application Identification Area and a Data Area (see figure 15). The **Application Identification Area** contains the data that the systems need in order to know where the Message comes from, where the response should be sent, whether the other system also wants confirmation, and so forth.

The **Data Area** contains a Verb and a Noun. The combination of Verb and Noun produces a unique command, such as GET *equipment ID 201*, in which GET is the Verb and *equipment ID 201* the Noun. The **Nouns** are the data (Objects) already specified by the object models in Parts 1 and 2 of the standard. The Verbs are new. Which Verb applies depends on whether the systems exchange information with one another according to the Pull Model, the Push Model, or the Publish Model. In the **Pull Model**, one system requests information from the other system. The requesting system uses the Verb GET, as in the example *GET equipment ID 201*. The system that must deliver the data responds with the Verb SHOW, as in *SHOW equipment ID 201*. In the **Push Model**, one system sends data on its own initiative to the other system. It uses the Verbs PROCESS,

CHANGE, or CANCEL. For example, an ERP system might send the Message *PROCESS Schedule 01-04-2006* to an MES system. The MES system might then respond with *ACKNOWLEDGE - ACCEPTED Schedule 01-04-2006*.
The third way in which systems can communicate with one another is according to the **Publish Model**. In this model, a system sends data to one or more systems. The data are "published," as it were (compare with television and radio), and the sending system in many situations does not know whether the receiving systems will do anything with the information. The sending system announces that it has created, changed, or deleted data by using the Verbs SYNC ADD, SYNC CHANGE, and SYNC DELETE. An example is *SYNC DELETE equipment ID 201*. (*SYNC* here stands for the Verb *Synchronize*, and thus not for synchronous communication.) Part 5 of ISA-95 describes separately for each combination of a Verb and a Noun what action the Message should generate. For example, the combination of the Verb GET with the Noun Material Lot + ID should ensure that the system delivering the information sends the Material Lot ID with all its associated Attributes, Properties and their Attributes, and a list of all Sublots. (For more information about implementing Part 5, see chapter 4.)

1.4 Opportunities for Applying ISA-95

Since the year 2000, companies such as Nestlé, Arla Foods, BAT Manufacturing, and Masterfoods have employed ISA-95 to standardize the exchange of information between their ERP packages and their MES systems. BAT Manufacturing in Zevenaar, the Netherlands, has even developed its own MES modules based on the ISA-95 data models, and Masterfoods in Veghel, the Netherlands, has implemented an ISA-95-compliant scheduling package. At trade shows and conferences, ISA-95 has in recent years been an oft-heard cry that software vendors and system integrators cannot ignore. On the level of MES and control systems, software vendors now offer standard ISA-95 interfaces. On the ERP level, we encounter SAP in particular as a vendor of software with ISA 95-compliant interfaces. Given the title (*Enterprise-Control System Integration*), it's no wonder that ISA-95 is primarily known as a method for standardizing information exchange. Far fewer people know that you can also use ISA-95 for other objectives. Consultants and end users regularly employ the ISA-95 models to analyze all kinds of things. ISA-95 is thus - in addition to the definition of standard information flows - also a guideline, a kind of encyclopedia, a checklist: in short, a useful tool for performing analyses within manufacturing companies. Roughly speaking, the opportunities for applying ISA-95 can be divided into three categories:

- Using ISA-95 (Parts 1 and 3) as an analysis tool.
- Using ISA-95 (Part 2) as a basis for developing software with MES functionality.
- Using ISA-95 (Parts 1, 2, and 5) for standardized information exchange between enterprise and control systems.

1.4.1 ISA-95 as an Analysis Tool

When, at the end of 2003, I wrote my first articles on the subject of ISA-95 for the Dutch trade magazine *Automatie*, there were worldwide virtually no companies that had gone public on their experiences with this standard. ISA-95 had at that time been relatively rarely implemented, and every company that did have experience with it could be counted among the pioneers. I wanted to let those pioneers speak about their experiences, and thus conducted an interview[m] with John Overkleeft, a consultant with MPE Industrial Automation in the Netherlands. MPE Industrial Automation is, in its role as system integrator, specialized in automating manufacturing processes.

I've noticed that many system integrators are diving into the ISA-95 standard because the end user is asking for it. Does your choice to use ISA-95 also stem from the end user's desires?

No, we came up with the idea ourselves, and the influence of the supplier of the MES package also played a role. We're using ISA-95 in two projects now. One is focused on optimizing the production process in terms of quality and capacity. The other project involves implementing a standard MES package (the Simatic IT framework), which has to exchange information with the ERP system (SAP R/3), in order to better schedule personnel.

