Systems Engineering Influence Throughout the CMMI

Tim Kasse

Kasse Initiatives LLC

+1 – 972 - 987 - 7706 USA

+49 (0) 7721 - 407 - 851 Europe

+65 6430 6769 Singapore

Welcome

WelKom

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Agenda

- Engineering Systems Think
- What is Systems Engineering?
- Systems Engineering and Systems Management Overview
- Systems Engineering Capability Model EIA – 731
- Processes for Engineering a System EIA – 632
- IEEE Standard for Application and Management of the Systems Engineering Process IEEE 1220
- Systems Lifecycle Processes

Engineering Systems Think

Laws of Engineering Systems Thinking

- Systems Thinking is a discipline for seeing the whole
- In all of the project's phases/stages, and along the system's life, the systems engineer has to take into account:
  - The customer's organization vision, goals, and tasks
  - The customer's requirements and preferences
  - The problem to be solved by the system and the customer's needs
- The whole has to be seen as well as the interaction between the system's elements
  - Iterative or recursive thinking must replace the traditional linear thinking

What is Systems Engineering?

Systems Engineering Definitions

- Systems Engineering is the application of scientific and engineering efforts to transform an operational need into a description of system performance parameters and a system configuration through an iterative process of definition, synthesis, analysis, design, test, and evaluation
- Systems Engineering is an interdisciplinary approach that encompasses the scientific and engineering efforts related to the development, manufacturing, verification, deployment, operations, support, and disposal of systems products and processes

Systems Management

- Systems Management and integration issues are of major importance in determining the effectiveness, efficiency, and overall functionality of systems design
- To achieve a high measure of functionality, it must be possible for a system (product or service) to be efficiently and effectively:
  - Produced
  - Used
  - Maintained
  - Retrofitted
  - Modified

Systems Engineering Capability Model EIA - 731

EIA – 731 Standard Scope

- EIA – 731 was developed to support the development and improvement of systems engineering capability
  - Includes all activities that associate with or enable systems engineering
  - Focuses on an inter-disciplinary approach to enable the realization of a successful system
  - **Not limited to what a Systems Engineering organization or Systems Engineers do**
  - Interaction of many people, processes, and organizations resulting in the accomplishment of the required activities

EIA – 731 Standard Scope - 2

- EIA – 731 applies to programs and organizations doing systems engineering
  - Small or large
  - Simple or complex
  - Software intensive or not
  - Precedented or unprecedented
  - Contains hardware, software, personnel, facilities, data, material, services, or techniques
  - Engineering of a new system or the reengineering of a legacy system

EIA – 731 Standard Scope - 3

- EIA – 731 is intended to provide complete coverage for EIA – 632, Processes for Engineering a System
- EIA – 731 is intended to be consistent with EIA – 632 and IEEE 1220, Standard for Application and Management of the Systems Engineering Process

EIA - 731 Model Architecture

- The components of the model are:
  - **Categories** – A category is a natural grouping of Focus Areas.
    - Technical, Management, and Environment
  - **Focus Areas** – A Focus Area is a set of related unique practices that address some aspect of Systems Engineering
  - **Themes** – A Theme is a subdivision of a Focus Area that defines a related set of Specific Practices
  - **Specific Practices** – An activity that is essential to accomplishing the purpose of a Focus Area or that helps accomplish the purpose of the Focus Area more effectively or efficiently

EIA - 731 Model Architecture - 2

- **Generic Practices** – A Generic Practice is an activity that, when applied to the Specific Practices of a Focus Area, enhances the capability to perform those practices.
  - Generic Practices are applicable to any Focus Area
- **Generic Attributes** – A Generic Attribute is an assessment of the effectiveness of the applied process and of the value of the products of the process.
  - Generic Attributes are applicable to any Focus Area

Levels of Capability

- The EIA - 731 defines six levels of capability which corresponds to the Continuous Representation of the CMMI
- The six capability levels are:
  - Initial – Incomplete (CMMI)
  - Performed – Performed (CMMI)
  - Managed – Managed (CMMI)
  - Defined – Defined (CMMI)
  - Measured - Quantitatively Managed (CMMI)
  - Optimizing – Optimizing (CMMI)

Generic Practices

- The Generic Practices in the SE CMM are consistent with those found in the CMMI but not as extensive:
  - GP 2.1 SE CMM – Follow recorded and approved plans and processes, that were developed to meet program performance goals, in implementing the Focus Area

GP 2.1 EIA - 731

- Plan the performance of the process in accordance with the established program goals (such as profit, customer satisfaction, schedule delivery, and quality goals)
- Document the approach to performing the activities of the Focus Area (FA)
- Use the documented plans, standards, or procedures in implementing the process
- Assign responsibilities for developing the work products, and providing the services
- Allocate adequate resources including people, training, tools, budget and time for performing the activities of the Focus Area
- These activities are consistent with GP 2.2, GP 2.3 and GP 2.4 of the CMMI

GP 3.1 EIA - 731

- Standardize and record a well-defined FA process for the organization that is designed to meet specific business goals, and is based on experiences captured from previous programs
- A well-defined standard process or family of processes is characterized by:
  - Entrance criteria
  - Inputs
  - Standards and procedures
  - Verification mechanisms (Defect reviews)
  - Outputs
  - Completion criteria
  - Metrics
- Corresponds to SP1.1 in Organizational Process Definition of the CMMI

Focus Areas

- Systems Engineering Technical Category
  - Define Stakeholder and System Level Requirements (RD, TS)
  - Define Technical Solution (RD,TS)
  - Define Solution (TS)
  - Assess and Select (TS, DAR)
  - Integrate System (PI)
  - Verify System (VER)
  - Validate System (VAL)

Focus Areas - 2

- Systems Engineering Management Category
  - Plan and Organize (PP)
  - Monitor and Control (PMC, GP 2.8)
  - Integrate Disciplines (IPM)
  - Coordinate with Suppliers (SAM, ISM)
  - Manage Risk (RSKM)
  - Manage Data (PP – Data Management)
  - Manage Configurations (CM, GP 2.6)
  - Ensure Quality (PPQA, GP 2.9)

Focus Areas - 3

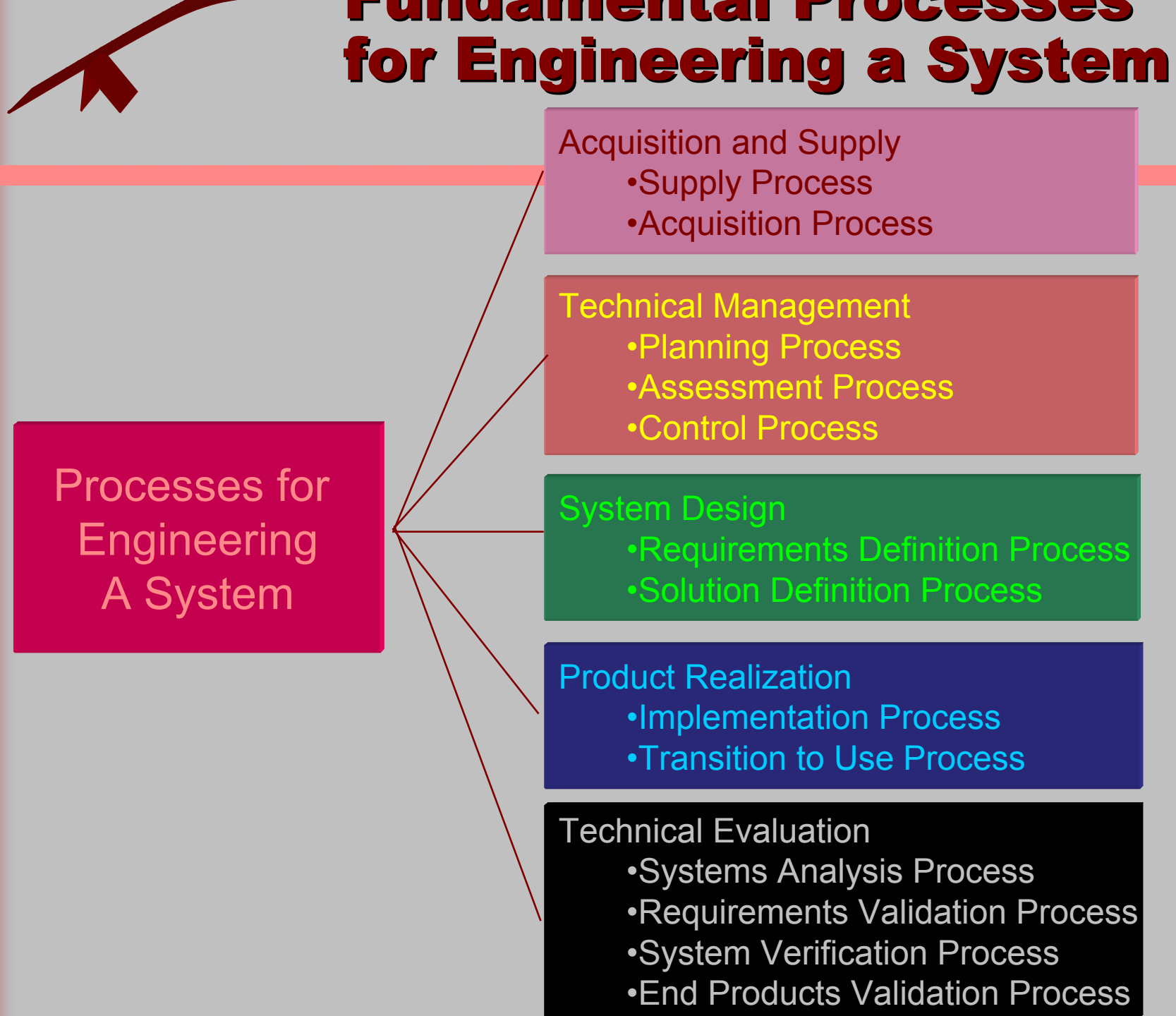
- Systems Engineering Environment Category
  - Define and Improve the Systems Engineering Process (OPF, OPD)
  - Manage Competency (OT)
  - Manage Technology (TS, ISM, GP 2.3, OID)
  - Manage Systems Engineering Support Environment (OPF, OPD, OEI)

