PERA Master Planning Guide

General Enterprise Planning

July 1, 2006

Enterprise Consultants International

Preface

The Purdue Enterprise Reference Architecure (PERA) and the Purdue Reference Model for CIM were first published in 1989 by a consortium of industrial users, suppliers and academia. The PERA Handbook of Master Planning was published in 1995 to provide a guide for using PERA in Enterprise Integration projects. In the intervening years PERA has been used in hundreds of enterprises in Metals and Mining, Oil and Gas, Chemicals & Petrochemicals, Power, Food and Beverage, Pharmaceuticals, Government, and many other industries.

There have been many new developments in engineering, IT and Telecommunications since these documents were first published, and it was considered worthwhile to reflect these changes in a new document that provides users with a simplified "Guide" that refers to, and builds upon, the original documents.

The following *PERA Master Planning Guide* reflects updates to the Original PERA Master Planning Methodology based on these new developments and on experience gained by Enterprise Consultants International (ECI) in application of the PERA principles on many large and small enterprises.

Originally, the PERA concepts were designed for large new enterprises and upgrade projects with very long lead times for design of work processes and systems. Now, software tools such as Business Process Modeling (BPM) and Configuration Management (CM) enable organizations to modify their Work Processes, databases and systems "in real time". This updated Master Planning Methodology must support retrofitting this new "Adaptive" model, as well as more traditional large project design.

The formalization of Enterprise Requirements Planning (ERP), Manufacturing Execution Systems (MES), and the Industrial Control Domain (ICD) has evolved since the original PERA work. In addition, the Role of the Process Operator has expanded to include MES Activities, and increased data exchange with MES requires better security in the Industrial Control Domain (ICD).

Some of the new developments which have influenced the PERA Master Planning Process include the following:
- The Purdue Reference Model for CIM has been adopted as the basis for a number of key standards including ISA-95 and ISA-88. This involved formalizing and extending the original PERA concepts, and makes them more widely adopted and recognized.
- Software, database and communications Technology has advanced rapidly and the terminology has evolved and been standardized.
- Organization design, Employee Motivation, and other Human Factors have evolved (for example the PERA Critical Performance Factors (CPFs) have evolved into Key Performance Indicators (KPI's) which are widely used to determine bonuses and incentive payments at all levels in the organization.
- The concept of ERP, MES, and ICD Domains at specific levels in the Enterprise Architecture has been formalized. Each of these has different requirements which become more industry-specific as one moves lower in the Architecture.
- Network security standards including ISA-99 have evolved which influence design of Corporate, Plant MES and ICD networks. These new standards have been integrated with the concept of architectural levels in the Reference Model
- Industrial control standards for SIS/SIL (Safety Instrumented Systems/Safety Integrity Level) have been codified in IEC 61508 and 61511, which also influences design of ICD systems and networks.
- Quality standards have been introduced including ISO 9000 and SOX (Sarbanes Oxley) which also influence design of ERP and MES systems.
- The concept of Human and Organizational "Roles" was added. Roles are assigned to "Positions" in the organization. These Human Roles directly relate to specific "Functions" in the Control and Information Systems Model.

- ISO 15000-5 introduced the concept of "Core Components" which are similar across enterprises (for example within the Physical Facilities Model, pumps or control valves have many common elements). These core components are supported by "Product Classes" within the Engineering Workbench.
- Since requirements for facilities, people and systems architectures vary with different Industries, an industry classification system has been added to the Engineering Workbench which recognizes similarities in facilities, human and systems aspects of these industries.
- A Internet "Engineering Workbench" has been added which manages information such as Standards, Roles, Industry Codes, Product Classes, "go-by documents", etc. This extends the basic information provided on the PERA website

Despite the above developments, the basic principles of PERA have been confirmed including:

- Division of Enterprise into People, Facilities and Systems aspects with special care to address the interfaces between these.
- Strong Phasing as the Enterprise develops from planning through engineering and construction to operations
- Network Architectural Levels with unique requirements for Reliability, Response, Resolution and Reparability

Several versions of this Master Planning Procedure are provided which are adapted for;

- General Industrial Enterprise Planning
- Planning of Enterprise Control and Information Systems and Upgrades
- Planning of Engineering and Construction Enterprises

I hope you find this document useful and informative.

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Overview of Planning Process

The master planning process is comprised of 17 clearly defined steps. Each step produces a set of deliverables (e.g. reports or drawings) which are reviewed and approved by management before proceeding to the next step.

This document provides a "Guide" for each step in the Master Planning Process. For additional detail, see the "Handbook on Master Planning" on the PERA website (www.pera.net). The numbers in the above diagram refer to Chapters in the Handbook.

The following diagram indicates the information which should be assembled, reference materials, and a time base for assembling and analyzing the information.
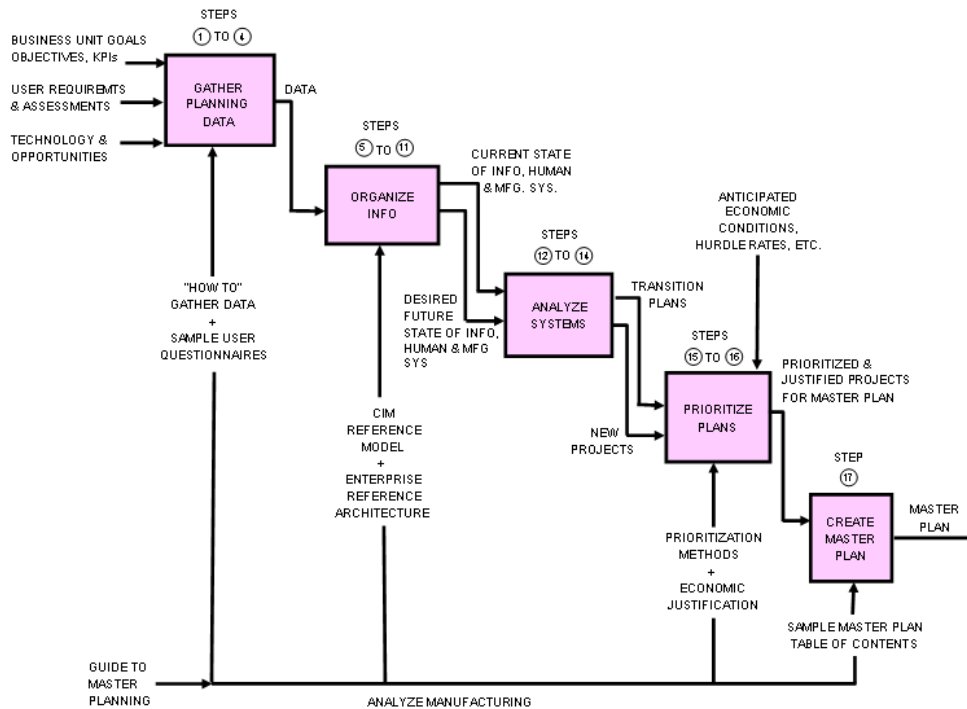
Step-by-Step Discussion