The ISA-95 standard has the goal of integrating enterprise and control systems with each other, but in practice companies also use the standard for other objectives. How have you used Parts 1 and 2 in projects?

For us, Part 1 of ISA-95 is a reference model for clarifying the desires and needs of the client and investigating which solutions best fit with these. We've hardly applied the data models and object models in Part 2 at all, because the ISA-95 interpretation of the MES vendor is based on an earlier [draft] version of the standard and thus deviates from the definitive form of ISA-95. As a system integrator, we're bound to the vendor's interpretation.

To date, no figures have been disclosed about the advantages of implementing ISA-95. Can you name any advantages related to the use of ISA-95 in projects?

Time gains, completeness, and reusability. Because you can start from a reference model, the information analysis goes much more quickly. Moreover, you can use ISA-95 as a checklist, which makes it easy to determine whether you've charted all the desires and requirements without missing anything.
In the long term you also have the advantage that database structures and completed interface program code or configurations can be reused, as can of course the experience we've gained.

And disadvantages?

If you want to convert an existing database to an ISA-95-compliant database, you'll actually need more time. For the rest, our experience is the same as during the early years of the ISA-88 standard: there's not much experience and ISA-95 is very complex and abstract. The object models in particular are difficult to apply to an actual situation. For MPE Industrial Automation, ISA-95 is for the time being a tool for use in projects. It's too early to change our project approach for it. We did do that with ISA-88, but ISA-95 will first have to prove itself in more than two projects. This doesn't detract from the advantages I stated, however, which all in all make up for the disadvantages.

(Note that this interview dates from 2003.)

One of the first opportunities in Europe to hear companies speak about their experiences applying ISA-95 was the European conference of the World Batch Forum[n] in 2004. Since its inception in 1994, the World Batch Forum has striven to help batch specialists attain better results. One of the most effective ways to do that is to bring people together so that they can exchange ideas and learn from each other. In Mechelen, Belgium, in October 2004, over a hundred end users, consultants, and system integrators from more than twenty countries gathered to share their knowledge on various subjects with each other.[o] It was not a commercial exhibition, where vendors use slick presentations to try to sell their products. During the three-day conference, companies such as Nestlé, BAT Manufacturing, and SABMiller gave valuable presentations about their experiences with the implementation of new standards such as ISA-95 and modern technologies such as XML.

Several topics passed in review. The program's accent lay heavily on the application of the ISA-95 standard by end users. ISA-95 was relatively new. The market had at that moment a large need for information about the opportunities for and risks of implementing this standard, in order to decide whether to start working according to the ISA-95 method. Fortunately, various end users were prepared to talk about the projects in which they had used ISA-95. From these it became clear that this standard can be used for much more than just integrating enterprise and control systems.

Willy Lotz, automation consultant for South African Breweries, told how SABMiller employed ISA-95 to gain more insight into the capacities of different manufacturing sites. SABMiller is one of the largest brewers in the world and has 121 breweries, seven of them in South Africa. As a result of rapid expansion and acquisitions, there was a lot of difference in the level of development of the production systems at different sites. This applies especially to the seven breweries in South Africa, because they were built in very different periods. This difference in development confronted SABMiller with the challenge of introducing improvements in the capacity of process installations, control systems, personnel knowledge and skills, and automation levels, for example.

In a scenario in which factories that manufacture the same products are spread around the world, a well-structured approach is important in clarifying the existing and required characteristics for the different production sites. This also makes strategic planning, budgeting, and reporting on production results possible. SABMiller made thankful use of ISA-95 for this as a reference model and to improve communication. The focus of ISA-95 Part 3 on the MES layer helped convince the production facilities that this standard can be used to compare the manufacturing locations' characteristics. Using ISA-95, SABMiller created a *capability maturity model*, a tool that gives management more insight into the development of various manufacturing locations and thus helps to determine strategy for further production systems development.

1.4.2 ISA-95 Applied to the Development of MES Applications

For the same article in which I interviewed John Overkleeft from MPE at the end of 2003, I also conducted a question-and-answer session with Bas van de Kerkhof, one of my past students in a series of ISA-certified ISA-95 courses.[p] Bas van de Kerkhof is responsible for the development of the ISA-95-compliant scheduling package Resource to Time (R2T) for the company CARE Automation. CARE Automation is a vendor of software for detailed scheduling.

There are still relatively few ISA-95-compliant software packages on the market. What led CARE to decide to start working entirely according to the ISA-95 standard?