Theme: Problem Refinement

- Develop a detailed operational concept of the interaction of the system, the user, and the environment, that satisfies the operational, support, maintenance and disposal needs
- Derive, from the system and other requirements, requirements that may be logically inferred and implied
- Identify key stakeholder requirements and constraints that have a strong influence on cost, schedule, functionality, risk or performance
- Identify and manage non-technical requirements concurrently with operational, functional, support, maintenance and disposal requirements
- Capture relationships between requirements for consideration during change management and requirements allocation

Processes for Engineering a System EIA - 632

Fundamental Processes for Engineering a System



Relationship of Processes for Engineering a System - 2

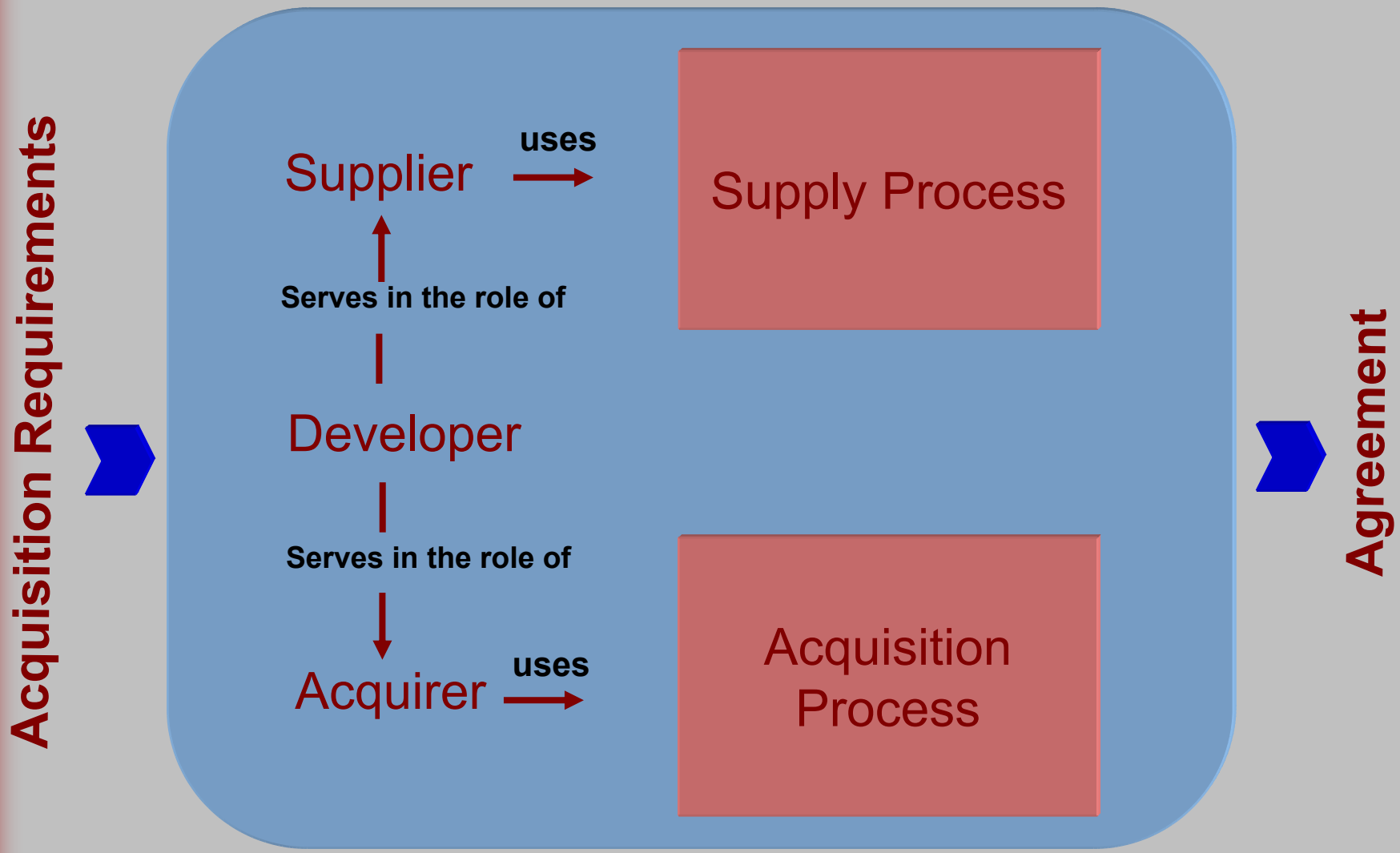
- ***The appropriate processes are applied recursively and iteratively to***:
  - Define the system products of the system hierarchy from the top down
  - Implement and transition the system products from the bottom up to the user or customer
- The requirements that are assigned to the proposed engineering processes are, in practice, implemented **concurrently** and are highly iterative

Acquisition and Supply

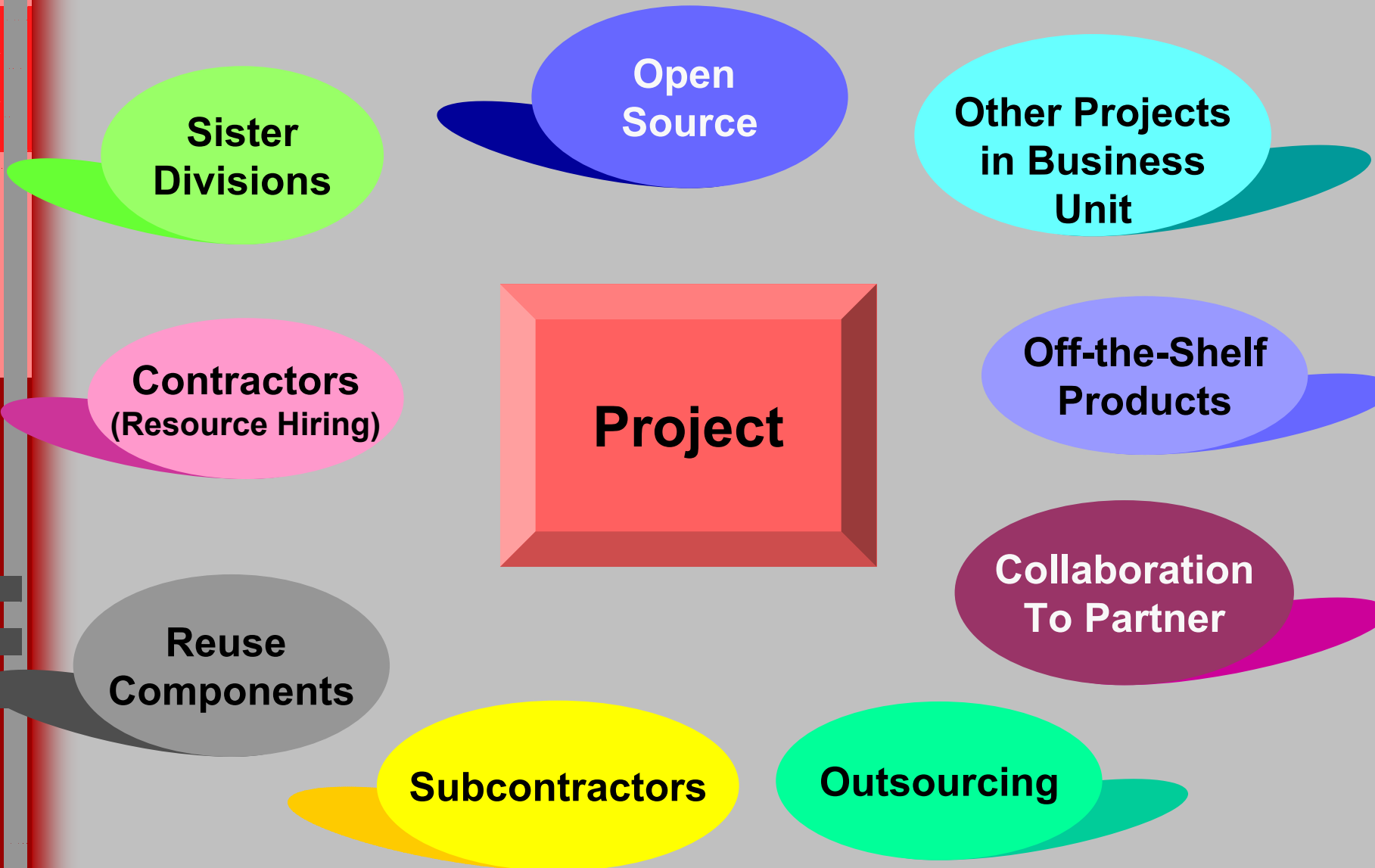
Acquisition and Supply

- The Acquisition and Supply Processes are used by a developer to arrive at an agreement with another party to accomplish specific work and to deliver required products
- The parties can be inside the developer's own enterprise (another project, functional organization, or project team) or can be in a different enterprise