Step 1 -Define Enterprise Business Entity

In this first step, the **Enterprise Entities** involved are documented (e.g. the organizational and geographic entities where business will be done).

Then the Enterprise's business leaders are interviewed. For new enterprises this may be the project's Program Directors and/or the Corporate Sponsor if these are identified at that point in time. If the Enterprise is existing, it may be the CEO, CIO and Directors of Production, Finance, HR and Sales/Marketing.

Next the **Enterprise Mission** (Executive-level statement of what the Enterprise is to accomplish) is documented with assistance of senior management. A **Vision** (a forward-looking description of what the company will be), and a set of **Values** (such as company priorities and human values) also documented or, if necessary, developed.

Finally, the **As-Is and To-Be status** of facilities, people and systems are assessed.

After senior management, interviews will be continued with key Enterprise staff. For existing enterprises it is particularly important to include those with actual operations responsibility. A series of interview forms are provided (see the Engineering Workbench at www.engwb.com) which address key aspects of the Enterprise (including facilities, people and systems). It may also be necessary to tour existing facilities, or study available technology (possibly including site visits). There may also be a value to "Town Hall" meetings, computerized surveys and other mechanisms for getting input on the As-Is and To-Be facilities, systems, and people organization.

Definition of As-Is and To-Be Control and Information systems has been greatly facilitated by new standards such as ISA-95, ISA-88, SIS/SIL, ISA-99, and MESA standards which standardize enterprise systems functions, nomenclature, architectures, and interfaces. Some of the major areas covered by these user input forms include the following. The source of the standard definitions for major systems, subsystems, sub-subsystems, etc. is also indicated

System or Subsystem	ISA-95	MESA	ISA-99	SIS/SIL
Order Entry	1.0			
Production Scheduling	2.0	2.		
Production Control	3.0			
Process Support Engineering	3.1	8.		
Operations Control	3.2	3.	1.	1.
Operations Planning	3.3	1.		
Material and Energy Control	4.0	10.		
Product Procurement	5.0			
Quality Assurance & Management	6.0	7.		
Product Inventory Control	7.0			
Product Cost Accounting	8.0	11.		
Product Shipping Administration	9.0			
Maintenance Management	10.0	9.		1.

System or Subsystem	ISA-95	MESA	ISA-99	SIS/SIL
Document Control		4.		
Data Collection / Acquisition		5.		
Labor Management		6.		
Process & Human Safety				1.
Control & Information Systems Security			1.	

All of the above systems have standardized Functions, data elements, and data interface flows. Typically, the Functions and Information Flows of one level deeper in the hierarchy are included in the questionnaire. Thus the survey is composed of approximately 100 Functions (note the number of functions that are necessary are strongly influenced by the industry involved, whether operations are continuous, batch, semi-batch, manufacture to inventory, manufacture to order, or custom-engineered to order. See Engineering Workbench for Industry Type Codes, and lists of Opportunities by Industry.

Forms may be completed in hard copy, or as computerized surveys (which are easier to analyze). Survey forms will be completed by people who have "Roles" which correspond to specific Functions and Sub-Functions (see professional "Roles" listing and assignment of Roles to organizational "Positions" on Engineering Workbench. Each form will contain either "assessments" for existing systems, or "anticipated value" for proposed new systems. See Engineering Workbench for example surveys.

## Step 2 –Define Objectives, Strategies, Goals, Business Plan & KPIs

After approval of the information developed in the previous step, the High Level **Objectives**, and the **Strategies** to achieve those objectives, as well as **Goals** to be met along the way are identified.

The **Business Plan** for each Enterprise Entity is then reviewed, and a number of **Key Performance Indicators** (KPIs) by which performance will be measured are selected and documented.   These KPIs must be expressed in terms that are quantifiable, and will be used as ongoing measures of the success of the Enterprise. In many cases these KPIs form the basis for rewarding management at multiple levels, and may even be reported in the company's annual report.

Step 3 - Define "To–Be" Policies

After approval of the information developed in the previous step, the future **Policies** of the Enterprise are established. Policies are deliberate decisions made by management which must be followed by all Enterprise Entities. These Policies will be applied without further evaluation. As such, they focus the study and avoid evaluation of alternatives that are not acceptable in principle.