During the course, I became convinced that this standard offers very good solutions to specific scheduling problems that we run into in practice. And so the idea to make R2T ISA-95-compliant was born. This seemed within reach, because the ISA-95 object models in general were not far removed from the then-current R2T models. We still fully support this choice, even though the switch to ISA-95 took much longer than we anticipated beforehand.
That's primarily because it's very complex to develop an application based on the ISA-95 object models. You want to follow the standard completely, because it's generic, even though it would be so much easier to choose "quick and dirty" solutions. Normally you start with a particular situation and build suitable models. Now, however, we had to build an application based on existing models. That makes it much more difficult, but the big advantage is that you keep pushing in the right direction.
You're obligated to exert yourself more. Don't forget that a scheduling package like this is always part of a larger logistics chain that's supported by various software applications. The more you opt for quick and easy solutions when developing the application, the less well your product will fit into that greater whole. As soon as you (partially) let go of the ISA-95 models, you lose the associated advantages. The models are perfectly constructed. I haven't found a single error. On the other hand, I don't believe that ISA-95 makes it that much

easier to build an interface. If you leave all the models intact, of course you'll have a well-described interface, but realizing that interface remains a time-consuming affair.

What experience has CARE since acquired in implementing ISA-95 for end users?

For Masterfoods in Veghel [the Netherlands], we built an application for detailed scheduling of the packaging materials demand for the whole factory based on an existing system for production scheduling. The amount of packaging material required per half day depends on the number of active production lines. You want to avoid filling up the entire factory, but if there isn't enough material, then production will come to a halt. This involves extremely detailed scheduling, because the variations within eight hours are very large. Both CARE and Masterfoods wanted to use the ISA-95 object models, because of the strong structure. There was an expectation that this structure would make information easy to locate.
Moreover, the standard has as its purpose exchanging information between systems, which also played an important role in this project. The new system would have to be based on the database from the old system. The expectation was that ISA-95 would take a lot of the work out of our hands, because the structure is already there, but in fact it cost extra time to normalize the existing database. ISA-95 forces structure on you, which is in itself an advantage, but it also brings several disadvantages with it. It cost those involved a lot of time and effort to become familiar with the structure and the complex terminology, for example. And the standard is so generic that you can store certain information in different places. Still, the extra effort is worth the trouble, because you lay a very good foundation for the future: the application is logically structured and is relatively simple to extend.

The ISA-95 standard produces clear advantages for software vendors, such as the ability to develop a generic system suitable for various kinds of manufacturing processes. But why would an end user choose ISA-95?

ISA-95 is a familiar framework and thus applications based on it fit together. Some vendors choose to conform to large companies like SAP, but the advantage of ISA-95 is precisely that it is vendor independent. That also makes it easier for end users to extend applications, independently of the original vendor. The ISA-95 models are available to everyone, which makes these applications transparent.

Another example of ISA-95 as the basis for developing software with MES functionality can be found at British American Tobacco Manufacturing in Zevenaar, the Netherlands. Erwin Winkel, senior project manager at BAT Manufacturing, described at the WBF European Conference in 2004 how, based on ISA-95, BAT Manufacturing developed several MES modules around a central database. BAT Manufacturing began by using the ISA-95 standard to specify the user requirements. They then investigated which of the commercially available packages met the requirements, ultimately concluding that they could best build their own MES environment. (At that time, there were very few standard MES packages available on the market.) The MES modules they built give the operators current information about the manufacturing process, in which cigarettes are made and packaged.

The database model is partially based on the ISA-95 object models, and BAT Manufacturing used the ISA-95 interface definitions for the interface to other information systems. BAT Manufacturing was one of the first to use the XML schemas (B2MML) developed by a World Batch Forum working group for information exchange using ISA-95. They discovered a few important bugs in the schemas and reported these to the working group, after which the schemas were corrected. BAT Manufacturing has developed modules for material control, quality control, and planning control. Each material is now, before starting production, scanned with a barcode scanner, so that operators make fewer mistakes in selecting the right material. This has also reduced the amount of waste and the number of repairs.

Test data are automatically collected and displayed to the operator so that he can apply the SPC rules. The MES application also stores real-time production data and checks whether these match the schedule and the targeted goals. All in all, the process has become more stable, with more predictable output. Erwin Winkel went on to say that this was the first project in which BAT Manufacturing used ISA-95, and so there were a few learning points. The choices made in the beginning weren't always the best ones. For this reason, they will optimize the applications in the future by restructuring them based on the new insights.

1.4.3 ISA-95 Applied for Vertical Integration

In 2003, I conducted the interview below with the same Erwin Winkel from BAT Manufacturing for the trade magazine *Automatie*.[q] BAT Manufacturing not only applies ISA-95 to developing software with MES functionality, but also to building standardized interfaces to the ERP package.