Acquisition and Supply Process



Supplier Management Overview (CMMI)



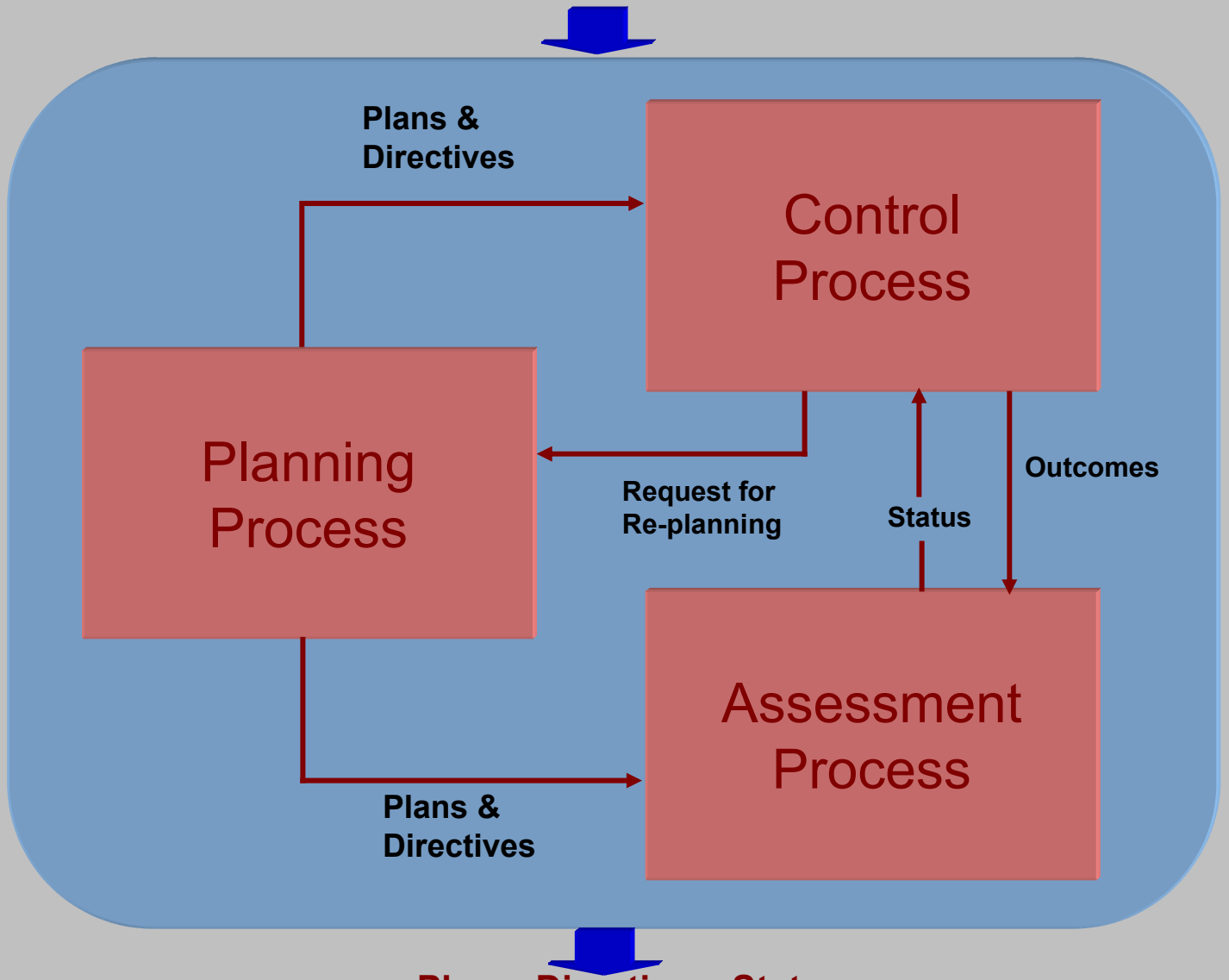
Technical Management

Technical Management

- The Technical Management Processes are to be used to plan, assess, and control the technical work efforts required to satisfy the established agreement.

Technical Management Process

Acquisition, Documents, Agreement, Outcomes, and Feedback



Planning Process

- This process is used to support enterprise and project decision making and to prepare all necessary plans that support and complement the project plan
  - Risk Management Plan
  - Technical Review Plan
  - Verification Plans
  - Validation Plans
  - Quality Plan
  - Configuration Management Plan
  - Measurement Plan

Assessment Process

- The Assessment Process is used to:
  - Determine progress of the technical effort against both plans and requirements
  - Review progress during technical reviews
  - Support control of the engineering of a system

Control Process

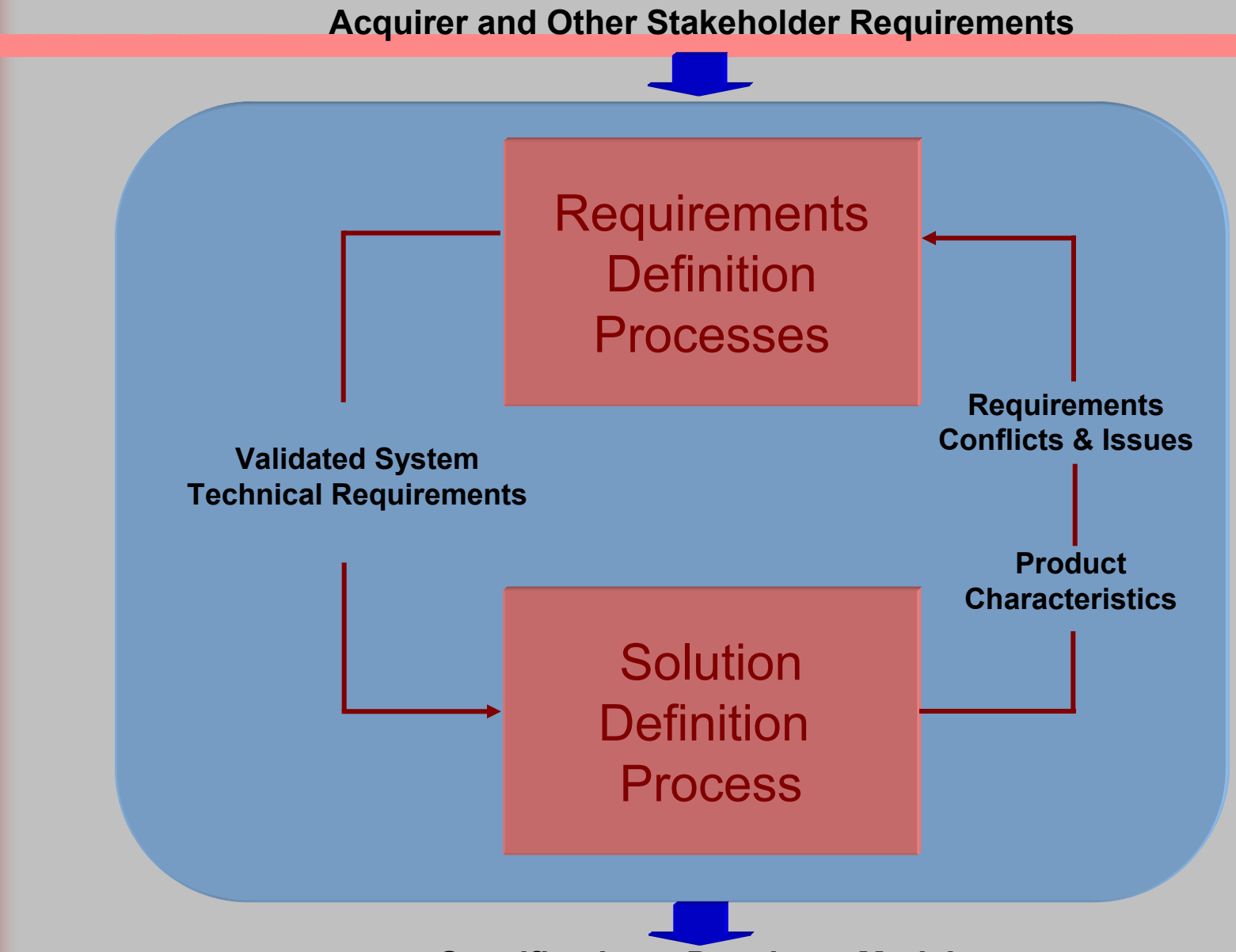
- The Control Process is used to:
  - Manage the conduct and outcomes of the Acquisition and Supply Processes, System Design Processes, Planning and Assessment Processes, Product Realization Processes, and Technical Evaluation Processes
  - Monitor variations from the plan and anomalies relative to the requirements
  - Ensure necessary communications