Policies are typically implemented by area, such as Manufacturing, Sales/Marketing, IT, Business Processes, Engineering Policies, and others. A single set of Business Objective and Goals may result in several sets of Policies as shown below.
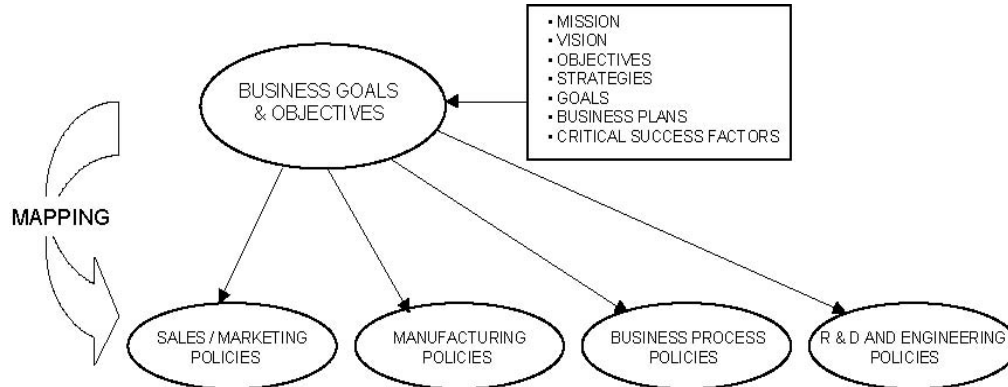

Step 4 - Define & Document Significant Opportunities

Evaluation and selection of "To-Be" Opportunities begins with a set of Opportunities drawn from successful implementations in the same industry. This list (typically 30 to 50 Opportunities) is reviewed in context of the Objectives, Strategies, Goals, CSF's and Policies agreed for this enterprise. Using these criteria, the list is winnowed to the set which best serves these criteria, and which are practical to implement with the resources and time available (typically 10 to 20 Opportunities). A more detailed evaluation of the cost / benefits for each of the Opportunities identified is done later in Step 15 when additional "As-Is" and "To-Be" information is available.

Each Opportunity will relate to one or more of the 3 PERA components (Facilities, People and Systems) and these will first be documented as part of each Opportunity, and then combined into an overall view of Enterprise Facilities, People and Systems.

As part of documenting the overview of Enterprise Facilities, People and Systems, a "To-Be" Enterprise Architecture Diagram is developed which attempts to convey the relationship of the Physical Facilities, Control and Information Systems, and the Human interfaces in a single drawing. This is a unique document, since the best way to best convey this is different for a pipeline or a refinery, a manufacturing plant or a police/fire emergency response center. The following example Enterprise Architecture Diagram is for a construction wallboard manufacturer. As was done for Opportunities, a library of such diagrams was compiled by industry, and is maintained on the Engineering Workbench.

ENTERPRISE ARCHITECTURE DIAGRAM
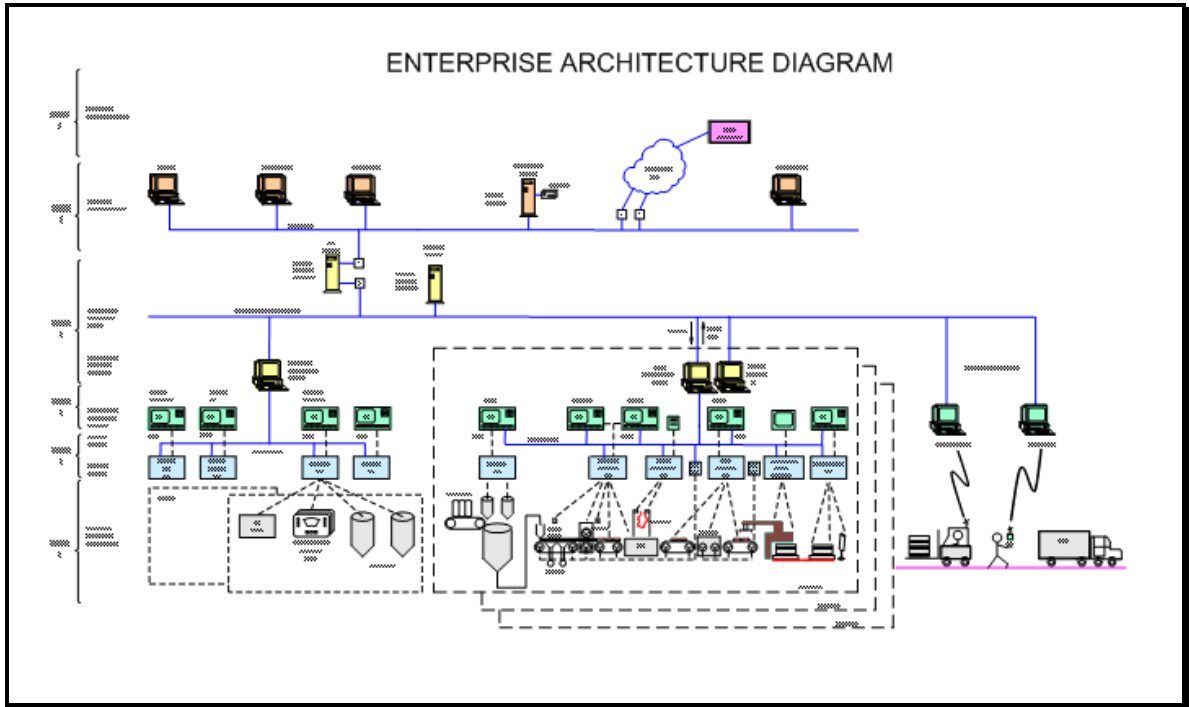
Source: Enterprise Consultants International

The end of Step 4 marks the completion of the first "pass" as general user requirements and assessments of existing facilities, systems and human factors are defined together. With the beginning of the second "pass", more detail is compiled in each area, and it is necessary to separately document "To-Be" and "As-Is" facilities, systems and human factors as shown below.

