



NATIONAL COUNCIL on SYSTEMS ENGINEERING

SEP WG
Systems Engineering Process
Working Group

A Process Description for a New Paradigm in Systems Engineering

Richard B. Wray, Chair
John Snoderly, Co-Chair
Robert Olson, Co-Chair
10 August 1994



Notices

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- Introduction - why a new paradigm is needed
- A new systems engineering paradigm is described
- Systems engineering activities in the new paradigm are identified
- Conclusions - NCOSE enabled a better model of SE to be developed

How was this accomplished?

- ⇒ **Systems Engineering was applied to the SE Process**
- ⇒ **By >60 NCOSE members representing many companies, industries and government agencies**



Large Projects Need a New Paradigm for Systems Engineering

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- Systems engineering occupies a key position of technical responsibility
 - But responsibility is ambiguous
- Operational needs must be balanced with support and disposal needs for success
 - Only SE addresses the entire system life cycle
- Note: Small project practices can be tailored down from large project practices



SE Needs a New Paradigm for Systems Engineering

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- SE tends to focus on initial definition of system through preliminary design review
- The scope of SE activities are often underestimated, leading to:
 - Cost overruns, schedule delays, and inferior products by downplaying of need for SE after preliminary design
 - Poor support provided to deployment, support and disposal elements
 - Loss of hard-won, critical system knowledge when systems engineers depart from a project
 - Requirements problems later in development with insufficient SEs to determine scope of changes and impact
 - Treatment of SE as crisis control capability, not as crisis anticipation and avoidance
- Traditionally, a “throw-it-over-the-wall” mentality on SE products



What are the New Systems Engineering Requirements?

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SE must recognize and meet the needs of

- Management for a product meeting user and buyer needs, short term and long term
- Complete and consistent technical mission needs
- Concepts and requirements for design and production system elements
- Construction of models and prototypes, not just documentation
- Balanced needs of users, customer, and acquisition system for both operational and manufacturing system
- The system and entire life cycle for balance and a champion
- Systems engineering process which is repeatable, robust and reliable and ensures delivery of products that are robust and reliable
- SE as a discipline which can be taught and measured
- SE which is useable by practicing systems engineers



What is the New Systems Engineering Paradigm?

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Recognition that there are:

- Two levels of systems engineering
- Internal and external customers
- A simpler view of the system life cycle



There Are Two Levels to Systems Engineering

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- **SE activities are the upper level process to enable:**
 - Development of a product applied to meeting needs for specific systems
 - Process element tailoring to specific missions, customers and users
- **SE process engines are the basic lower level process to provide:**
 - Fundamental SE capabilities to be mastered for effective SE practice
 - Key primitive processes, elemental disciplines, teachable skills and measurable performance areas needed by systems engineers
- **SE activities and process engines feature:**
 - Iterative, cascading process with both parallel and sequential loops
 - Process that can be used by any engineer

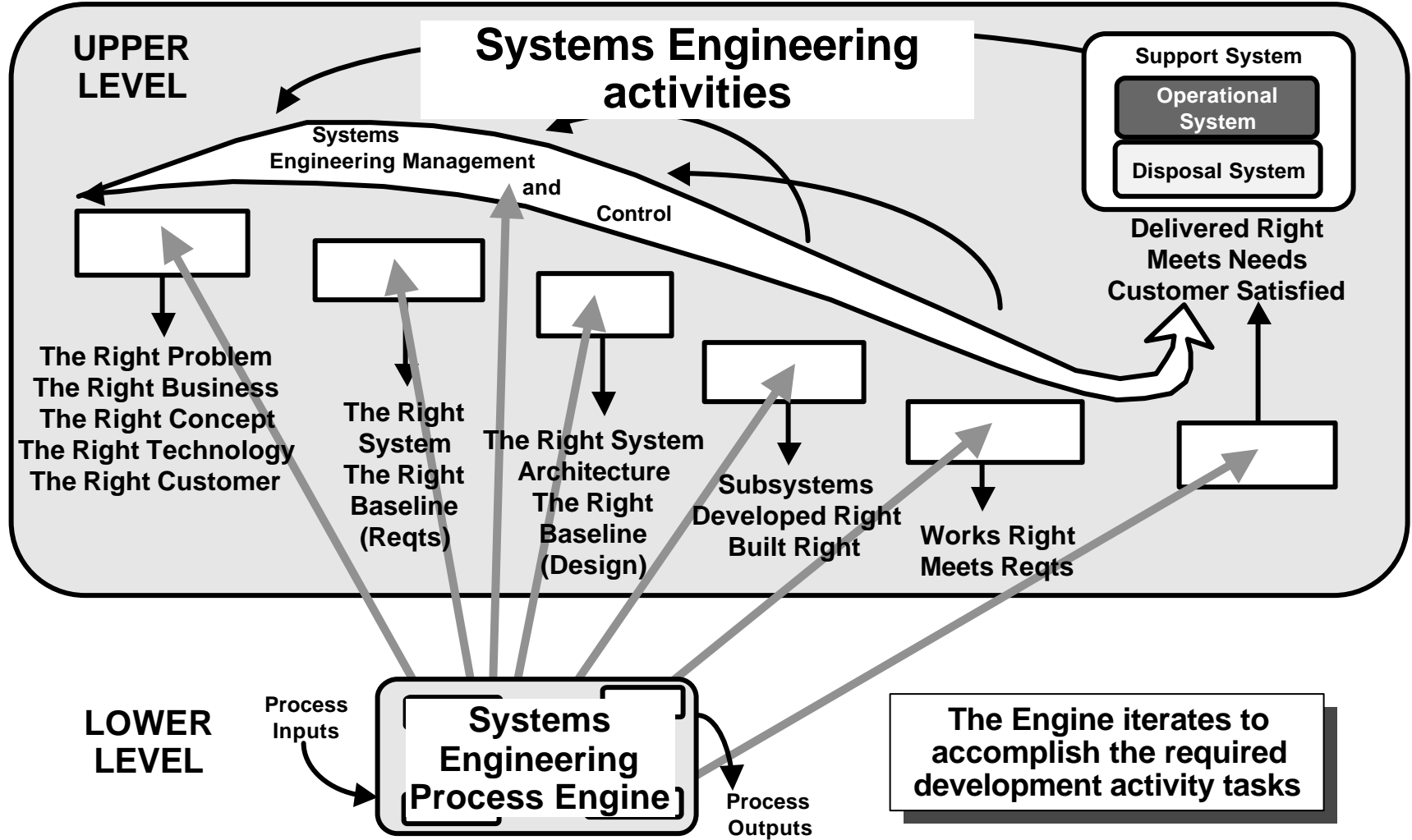
The Vision of Two Levels of Systems Engineering