System Design

System Design Process

- The System Design Processes are used to convert agreed-upon requirements of the buyer into a set of realizable products that satisfy buyer and other stakeholder requirements
- Two processes are linked together
  - Requirements Definition
  - Solution Definition

System Design Process - 2

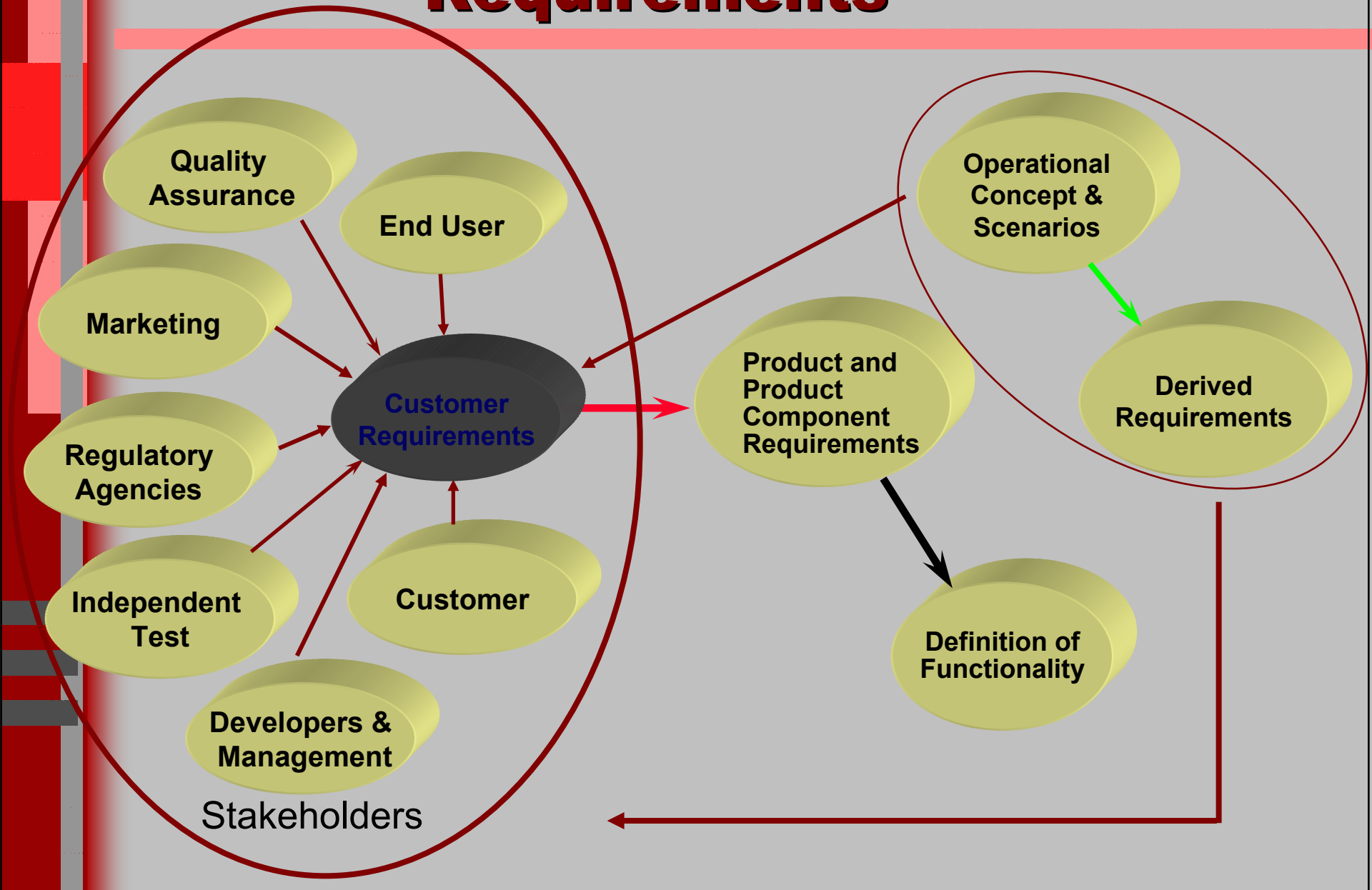


Requirements Definition Process

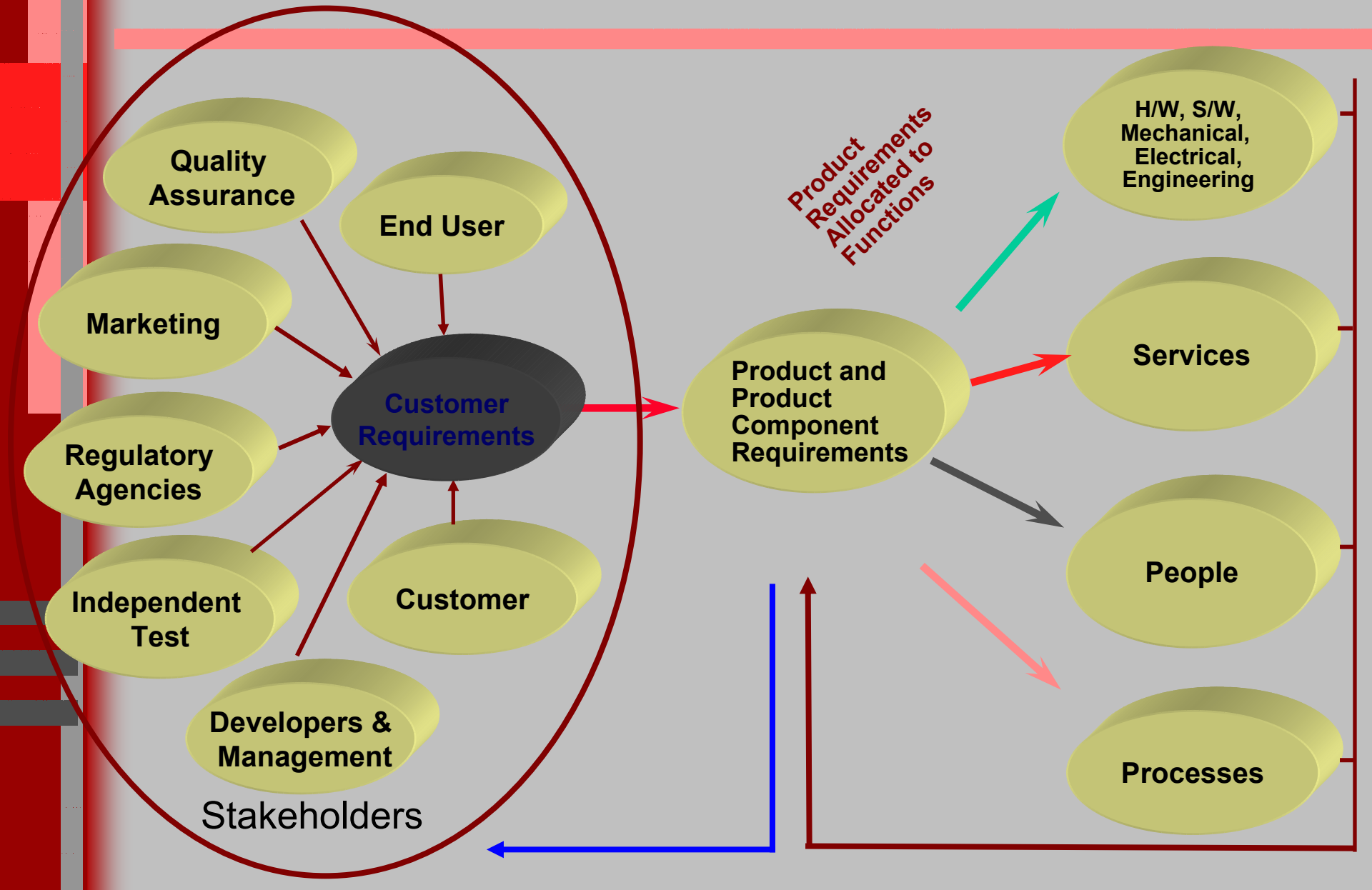
- System Technical Requirements
  - The developer shall define a validated set of system technical requirements. Tasks to consider include:
    - establishing required transformation rules, priorities, inputs, outputs, states, modes, and configurations
    - defining operational requirements and utilization environment
    - defining performance requirements
    - analyzing human factors effects
    - resolving conflicts between sets of buyer requirements and other stakeholders
    - preparing a set of system technical requirements