ENTERPRISE MASTER PLANNING
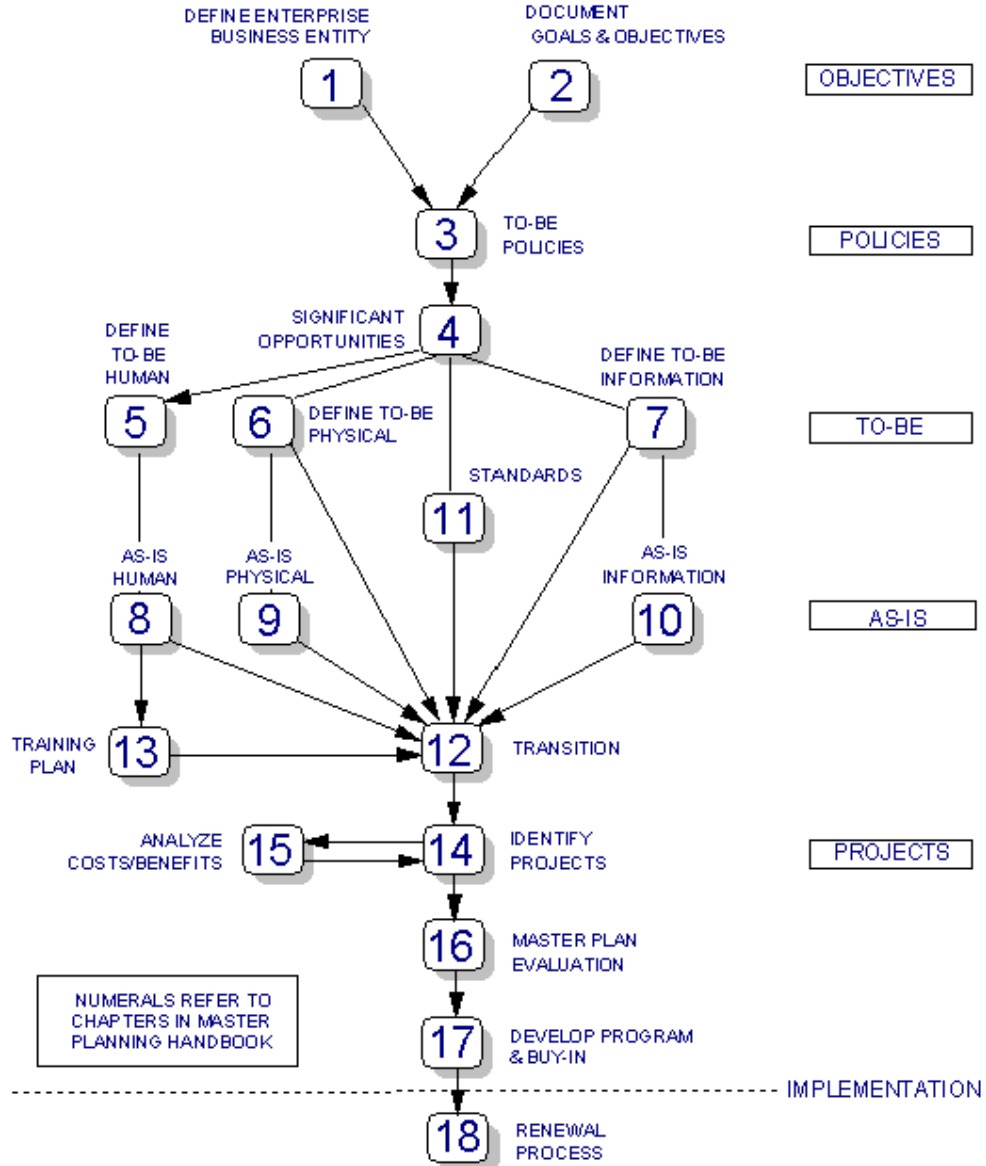
It should be noted, that unlike the previous pass, where "As-Is" facilities, systems and human aspects are examined first, and "To-Be" second, in this first pass, the To-Be aspects are defined first, and the As-Is are second. This is appropriate, as many of the "As-Is" aspects may not be carried forward to the To-Be. In this case it would be wasteful to spend time assessing those aspects in more detail, since they are being eliminated. Of course, identifying which of the As-Is aspects will be developed further can only be done once the next pass definition of the "To-Be aspects is documented.

Step 5 -Define "To-Be" Human and Organizational Architecture

The "To-Be" Human Architecture will typically include conceptual level organization charts for each phase of the Enterprise (beginning with Conceptual Engineering, and progressing through each PERA enterprise phase to Operations). These organization charts are linked to provide an "Organizational Architecture.

As part of this process, a list of "Roles" is identified (see Engineering Workbench for example Roles for different industries). Roles are then assigned to "positions" in each Organization Chart for each phase of the enterprise.

Example Process Plant Organization Chart
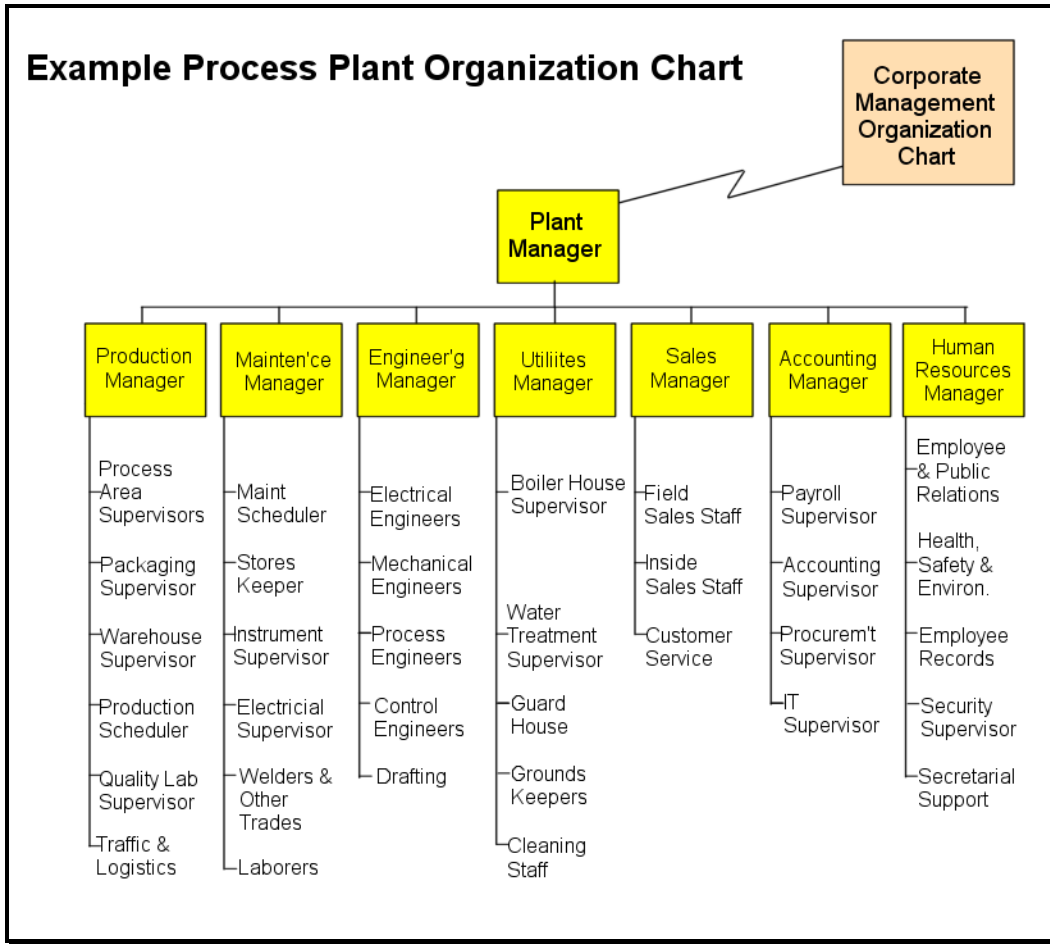
Step 6 -Define "To-Be" Control & Information Systems Architecture