Part 1 of the ISA-95 standard came out at the end of 2000 and Part 2 only at the end of 2001. Part 3 is not yet completed.[r] *Your project was begun a few years ago. How and when did you come into contact with the ISA-95 standard?*

We were introduced to the standard at the end of 2000 by a Dutch system integrator. At that time, there was only a draft version of Part 1. At BAT Manufacturing, we are in principle open to standards. For example, based on our corporate strategy we selected the OAGIs standard for XML messaging. In this project we also needed message formats not covered by OAGIs, because OAGIs focuses on the supply chain layer. That's why we took on the ISA-95 XML schemas as an addition.

ISA-95 is now an accepted standard within BAT Manufacturing. We've used ISA-95 since the initiation phase of the project. We compiled the functional specifications based on the models and terminology in Part 1 of the standard. In the beginning, it took a lot of effort to convince people. They asked themselves, "What do we need that for? We know what we want, let's not make things so difficult."
My argument was, however: we know what we want now, but not what we'll want later. If you base yourself on a standard, then it becomes easier to extend things, and you'll be more compatible in the future with packages based on the standard. The production project leader in particular agreed, and after a lot of effort, there was finally enough support.

The standard is relatively young and there's virtually nothing known about applying it in practice. There is thus not a lot of opportunity to learn from others' experiences. Did you have start-up problems using ISA-95?

There was an external party who was going to translate the functional design to a technical design. At that moment ISA-95 was put onto a back burner. After a while I asked what had happened to ISA-95. It turned out that the standard hadn't been used in developing the database structure. We got back on track right then and kept every new development in line with ISA-95. For the parts developed up to that point, we had to do a database redesign. We advised the system integrator to have its people familiarize themselves with the standard, which they did.

You've used the ISA-95 standard from the very first moment for the information analysis and the database structure, but ISA-95 was specifically developed for creating interfaces.

It was clear right from the start that we would in fact use the standard precisely for creating interfaces. We implemented an interface to our ERP system. In the future we want to interface with SAP, but right now we still have a different ERP system. We also interface with the SCADA layer. Our selection of ISA-95 is directly related to this. We want vendors to limit us as little as possible, but on the other hand we want to choose widely available standard solutions as often as possible. Thanks to ISA-95, we can already create an interface with our current ERP solution before switching to SAP. When we switch over to SAP, the interface definition can stay the same, and we won't have to change the MES environment. These advantages spring in large part from the use of middleware and XML, by the way, which decouple applications on the physical and logical levels. If we replace the current system by SAP and SAP has an ISA-95 interface, then it will be very easy to create an interface. If not, then we'll have to add an ISA-95 interface to SAP ourselves. Thanks to middleware, we only have to do that on one side; we don't have to make any changes to the application itself. Our effort is relatively small and reusable, because we've already defined the message structure based on ISA-95.

Do you expect to see benefits only in the future, or has your implementation of ISA-95 already produced advantages?

We've made an investment that you hope will have results. It could in the future become a BAT Manufacturing requirement for vendors to be ISA-95 compliant. But we have already seen benefits in the project. The end users for the MES systems keep coming up with new desires, for example, things they hadn't thought of before. Thanks to the ISA-95 structure, it's relatively easy to, say, add material attributes. The effort required to make extensions is thus small. We also already see benefits in terms of maintenance. If employees go on vacation and others have to take over their work, it's relatively easy, because the standard is unambiguous.

You've now gained a lot of experience with the standard. What's the most important thing you've learned in terms of ISA-95?

We had decided to implement the standard, but it was hard to stick to that decision. People think it's complex and difficult; it takes a lot of effort to familiarize yourself with a new standard. Those arguments kept coming up. Still, I wanted to keep following the standard. In hindsight, I'd spend more attention on that. As soon as the first advantages were clear, it fortunately became easier to convince people. Since then everyone has become positive about the standard. In fact, when there are new developments, now sometimes employees even ask if they are compliant with the ISA-95 standard.

I understand that you're definitely going to continue using ISA-95 in projects?

Yes, and we're also trying to propagate the advantages of the standard further within the company. If different sites base themselves on ISA-95, it'll be easier to exchange information and we can profit even better from each others' developments.