Requirements Development CMMI®

Customer, Product, and Product Component Requirements



Product Component Requirements - 2



Operational Concepts and Scenarios

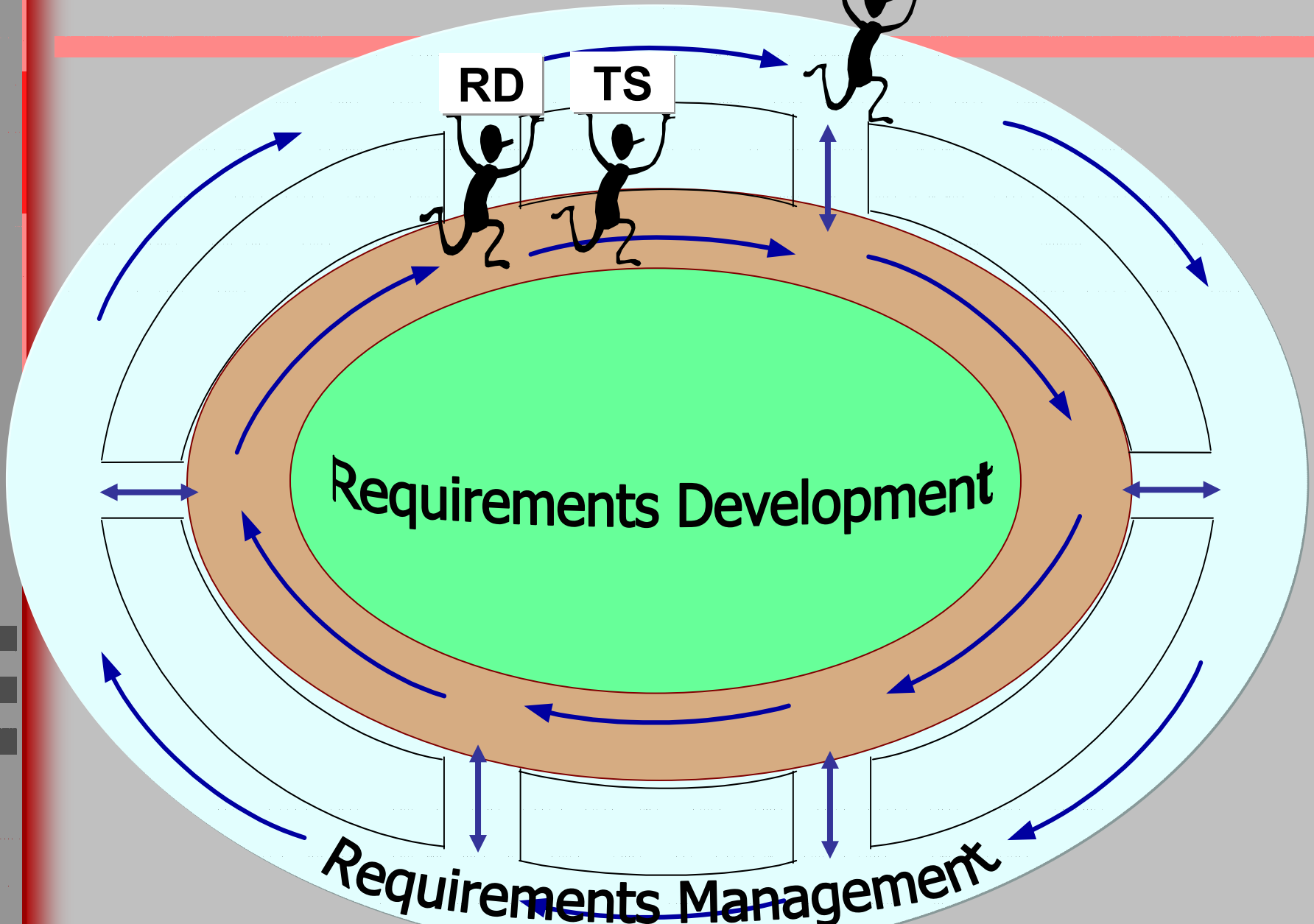
- Scenarios and Operational Concepts are developed, analyzed, and reviewed to refine existing requirements and discover new requirements, needs, and constraints
  - Scenarios are normally sequences of events that might occur in the use of the product
  - Operational concepts depend on both the design solution space and the scenarios
    - define the interaction of the product, the end user and the environment
    - define the operational, maintenance, support, and disposal needs

Product and Product Component Requirements

- Customer requirements are analyzed in conjunction with the development of the operational concept to derive a more detailed and precise set of requirements called "product and product component requirements"

Requirements Management

Requirements Development Partnership



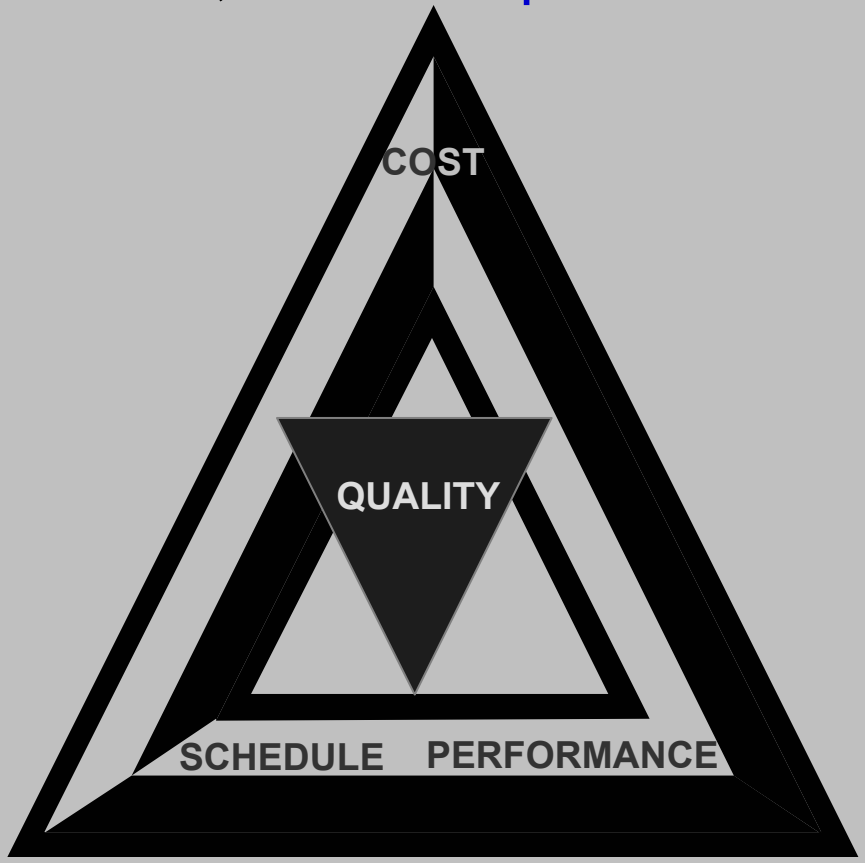
Solution Definition Process

- Logical Solution Representations
  - The developer shall define one or more validated sets of logical solution representations that conform with the technical requirements of the system
  - Tasks to consider include:
    - perform necessary tradeoff analyses
    - identify and define interfaces
    - assign performance requirements and constraints
    - identify and define derived technical requirements statements
    - select and implement one or more appropriate approaches

Alternative Solutions CMMI®

Develop Detailed Alternative Solutions and Selection Criteria

- Problem: Alternative solutions need to be identified and analyzed to enable the selection of a *life-cycle balanced solution* in terms of the quadruple constraint of cost, schedule, technical performance and quality



Develop Detailed Alternative Solutions and Selection Criteria - 2

- Solution: This may be accomplished through the allocation of the requirements to:
  - Software
  - Hardware
  - Electronics
  - Mechanics
  - Optics
  - Hydraulics
  - Manufacturing Processes
  - Services
  - People
- It may be accomplished through:
  - In house development
  - Purchase of Commercial-Off-The-Shelf products
  - Use of Suppliers
  - Use of Re-use components