At this stage, overview diagrams of the Control and Information Systems are prepared, including;

- A **Physical Network Architecture Diagram** showing the Prinicpal LANs, WANs, Servers and groups of end user computers.
- A **Logical Systems Architecture Diagram** showing Major Systems and information flows between systems.

See the Engineering Workbench for documentation standards for these drawings.

Physical Network Architecture Diagram
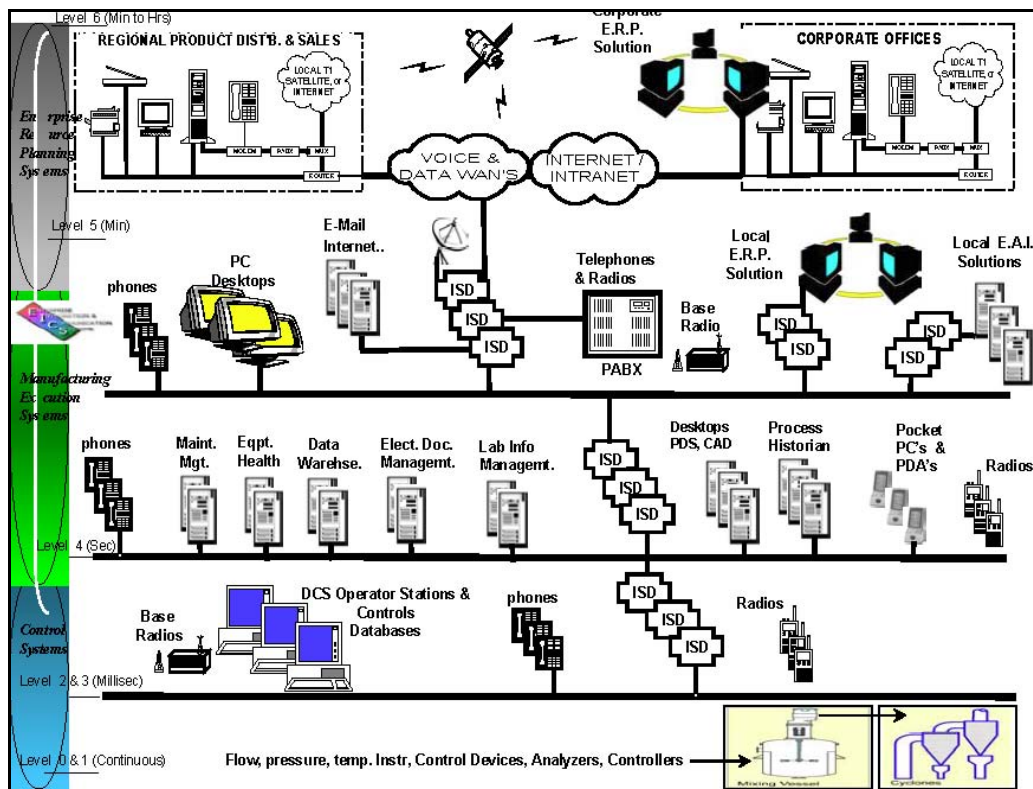
Source: Fluor Daniel EICS Group

The Physical Network Architecture Diagram shows the computers, networks, routers, and other devices and how they are connected. By convention, the networks are shown as horizontal busses and equipment is connected to the networks at the appropriate "Level" in the physical architecture. This Architecture Level is determined during the design according to the "4Rs" (Response, Resolution, Reliability, and Reparability) that is required of that equipment. Networks at different levels are carefully isolated (e.g. with a router or firewall) to ensure that the 4R performance of each network can be assured.