1.5 Advantages of Applying ISA-95

ISA-95 isn't restricted to creating an interface between enterprise and control systems, as the title of the standard suggests. It's also a good guideline for compiling user requirements, describing functional requirements, selecting vendors, developing MES applications and databases, analyzing and comparing capacities at different production sites, and gaining insight into and optimizing production processes. Jean-Marc Desbaillets, responsible for enterprise and control systems integration at Nestlé, explained in 2004 in his presentation at the World Batch Forum European Conference that ISA-95 can help in developing a library of standard messages, which can then be reused at all production locations to create a link between the company-wide SAP application and various local Nestlé MES applications. Improvement in communication between people and systems also turns out to be a significant advantage. Arne Svendsen of Arla Foods in Denmark - *the* ISA-95 pioneer - explained this by summing up the number of people with different backgrounds, tasks, and functions who are involved in ERP-MES integration projects. The ISA-95 models and standard terminology ensure that all those people think and talk the same way about manufacturing activities, systems, and information. Erwin Winkel of BAT Manufacturing also stated that use of the ISA-95 object models led to a speedup in the MES application development process, and that use of an MES framework based on ISA-95 will simplify future changes to and extension of the MES environment. Willy Lotz of SABMiller emphasized that the models are generic (vendor independent), yet detailed enough to be able to discuss concrete matters and thus quickly progress. Sudipta Bhattacharya of SAP indicated that ISA-95 ensures separation of administrative processes and production processes, so that changes to production processes no longer have large consequences for logistic and scheduling processes, and vice versa.

1.6 The SP95 Committee

ISA standards are developed by the SP (Standard Project) committees. So too ISA-95. The SP95 committee consists of a group of representatives from manufacturing companies, system integrators, consulting companies, software vendors, universities, and organizations. In January, 2006, I spoke, prior to an international meeting in Paris, with Dennis Brandl, one of the driving forces behind the development of the ISA-95 standard. His function within the committee is that of editor. Brandl told me how the idea to develop the ISA-95 standard came about.

How did you personally come into contact with standardization?

I worked for Texas Instruments, where we tried to develop batch control systems for PLCs. We discovered by accident that ISA was developing a standard for this (ISA-88). We decided to become an active member of SP88, and through the years I've remained a member, when I worked successively for Siemens, Schneider Electric, Sequencia, and then finally went into business for myself.

How did the idea for ISA-95 come about?

Lynn Craig, chairman of SP88, Michael Saucier, president of Sequencia, and I realized that ISA-88 was a good standard, but that it had only a limited scope. And ERP wasn't always a good solution for the factory. We initially focused primarily on defining the boundaries, in a joint ANSI/ISA-88/-95 workgroup. So the idea for ISA-95 simply developed out of the realization that you need more to run a factory than just a batch process. For example, you have to schedule the lines, and there are not only batch processes, but also discrete

and continuous processes, and there's storage. The business plan also has to be converted into a form usable on the factory floor. That's the theoretical background for our initiative.
But it also has a practical background. We noticed that both ERP sellers and sellers of batch software were inordinately self-confident about the extent to which they could control and supervise the entire factory. So we wanted to specify really thoroughly what the responsibility boundaries are within a factory.

How does a standard get developed?

We went to ISA with the idea, and ISA carried out due diligence. Then SP95 (Standards Project number 95) began. It took us less than six months to get started. From the start, we had the cooperation of virtually every control vendor and a few ERP vendors.
We held meetings at Oracle. During development, vendors and consultants discovered the holes and weak spots in the standard. In next week's meeting we'll discuss the comments from the Siemens group, for example, who've applied it in practice. So the standards aren't developed in an ivory tower. Most SP95 meetings take place in the United States. We get input from Europe in electronic form.

Who pays the expenses?

It's all volunteer work. In the United States, there's no support from the government. When I worked for Siemens and later for other companies, they paid for it. Now I do it on my own time and I pay my own expenses. I sometimes say to my wife, “It's my hobby.” I think it's important to work on standards that are useful to the industry. When I look back on it, a lot of the work I do involves this standard. But that's not the reason I started doing it.

How quickly is a standard developed?

Standards have to simmer for a while. The specialists need to have time to read it and think about it. Best case, developing a standard takes three to four years. On average it takes five years. You lose a lot of time because you have to vote and because you have to organize and coordinate the meetings, about four per year.

What are the most important considerations in developing a standard?

It's important when developing a standard that you keep in mind that we have a broad range of cultures, languages, and opinions. If somebody's talking passionately about something, there's always a reason for it. You have to listen well to what people say, but also to what people don't say. Sometimes something is assumed to be familiar, even though not everyone knows about it.

Promotion - we don't have to worry about that. Many of the committee members are very enthusiastic and go to a lot of trouble to promote it. And organizations such as ISA, OAGi, Mimosa, and MESA also take on that task.

Is the ISA-95 standard just as popular in the US as it is in Europe?