Develop the Product or Product Component Design

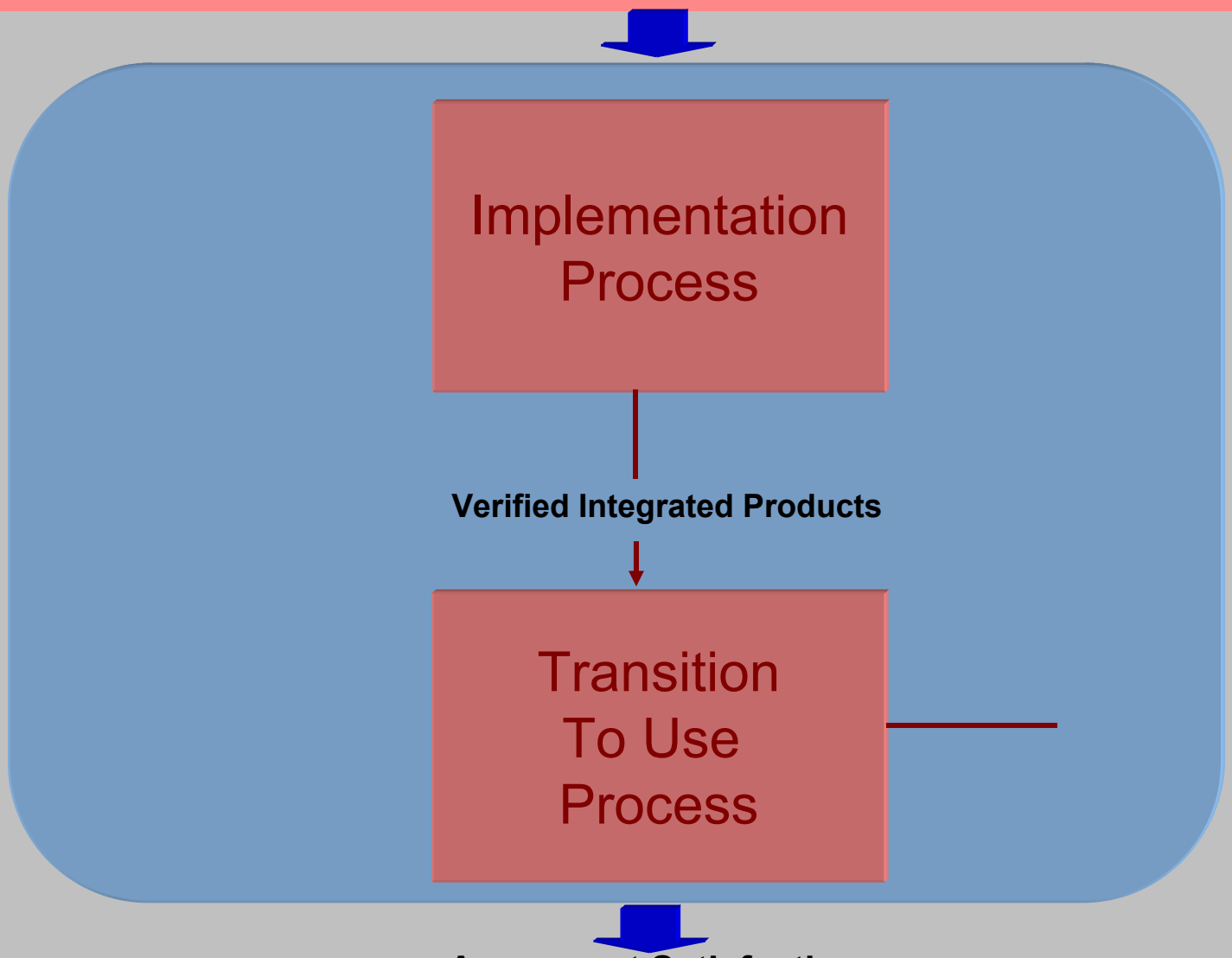
- Product or product component designs must provide the appropriate life-cycle content for:
  - Implementation
  - Modification
  - Reprocurement
  - Maintenance
  - Sustainment
  - Installation
- Design documentation provides a reference point to support the mutual understanding of the design by relevant stakeholders

Product Realization

Product Realization Process

- The Product Realization Processes are used to:
  - Convert the specified requirements and other design solution characterizations into either a verified end product or a set of end products in accordance with the agreement and other stakeholder requirements
  - Deliver these to designated operating, customer or storage sites
  - Install these at designated operating sites or into designated platforms
  - Provide interface service support

Product Realization Process - 2



Implementation Process

- Implementation
  - Tasks to consider include:
    - **receive the subsystem products** that make up the system's end products
    - validate the subsystem products received
    - assemble the validated subsystem or physically integrate the product components
    - verify each test article against its requirements
    - validate the verified end products

Transition to Use Process

- The Transition to Use Process results in products delivered:
  - To the appropriate destination
  - In the required condition for use by the buyer
  - For the appropriate training of installers, operators, and maintainers

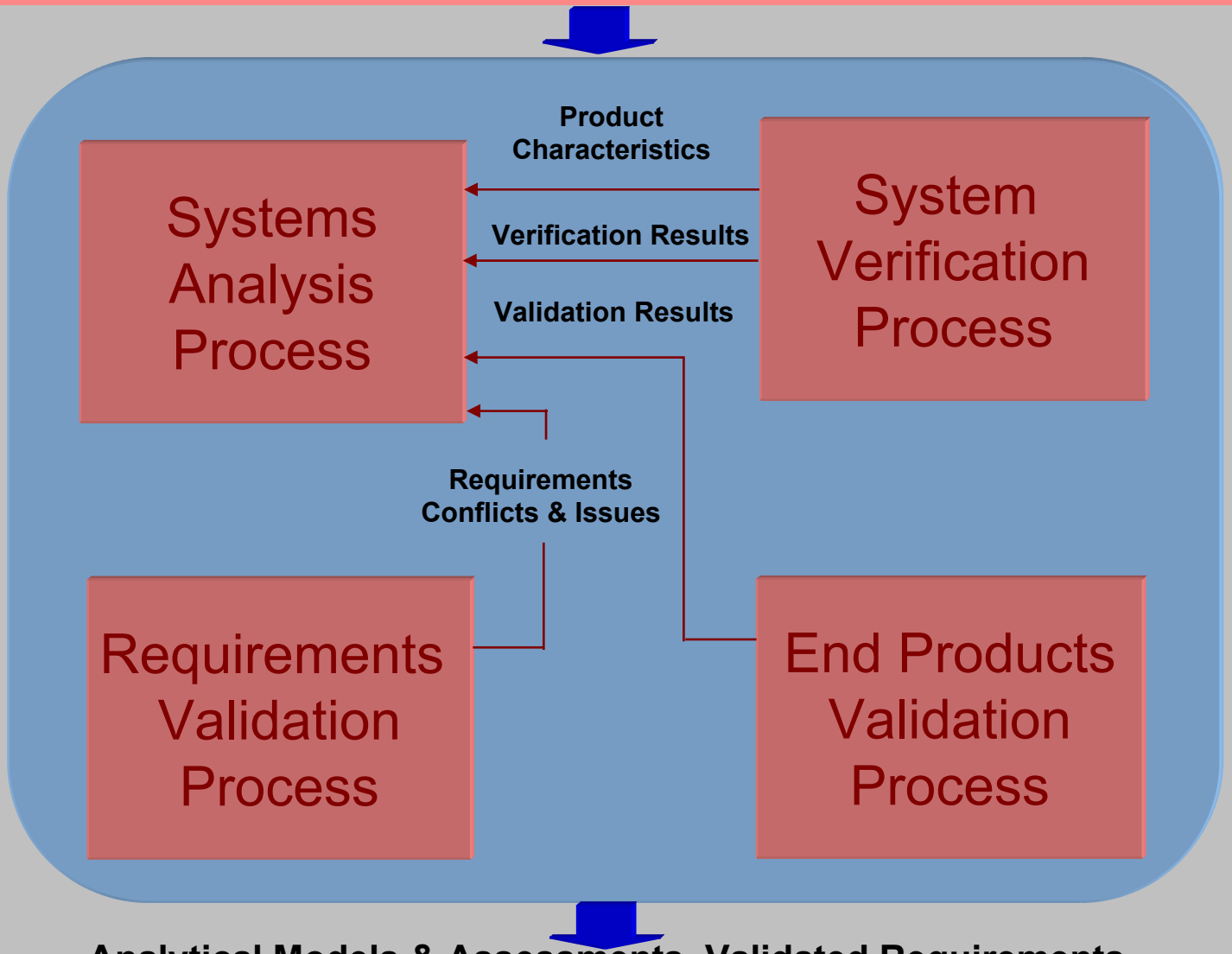
Technical Evaluation

Technical Evaluation

- The Technical Evaluation Processes are intended to be invoked by one of the other processes for engineering a system
  - Systems Analysis
  - Requirements Validation
  - System Validation
  - End Products Validation

Technical Evaluation Process

Analysis Requests, Requirements, Implemented Products



Analytical Models & Assessments, Validated Requirements Verified System Products, Validated End Products