Logical Systems Architecture Diagram
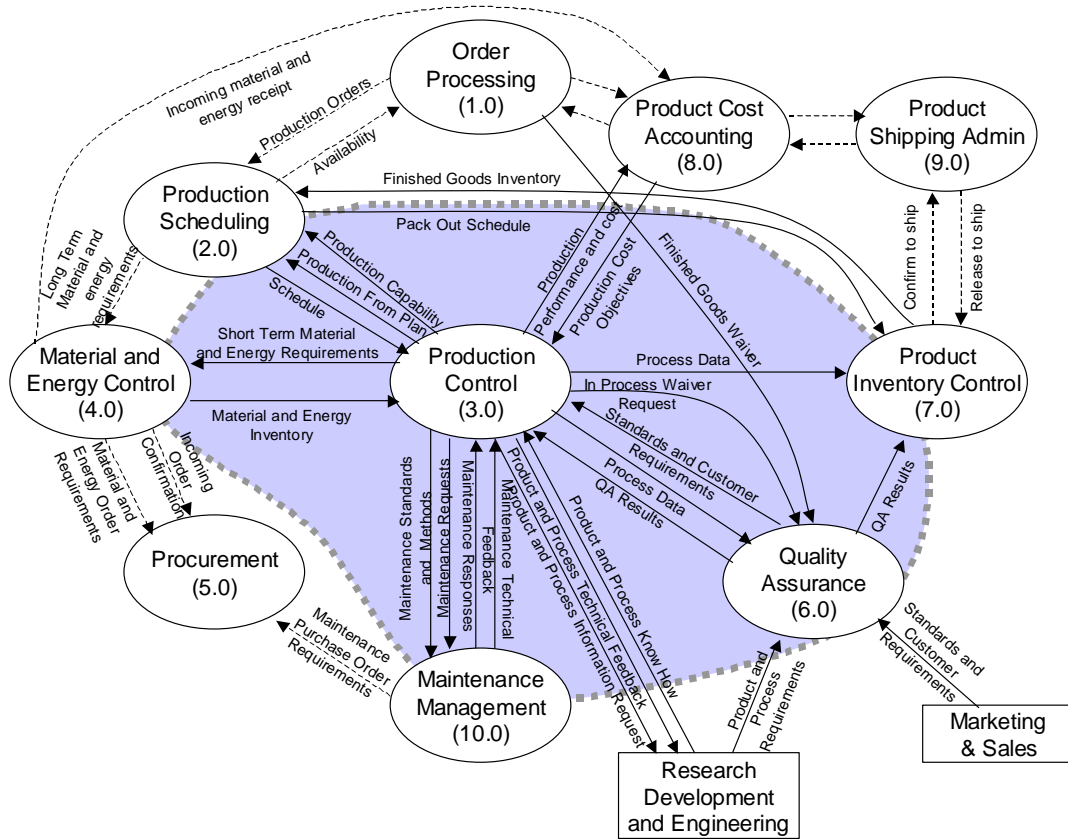
Source: Purdue Reference Model (used in ISA-95)

On the highest level, the ISA-95 Logical System Model identifies 12 main enterprise functions between which information is exchanged (see the arrows above). The colored area represents the manufacturing area (MES).

By splitting each function into sub-functions (with associated information flows) and sub-sub functions, all activities within the enterprise can be described. According to the opportunity being considered, more or less detail may be required at this Step.

For more in-depth analysis of high value opportunities, additional Business Process Modeling (BPM) may be done using Work Process Modeling tools such as ARIS, NetWeaver, etc. These tools can be used to clarify the functions and information flows for major systems, particularly as many now include the ISA-95 Reference Model as part of their core packages.

Step 7 -Define "To-Be" Facilities

The "To-Be" Enterprise Facilities describe the Physical Production Facilities required to deliver the products and services produced by the Enterprise. Depending on the industry involved, these facilities may be documented with Process Flow Diagrams, Mechanical Flow Diagrams, Facility Layouts, Block Diagrams, and other standardized documents.

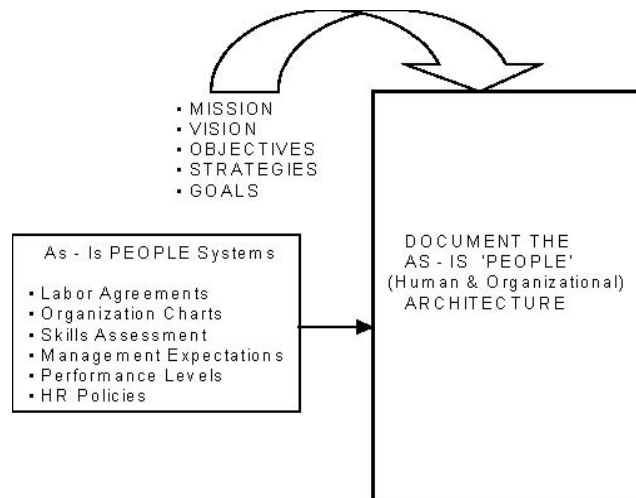## Step 8 -Define 'As-Is' Human & Organizational Architecture

For an existing organization, the organization charts and position descriptions (documented in terms of Roles) are assembled to establish a "baseline" for the Human Organization. For new organizations, the Project Organization will be transitioned to form the Operating Phase Organization. For existing organizations, the current Operations Organization will be transitioned to the new Operations Organization.

From this baseline, analysis of staff and training costs required to implement To-Be systems, benefits, and other factors can be estimated. The transition can then be defined later in Step No 12 (Transition) with greater accuracy. The diagram below illustrates some of the material which may be reviewed or inputs which may be required.

Step 9 -Define "As-Is" Control & Information Systems Architecture

Almost all Industrial Enterprises and their Control and Information systems are under more or less continuous change. What is necessary therefore, is a "snapshot" of the existing systems. Ideally these should be converted to the same format as the To-Be Systems, however this may not always be practical.

It is also desirable to assess the effectiveness of the existing systems in serving the Objectives of the Enterprise, with particular care to document perceived shortcomings.

- MISSION
- VISION
- OBJECTIVES
- STRATEGIES
- GOALS

As - Is PEOPLE Systems

- Labor Agreements
- Organization Charts
- Skills Assessment
- Management Expectations
- Performance Levels
- HR Policies

DOCUMENT THE
AS - IS 'PEOPLE'
(Human & Organizational)
ARCHITECTURE

User Survey Forms including most of the common Enterprise Systems, MES, and Control Systems is provided on the Engineering Workbench. This assessment will later be compared (in Step 12, Transition Plan) with the "To-Be" state, and will be used to assess the benefits of the proposed To-Be Systems.