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Projects Range from Pre-Conceptual to Disposal



What are the Systems Engineering activities?

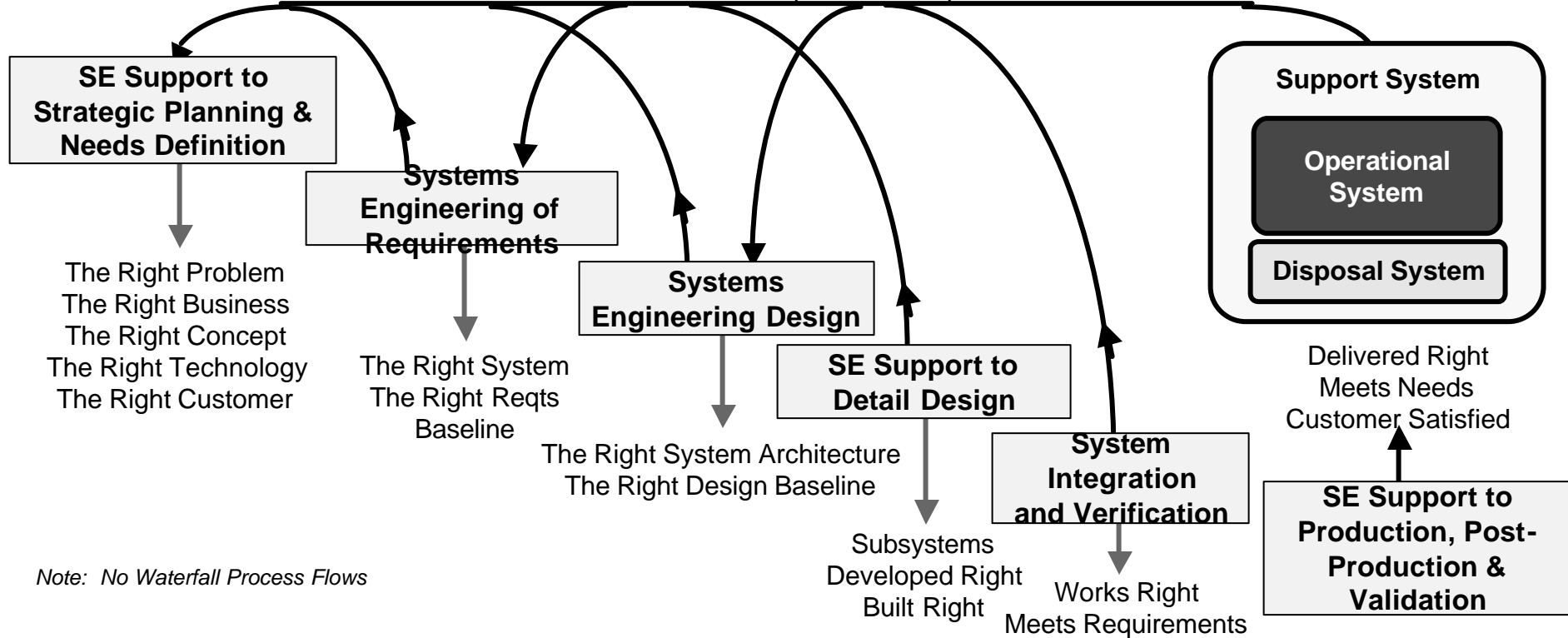
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Systems Engineering Management and Control