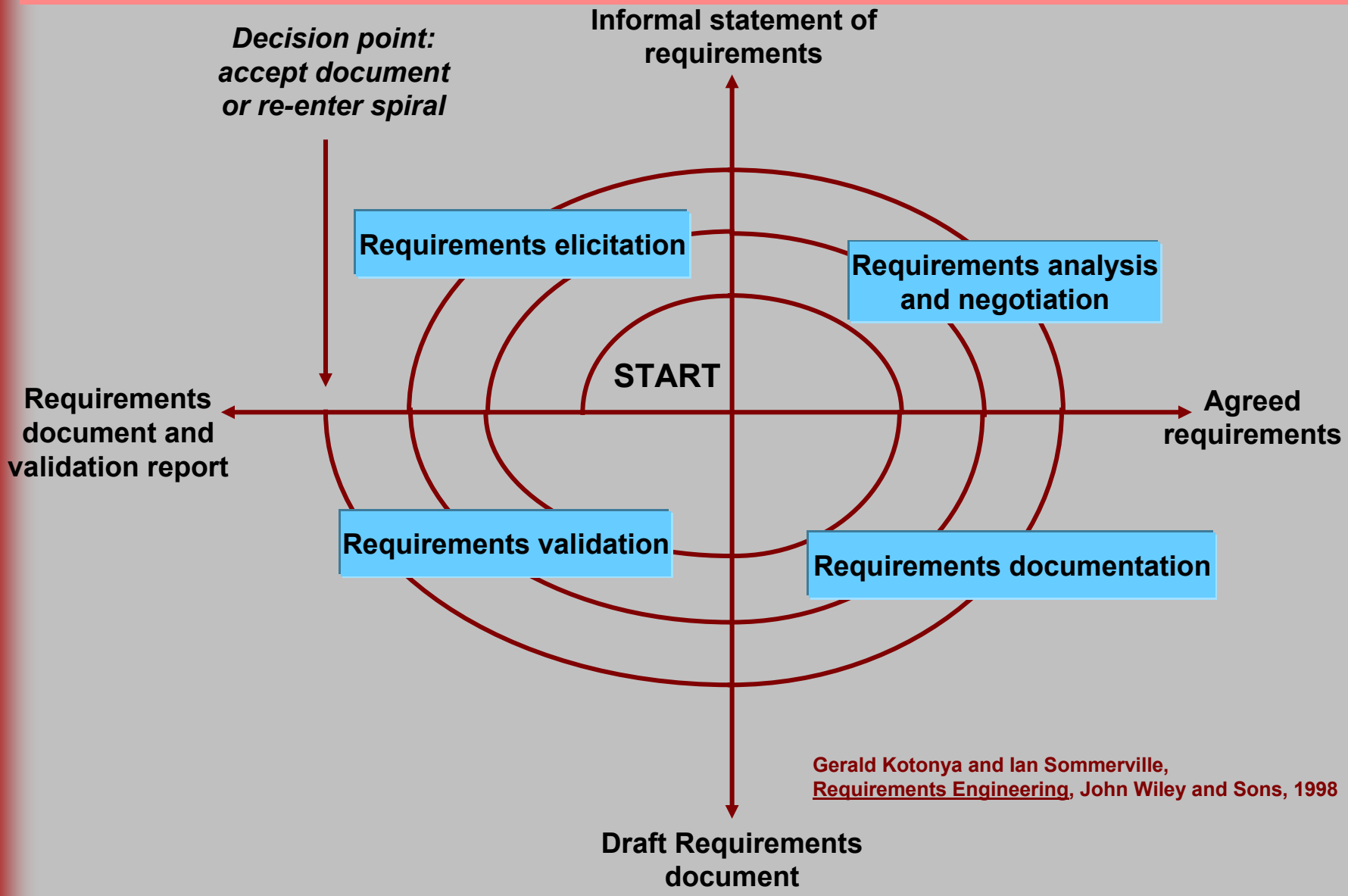
Systems Analysis Process

- The Systems Analysis Process is used to:
  - Provide a rigorous basis for technical decision making, resolution of requirements conflicts, and assessment of alternatives physical solutions
  - Determine progress in satisfying technical and derived technical requirements
  - Support risk management
  - Ensure that decisions are made only after evaluating the cost, schedule, performance, and risk effects on the engineering or reengineering of the system
  - Evaluate the effectiveness of each design solution
  - Define, calculate, and report the cost, schedule, performance, and risk effects of each functional, performance, and design alternative
  - Applicable quality factors such as maintainability, reliability, safety and security must not be degraded

Requirements Validation Process

- System Technical Requirements Validation
  - The developer shall ensure that the set of defined system technical requirements agrees with the validated buyer and other stakeholder requirements

Spiral Model of the Product Requirements Engineering Process (CMMI)



Gerald Kotonya and Ian Sommerville, Requirements Engineering, John Wiley and Sons, 1998

System Verification Process

- End Product Verification
  - The developer shall verify that an end product to be delivered to an acquirer conforms to its specified requirements
  - Tasks to consider include:
    - establishment and checkout of the environment in which the verification method and procedures will be implemented
    - verification of the end product to either show compliance or identify variances (untraceable requirements and constraints)

System Verification Process - 3

- Enabling Product Readiness
  - The developer shall determine readiness of enabling products for development, production test, deployment, installation, training, support / maintenance, and retirement or disposal

Confirm Readiness of Product Components for Integration (CMMI – PI)

- Confirm that each product component is compliant with its interface requirements
  - Ensure that the product components are delivered to the product integration environment in accordance with the planned product integration strategy
  - Verify the receipt of each product component
  - Verify the configuration status of the product component against the expected configuration
  - Verify the configuration status of the accompanying interface documentation against the expected configuration
  - Perform pre-checks of all physical interfaces before connecting product components together

End Products Validation Process

- End Products Validation
  - The developer shall ensure that an end product or an aggregation of end products, conforms to its validated buyer requirements
  - The types of end product validation include:
    - validation against validated buyer requirements in the anticipated usage environment with test conditions that span the expected range of actual operating conditions
    - certification tests against established certification requirements
    - **acceptance tests, using operational processes and personnel in an operational environment**

IEEE Standard for Application and Management of the Systems Engineering Process
IEEE 1220

IEEE 1220 Scope

- Defines the interdisciplinary tasks that are required throughout a system's lifecycle to transform customer needs, requirements, and constraints into a system solution (RD – SP 1.2)
- Specifies the requirements for the systems engineering process (SEP) and its application throughout the product lifecycle

IEEE 1220 Scope - 2

- The standard focuses on the engineering activities necessary to guide product development while ensuring that the product is properly designed to make it affordable to:
  - Produce
  - Own
  - Operate
  - Maintain
  - Dispose of without risk to health or the environment
- The standard describes how to manage a system from initial concept through development, operations and disposal

Basic System Building Blocks

- The basis building blocks of a system are:
  - System itself
  - Related products
  - Life-cycle processes required to support the products
  - Subsystems that make up the products

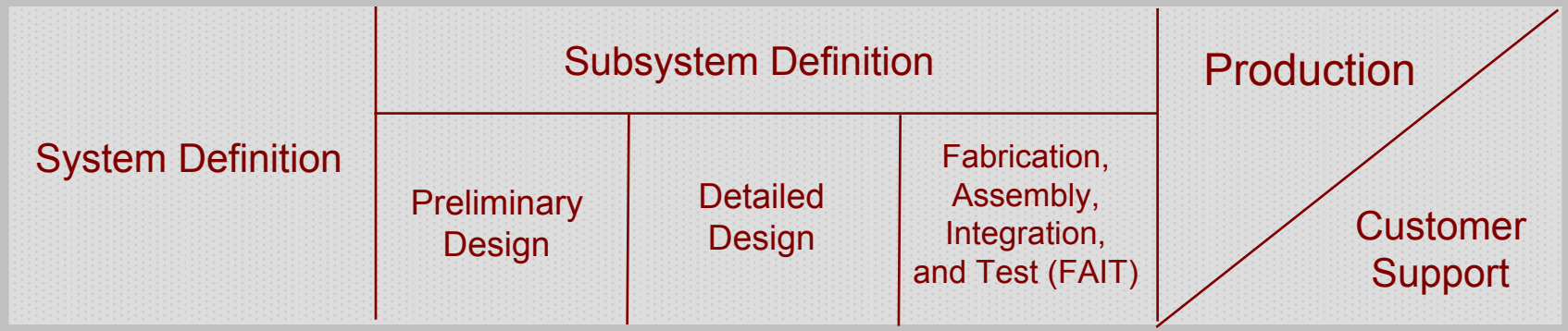
Basic System Building Blocks - 2

- The life-cycle processes include:
  - Development
  - Manufacturing
  - Test
  - Distribution
  - Operations
  - Support
  - Training
  - Disposal
- Each life-cycle process is itself a process

Basic System Building Blocks - 3

- Manufacturing life-cycle process:
  - Facilities
  - Equipment / tools
  - Procedures
  - Software applications
  - Computer resources
  - Parts inventory
  - Personnel
  - Suppliers / vendors
  - Quality Control

Typical System Lifecycle



Systems Lifecycle Processes

System Lifecycle Processes (ISO/IEC 15288)

- 23 Processes grouped four sets:
  - Agreement Processes
    - Acquisition
    - Supply
  - Enterprise Processes
    - Enterprise Management Process
    - Investment Management Process
    - System Life Cycle Process Management Process
    - Resource Management Process