Step 10 -Define "AS-IS" Facility Architecture

As in Step 9, what is desired is an "AS-IS" snapshot of the existing Enterprise Facilities and their effectiveness in serving the objectives of the Enterprise. To the extent feasible, this should be documented in a manner which is consistent with the "To-Be" Facilities to facilitate comparison and assessment of the Transition Plan

TYPICAL REFINERY BLOCK DIAGRAM
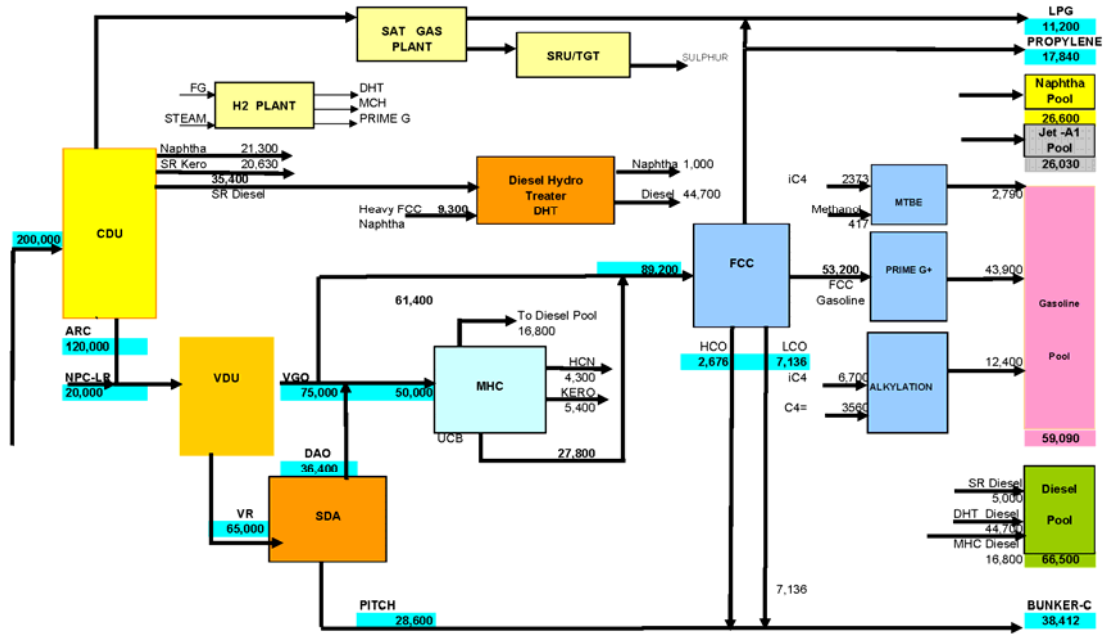
REFINERY PROCESS CONFIGURATION AND MATERIAL BALANCE

Step 11 - Standards Selection

Selection of Standards is a pivotal step in any engineering process. In many cases, standards for Physical Facilities vary by country, and many even have the force of law. Thus these standards will have a major impact on the design and documentation of Facilities, and should be identified at the earliest possible stage in the Enterprise planning process.

See the Engineering Workbench [Standards library](#) for descriptions of selected individual standards from groups such as:

- ANSI - American National Standards Institute
- API - American Petroleum Institute.
- ASME - American Society of Mechanical Engineers
- IEEE - Institute of Electrical and Electronic Engineers
- ISO - International Standards Organization
- BS - British Standards Institute
- DIN - German Institute for Standardization.
- EIA - Electronic Industries Alliance
- GOST - State standards of Russian Federation
- PIP - Process Industry Practices

In addition to the above general standards (which include Control and Information Systems), a large number of special Control and Enterprise Integration standards are available from groups such as:

- CEN
- Foundation Fieldbus Industrial fieldbus standard.
- IEC - International Electrotechnical Commission
- IEEE - Institute of Electrical and Electronics Engineers
- ISA - Instrumentation Systems and Automation
- ITU - International Telecommunications Union.
- MESA – Manufacturing Execution Systems Association
- OPC - Open Process Control
- TIA/EIA -

Particularly important for Enterprise Integration projects are standards such as:

- ANSI / ISA 95 (IEC/ISO 62264-1) which deals with how to design open architectures that allow integration of Manufacturing Execution Systems with upper level Enterprise Resource Planning Systems and with lower level Production Control Systems.
  - o Part 1: Models and Terminology (July 2000)
  - o Part 2: Object Model Attributes (October 2001)
  - o Part 3: Models of Manufacturing Operations (Draft)
  - o Part 4: Object Models & Attributes of Manufacturing Operations Management
  - o Part 5: Business to Manufacturing Transactions

- ANSI /ISA 99 and IEC 62443 that describes how Control and MES networks are designed, implemented and maintained in a secure, consistent manner. ISA S99 provides guidance documents and standards for IT security for existing industrial control and automation Systems.
  - o Part 1 – defines terms and models used in automation security, and
  - o Part 2 – establishing Cyber Security Management Systems. IEC 62443 – mainly addresses technical aspects of system security architecture.

Step 12 -Document Transition Plan From "AS-IS" To "TO-BE" Architectures

The transition plan identifies the best path to resolve the gaps between the "As-Is" condition and the "To-Be" state. This will involve the following activities:

- Review the three "To-Be" architectures against the overall Enterprise Integration plan.
- Determine the steps needed to migrate "As-Is" Systems to the "To-Be" systems.
- Estimate the time and costs to accomplish this.

Step 13 -Training and Documentation Plans

Upgrading the technical capabilities, and skills needed to effectively use and maintain the To-Be" systems must be planned in parallel with the systems themselves. This includes developing the following:

- A list of required training programs, including conceptual content.
- Estimate of needed resources in space, equipment, personnel and capital.
- A conceptual level 'Skill Development' matrix relating the personnel and training programs.
- An overall Training schedule

Step 14 –Document Proposed Projects

We now combine the Opportunities developed in Step 4 (and their resulting "To-Be" architectures of Steps 5 to 7) with the Transition Plan defined in Step 12. The "To-Be" opportunities and the Transition from "As-Is" systems are organized into "Projects" so that the work can be planned, developed and implemented most efficiently. Where possible, projects are organized into modular groupings where the interfaces are minimized in order to improve project execution effectiveness and reduce interfaces.