In both the US and Europe, only ten percent of companies can already use ISA-95 right now. We're still in the pioneer phase. One of the reasons is that ERP systems aren't ready for it yet. Moreover, end users have just finished their ERP implementations, so they're just now ready for it. In the US, companies like Proctor and Gamble, Genentech, and Merck use ISA-95.
In the beginning they used the standard primarily to specify which function belongs where, where which responsibilities lie. Now they're also starting to use B2MML[s] as a technical standard for information exchange. Oracle has lent its support, Microsoft has officially announced that it's going to support the standard, IBM has attended the B2MML meetings. Now that we're fusing the OAGi and B2MML standards, the standards will be able to be implemented by a much larger group of companies, especially in discrete industries.

Technologies develop rapidly. Will ISA-95 quickly become obsolete?

Over the long term, the ISA-95 standard will certainly age and be replaced. But the basic concept will always remain viable.

The ISA-95 standard was not developed in an ivory tower. End users, consultants, and software vendors, such as Siemens, have contributed and have tested the models in practice. In February 2006, I spoke with Charlotta Johnsson. She represented Siemens on the SP95 committee for several years.

I was exposed to standardization during my PhD study. The ISA-88 standard was still in development at that time. When I went to work for Siemens, I came into contact with the SP88 committee. People on the committee invited me to become a member. Siemens was also interested in the development of standards. There was a group inside Siemens that was working on standardization, led by Otto Ulrichs. But they weren't yet working with ISA-88 or ISA-95. I introduced Siemens to ISA-88 and ISA-95. It's hard to say how much time I devoted to the committee when I worked for Siemens. Sometimes up to eighty percent of my workweek. We provided a lot of input for the chapter on quality in Part 3, for example. But sometimes only ten percent. I was a system architect at Siemens, for Simatic Batch (which was called Xbatch at that time). Later, I was involved in product management for Siemens MES products. Now I work for Lund University in Sweden, and I spend about ten percent of my time on standardization activities. I'm no longer the Siemens representative on the SP95 committee. Someone else does that now. I've traveled to America quite often to attend SP95 committee meetings. I've gone to every meeting, about six times a year. There are no obstacles to

Europeans in attending these meetings, other than the travel time and expense. You can also send in your comments by e-mail. In itself that's a good way to do it, but it can never replace the face-to-face meetings, because they're still the most productive. All e-mail submissions are handled very carefully by the SP95 committee, for that matter.

1.7 The ISA-95 Hype

When a standard is developed and published, the question is, to what extent will the market adopt it? ISA standards are not developed in an ivory tower, but by people who know the tricks of the trade. That's a good foundation for the acceptance of such a standard. We've seen that the ISA-88 standard for batch control, which has been around for more than ten years now, is enormously successful, and that it's unanimously considered to be *the* standard around the world. The chance is great that ISA-95 will be just as successful, even though this standard has clearly needed a longer warming-up period. This is related to the greater impact that ISA-95 has within a company, in comparison with ISA-88. Now, however, we're slowly but surely seeing more and more examples of practical applications. All self-respecting MES vendors swear - at least in their marketing blurbs - that they support ISA-95, and many are also at the point where they can actually offer several of the ISA-95-defined information flows in B2MML form. Things are moving more slowly with the ERP vendors. Pioneers such as Nestlé, Arla Foods, and BAT Manufacturing have had the disadvantage that SAP and other ERP vendors didn't yet support ISA-95. In the spring of 2004, however, SAP proclaimed its concern about the lack of adoption of industrial standards, which made efficient exchange of information between the production level and the business automation level more difficult. SAP published the following press release (excerpted):

SAP Drives Accelerated Adoption of Manufacturing Industry Standards

Leading Companies Like Du Pont Engineering, Siemens, and Rockwell Automation Support "Shop Floor to Top Floor" Manufacturing Program for Enhanced Interoperability Across SAP and non-SAP Systems

NEW ORLEANS, La. - May 12, 2004 - Strengthening its commitment to enable adaptive manufacturing and provide customers with best-in-class manufacturing solutions, SAP AG (NYSE: SAP) today issued a call for action for the rapid acceleration of the adoption of manufacturing industry standards. Through the immediate development of a roadmap to improve connectivity between shop floor applications and manufacturing enterprise systems, SAP is addressing industry-wide global concerns about the current lack of agreement around adoption of defined standards, a factor that is preventing the efficient movement of information from the shop floor execution layer to the enterprise business layer. The announcement was made at SAPPHIRE

’04, SAP’s international customer conference being held in New Orleans, Louisiana, May 11-13. Starting with securing support for the acceptance of ISA-95, SAP is calling on customers and partners to participate in the development of roadmaps for the adoption of process industry standards. An additional objective of the program is to rally support for unresolved discrete industry standards, around which there is much indecision. Agreement on standards will enable tighter and more efficient integration of systems, helping customers drive down the costs of managing their manufacturing systems and redirect operational expenses into areas like innovation. . . .