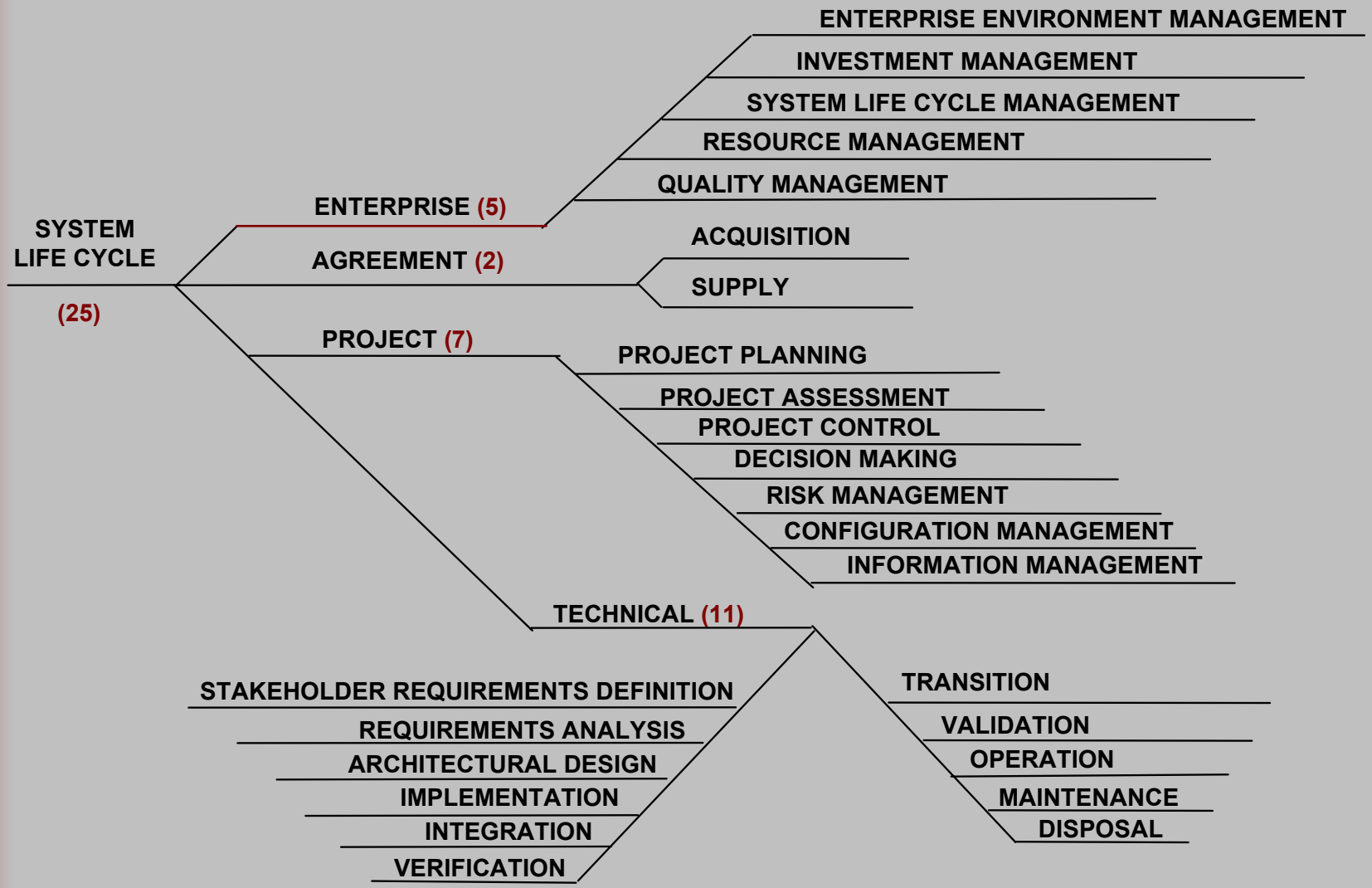
System Lifecycle Processes (ISO/IEC 15288) - 2

- Project Management Processes
  - Planning Process
  - Assessment Process
  - Control Process
  - Decision Management Process
  - Risk Management Process
  - Configuration Management Process
  - Quality Management Process

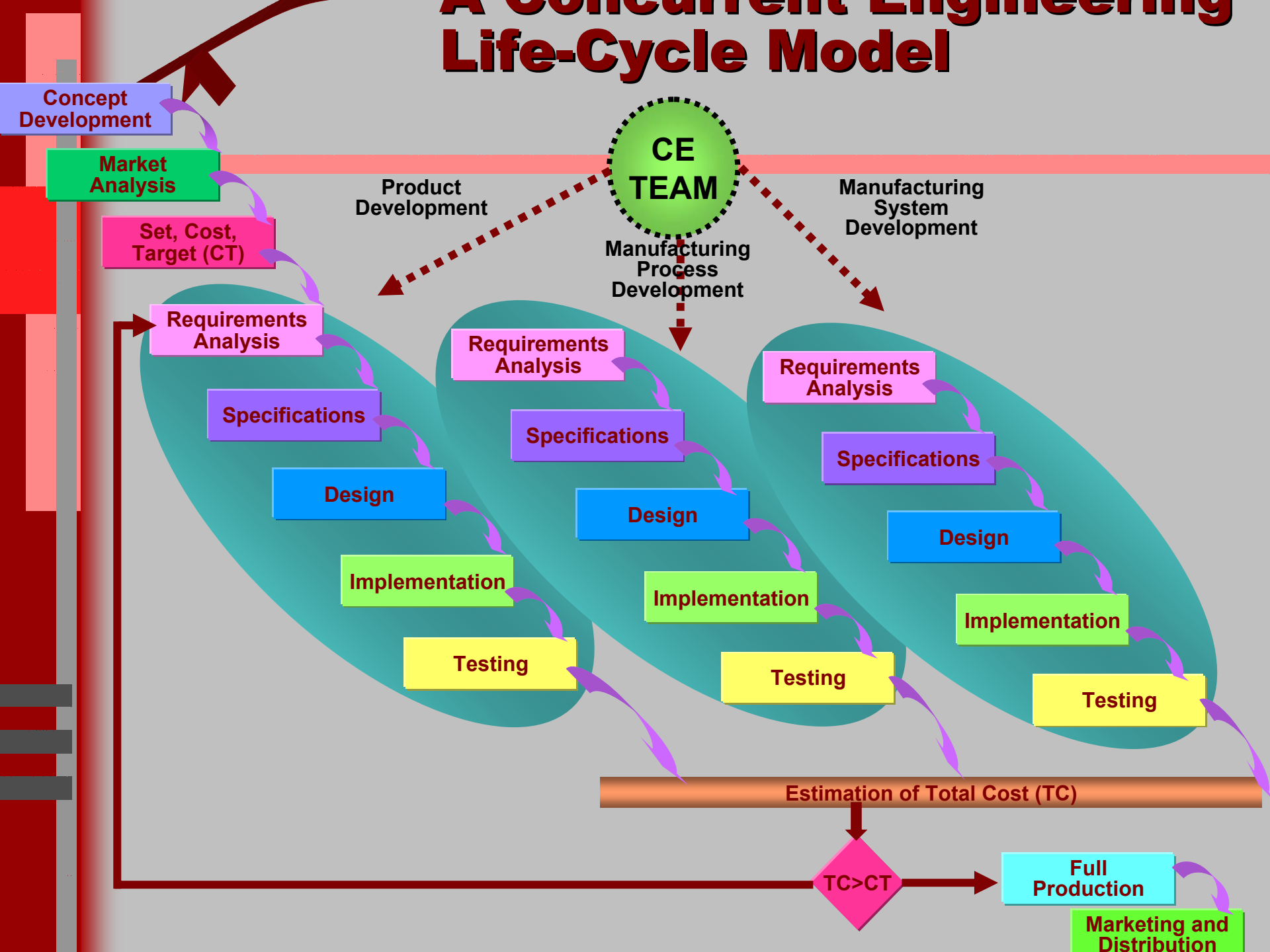
System Lifecycle Processes (ISO/IEC 15288) - 3

- Technical Processes
  - Stakeholder Needs Definition Process
  - Requirements Analysis Process
  - Architectural Design Process
  - Implementation Process
  - Integration Process
  - Verification Process
  - Transition Process
  - Validation Process
  - Operations Process
  - Disposal Process

ISO/IEC 15288 Systems Life Cycle Process Framework



A Concurrent Engineering Life-Cycle Model



Summary

- Systems Engineering is deeply integrated into the CMM Integration (CMMI®) and has reintroduced the concepts of “Engineering Systems Think”
  - EIA – 731 - Systems Engineering Capability Model
  - EIA – 632 - Processes for Engineering a System
  - IEEE 1220 - Standard for Application and Management of the Systems Engineering Process
  - ISO 15228 – System Lifecycle Processes
  - Handbook of Systems Engineering and Management – Andrew Sage, Willian Rouse, John Wiley and Sons, 1999

Thank You

Kasse Initiatives Contact Information

United States Address

Tim Kasse

CEO & Principal Consultant

Kasse Initiatives LLC

PMB 293

1900 Preston Road # 267

Plano, Texas 75093

United States of America

+1 972 – 987 – 7606 Business

+1 972 – 987 – 7607 FAX

Europe Address

Tim Kasse

CEO & Principal Consultant

Niedereschacher Strasse 6

78052 Villingen-Schwenningen

Germany

49(0)7721- 407 851 Business

49(0)7721- 407 852 Fax

www.kasseinitiatives.com

Kasse Initiatives
Contact Information

Pamelia S. Rost
Executive VP
Business Development

Kasse Initiatives LLC

PMB 293

1900 Preston Road # 267

Plano, Texas 75093

United States of America

+1 972 – 987 – 9878 Business

+1 972 – 987 – 7607 FAX

PameliaSRost@aol.com

www.kasseinitiatives.com

Kasse Initiatives Contact Information

Ingo Tegtmeier

Operations Manager

Kasse Initiatives LLC

Niedereschacher Strasse 6

78052 Villingen-Schwenningen

Germany

+49 7721 407 851 – Business

+49 7721 407 852 – FAX

itegtmeier@t-online.de

www.kasseinitiatives.com