The identification of the Projects is an iterative process with Step 15 (Analyze Costs, Benefits and Risks).

Step 15 -Analyze Costs, Benefits and Risks

A cost/benefits analysis is prepared for each of the selected projects. The process is a cooperative iteration with Step 14 to agree the benefits, cost effectiveness and priority levels of the projects. The projects are also evaluated in accordance with Enterprise Objectives, Strategies, Goals, and Critical Success Factors to insure their implementation will support these criteria in an optimal way. Finally the technological impact and business risks for each project are assessed to further refine the priority for their implementation.

Step 16 –Finalize and Document Enterprise Systems Project Evaluations

The proposed projects and implementation plan are now reviewed by all Master Planning Team participants. As a group, they agree all of the opportunities and projects to be taken forward as well as all supporting documentation (e.g. cost and benefits assessments).

This review is also intended to improve the understandability of the work for communication to other internal and external organizations involved.

Step 17 -Author Enterprise Master Plan

Finally, the Enterprise Master Plan is documented and formally presented to the steering committee.

The completed Master Plan will typically contain the following items:

- Executive Summary
- Enterprise Business Entities
- Goals / Objectives, CSF's
- "To-Be" Policies
- Opportunities Conceptual Description
- "To-Be" Human and Organizational Systems
- "To-Be" Control & Information Systems
- "To-Be" Physical Facilities
- "As-Is" Human and Organizational Systems
- "As-Is" Control & Information Systems
- "As-Is" Physical Facilities
- Standards Selections
- Transition Plan
- Training Plan
- Project Conceptual Descriptions
- Approximate Costs & Benefits Summary
- Final Project Disposition
- Approvals for Projects

Subsequent Project Phases

With completion of the Master Plan and approval of proposed projects, a new more formal engineering design process begins. PERA provides an overall framework for all parts of the subsequent engineering and design process, as well as construction and eventual operation of the completed facilities. This relates to the PERA Master Planning process as follows:

The PERA Master Planning process directly corresponds to the Study Phase and Conceptual Engineering Phase of the Purdue Enterprise Reference Architecture (and most other Phased Engineering methods). After Master Planning, the next phase is Preliminary Engineering, where (among many other things) formal purchase specifications are prepared for bid by vendors or for custom programming by in-house or outsourced groups.
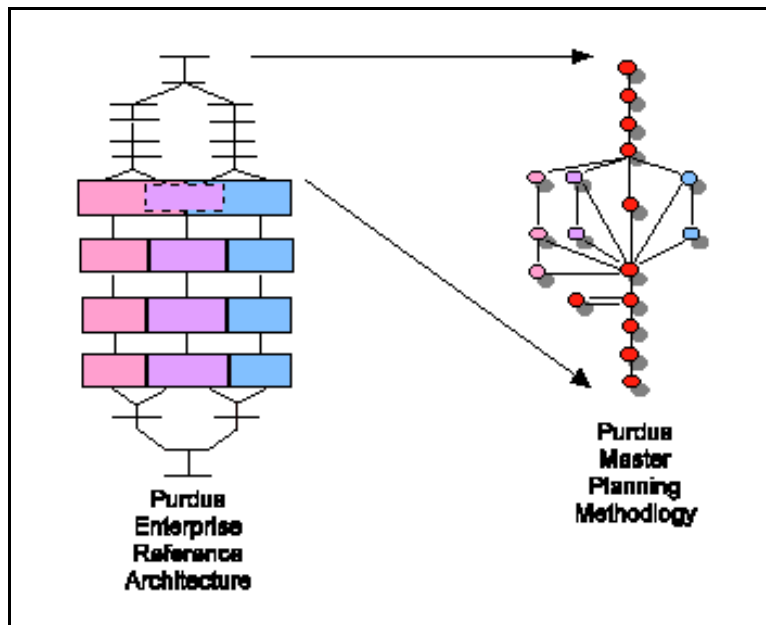
Client Approvals Process

In addition to the technical design of facilities, people, and systems there are parallel activities involving management and approvals by the owner (sometimes described as "Stage-Gate Processes), International Finance organizations (who have their own special documentation requirements), and Regulatory groups (whose documentation and approval processes vary widely by country). See Engineering Workbench for additional information on Stage Gate methodology.

Note:

Under the classical PERA definition, Facilities are associated with delivery of the Goods and Services that are provided by the Enterprise. Thus, Control Cabling, Computers, and Networks are part of the Control and Information Systems of an Enterprise; the logic being that in an enterprise with no automation, the Humans would directly interact with the Facilities (e.g. read gauges and directly manipulate valves), and the cabling, computers, etc., would be eliminated. The interface between Physical Facilities and Control and Information Systems is thus typically defined as "the first connection point above the plant sensor or valve actuator"

However, for some enterprises (e.g. a telecommunications company or an Internet web services company), the goods and services they provide are largely contained in these computers and networks. Also, for Enterprise Integration Master Plans the plan is largely focused on the Control and Information Systems, and on the Human components of the Enterprise, with little impact on the Physical Facilities which deliver goods and services. In both of the above cases, it has been the practice to define the Physical Networks and computers as part of the Enterprise Facilities. In practice, this means that the Physical Network Architecture Diagram (and associated documentation) is included in the Physical Facilities component of the Enterprise. In this case, the interface between the Physical Facilities and the Control and Information Systems is defined as "where Logical Systems and Networks interface with Physical Networks and Systems.

For a description of a Master Planning process for "Information Services" or Enterprise Integration projects see "PERA Master Planning Process – Enterprise Integration".

Either definition may be used, but once made for a given Enterprise, it should be used consistently.