Support from Leading Global Solution Providers

The current lack of standards agreement is adversely affecting enterprise-wide information flow, which in turn hinders visibility across manufacturing processes and affects a company’s ability to adapt to events that impact manufacturing operations. SAP has already received confirmation for support and participation in the standards program from leading manufacturing solution providers like Siemens, Rockwell Automation, OSISoft Inc., the Wonderware and ArchestrA business units of Invensys, Emerson Process Management, Apriso Corporation, Lighthammer Software Development Corp., FORCAM GmbH, PSI-BT Business Technology for Industries AG, MPDV Mikrolab GmbH, and ABB Group. “Given SAP’s reputation in the global manufacturing ecosystem and the breadth of SAP’s manufacturing solutions, SAP’s support of any standards gives those standards immediate validation,” said Bob Mick, V.P. Emerging Technology, ARC Advisory Group. “We believe that the adoption rate of standards like ISA-95 can also be positively impacted should SAP decide to build the requirements into its solution.”

Source: www.sap.com

This call to action from SAP has certainly contributed to the current hype around ISA-95. We are increasingly seeing that, at exhibitions and conferences, attention is being paid to the “missing link” that ISA-95 is supposed to provide. At the WBF European Conference in 2004, SAP, in the person of Sudipta Bhattacharya (vice president of Application Solutions Management), took the trouble to prepare a presentation to promote use of the ISA-95 standard. Bhattacharya pushed SAP NetWeaver forward as the integration and application platform that will make process integration possible. It contains an open, heterogeneous infrastructure based on Java and XML that ensures that ISA-95 compliancy is sufficient to communicate with SAP. The conversion from ISA-95 to SAP, which companies such as Arla Foods and Nestlé have had to undertake, will no longer be necessary in the future for companies that implement ISA-95 and use SAP. SAP and ISA-95 have since become close friends. SAP is using the popularity of ISA-95 to place its products NetWeaver and xMII in the market, while the ISA-95 standard is riding on SAP’s recognition and range and thus being introduced into diverse companies: a nice example of a win-win situation!

1.8 The Future of (and with) ISA-95

The use of standards is growing in the industry, but the question remains whether companies also follow these standards in their working methods. The past few years, I've been confronted many times with the question whether something like ISA-95 certification for products or vendors exists. That's why I began an investigation in 2004 into the global interest in such a service, together with Jean Vieille (Psynapsis), Charlotta Johnsson (Siemens and Lund Institute of Technology), Peter Partington (standards chairman for ISA district 12), Anders Fridh (Tetrapak), and Dennis Brandl (editor of ISA-95). Various software vendors, end users, and system integrators reacted positively to our questionnaire. We then made an official investment proposal to ISA. ISA is now working on a feasibility study regarding compliance with specific ISA standards. A compliance program would make it possible for end users to know with certainty that a company has conformed to the specific requirements of an ISA standard. If products are certified as compliant with a specific ISA standard, end users will have more confidence that both software and hardware products, implementation methods, and solutions can help them attain all the benefits of standardization. A company or product can, of course, never be 100% compliant. And that's not the point of this proposal. The objective is to have an independent institution judge *to what degree* a product or service is compliant, and to provide access to the results of this review to those who are interested.
As already mentioned, the SP95 committee has developed various parts that concentrate on specific aspects of the integration issue. Some parts are still in development and it isn't unthinkable that the SP95 committee will in the future develop new - as yet unforeseen - parts. Those new parts will focus on yet other aspects of integration. People sometimes ask me if the ISA-95 standard will quickly obsolesce. Considering the speed at which technology develops, I can understand this idea, but for the time being I am of the opinion that the standard offers various advantages that reach much further than the world of technology. So I expect ISA-95 to be used for decades to come, and I even think ISA-95 should be required reading in relevant university and trade school programs, such as Master of Business Administration at technical universities.

1.9 Summary

Below is a summary of the most important points in chapter 1.

- In many manufacturing companies, there is a gap between ERP systems and the process control layer. ISA has developed a standard to bridge this gap and thus reduce the risks, costs, and errors that go hand in hand with implementing interfaces between enterprise and control systems. This standard is ISA-95, *Enterprise-Control System Integration*. The standard comprises multiple parts.
- ISA-95 is a method, a way of thinking, working, and communicating.
- The standard defines an Enterprise Domain (Level 4) and a Control Domain (Levels 3 and lower).
- Part 1 presents models and terminology for analyzing and standardizing the information exchange between Level 4 and Level 3 within a specific manufacturing company.
- The most important models in Part 1 are the Functional Hierarchy model, the Equipment Hierarchy Model, the Functional Enterprise-Control Model, the Categories of Information Exchange Model, and the Object Models.
- Part 2 presents data models that standardize the structure and content of the information flows in Part 1.
- Part 3 presents models with which one can analyze the Control Domain in a specific manufacturing company.
- Part 3 defines four groups of activities within the Control Domain, namely Production, Maintenance, Quality, and Inventory. Using models, Part 3 makes clear which activities these groups comprise.
- Part 4 is still in development and standardizes the information exchange between maintenance, quality, and inventory systems internally and between these systems on one side and MES and ERP systems on the other.
- Part 5 presents standard verbs and nouns for the message exchange between ERP and MES systems. In this way, Part 5 makes clear what the ERP and MES systems should do with the information flows specified in Parts 1 and 2.
- ISA-95 can be applied in various ways: for example, as an analysis tool, as a basis for developing MES applications, and as a basis for standardized information exchange between MES and ERP systems (vertical integration). The following chapters in this book cover this in greater detail.
- Application of ISA-95 can provide various advantages:

    - ISA-95 analyses provide greater insight into diverse aspects of manufacturing companies.
    - Using ISA-95 as the basis for MES applications creates standardized, open, and well-conceived systems that are easier to interface with systems from other vendors and that are easier to maintain.
    - By integrating ERP and MES systems with each other in a

standardized way, end-user companies become less dependent on software vendors and interfaces become easier to maintain.
  - Vertical integration in general can produce benefits such as asset efficiency, supply chain optimization, operator empowerment, return on assets, flexibility, lower safety stock, and so forth.

- New parts are still in development: ISA-95 offers solutions for more and more aspects of the vertical integration issue within manufacturing companies.
- Even though new technologies are developing at rapid speed, the basic principles of ISA-95 will still be valid and applicable for years (perhaps forever).

Now that the theory's been covered, it's time to take a look at how ISA-95 can be applied in practice.
Chapter 2 explains how you can use ISA-95 as an analysis tool, in order to gain greater and quicker insight into various aspects of a specific manufacturing company in a structured way.
Chapter 3 describes how you can use the object models in ISA-95: for example, as a basis for developing MES functionality, in order to design a well-conceived, open system that's easier to integrate into an IT landscape with solutions from different vendors.
Finally, chapter 4 explains how ISA-95 can help you realize a standardized interface between ERP and MES systems in order to have the right information available in the right form at the right place at the right time. This can, for example, help a company reduce production time, use production materials more optimally, provide its operators with better information, provide its clients with reliable information, and more.

Notes

[a] Steven Alter, *Information Systems* (Upper Saddle River: Pearson Education Inc., 2002), 44.

[b] SP95 Committee, *ANSI/ISA–95.00.01–2000 Enterprise-Control System Integration Part 1* (Research Triangle Park: ISA, 2000), 13.

[c] Ibid., 18.

[d] Ibid., 22.

[e] ISA standard for controlling and automating batch processes.

[f] SP95 Committee, *ANSI/ISA–95.00.01–2000 Enterprise-Control System Integration Part 1* (Research Triangle Park: ISA, 2000), 26.

[g] Ibid., 59.

[h] Ibid., 40.

[i] Part 1 still talks about three categories. The model in figure 6 comes from Part 3 *(ANSI-ISA-95.00.03-2005, Enterprise-Control System Integration Part 3: Activity Models of Manufacturing Operations Management*, ISA, 2005, p.22). This model overrules the model from Part 1.

[j] Chapter 3 gives a detailed explanation of the object models.

[k] Chapter 3 covers the practical application of these tables.

[l] The actual execution of maintenance, quality, and inventory activities and the actual production take place on a lower level.

[m] Bianca Scholten, "S95 toegepast door eindgebruikers," *Automatie* (no. 10, 2003), 18.

[n] These days, WBF goes by the name *The Forum for Automation and Manufacturing Professionals*, but the original source of the acronym is *World Batch Forum*.

[o] For a report on this conference (in Dutch), see Bianca Scholten, "World Batch Forum's Europese Conferentie," Automatie (no. 10, 2004), 10.

[p] Bianca Scholten, "S95 toegepast door eindgebruikers," *Automatie* (no. 10, 2003), 18.

[q] Ibid.

[r] This interview took place in 2003.

[s] For an explanation of B2MML, see chapter 4.