Development and Operational Feedback



Systems Engineering activities Must Focus on Quality in Each Part of the Process to Achieve Effective System Performance

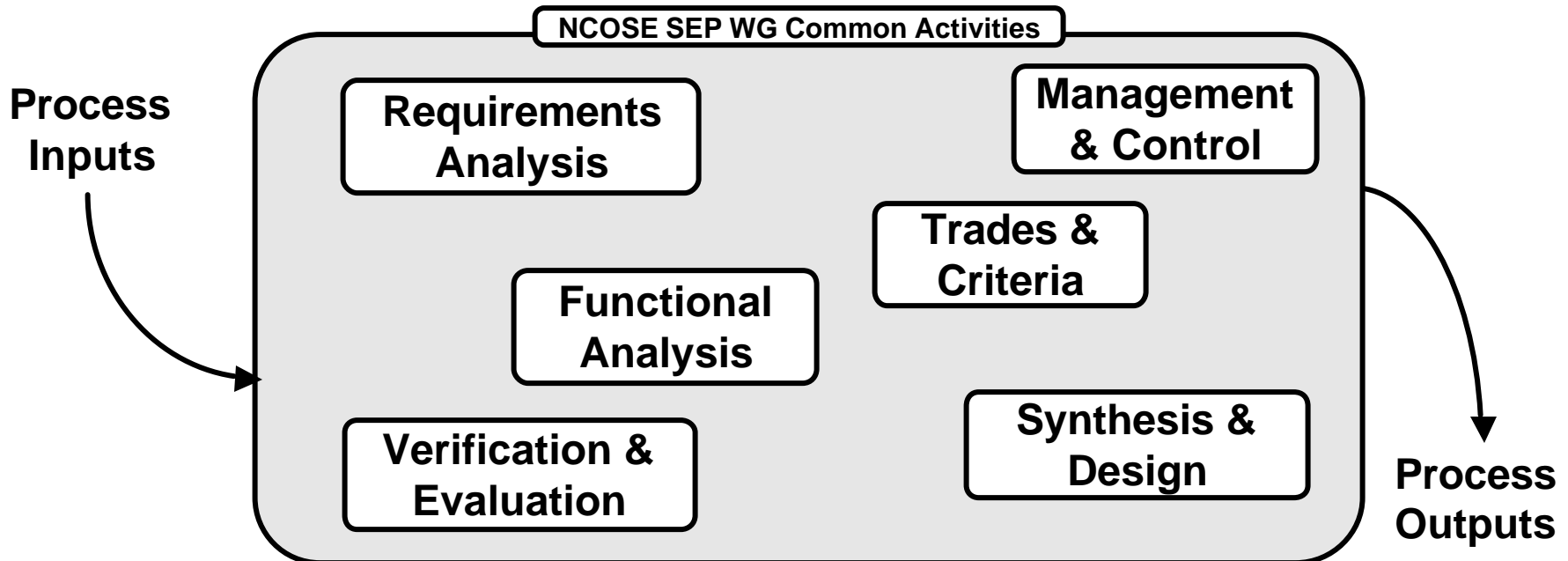
What are the Systems Engineering Process Engines?

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A SE Process Engine is the set of **primitive processes, elemental disciplines, teachable skills and measurable performance areas** that comprise the basic SE capabilities which iterate in all development activities



There is NO one best SE Process Engine for all uses and agencies and acquisition systems



Systems Engineering Must Satisfy Its Customers

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- Customers are all those involved in the process who depend on or use SE results, products or services
 - Design engineers
 - Marketing specialists

- Customers can be internal or external to the development process
 - Support engineers
 - Consumers

- Program management process is also a customer



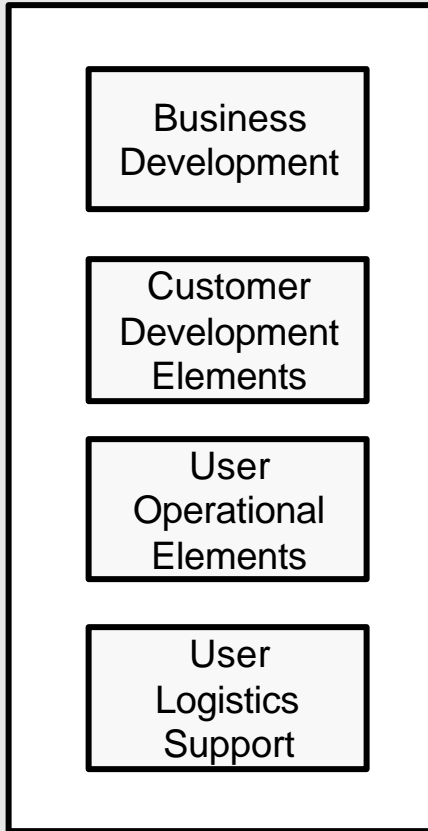
Customers Supply and Use Systems Engineering

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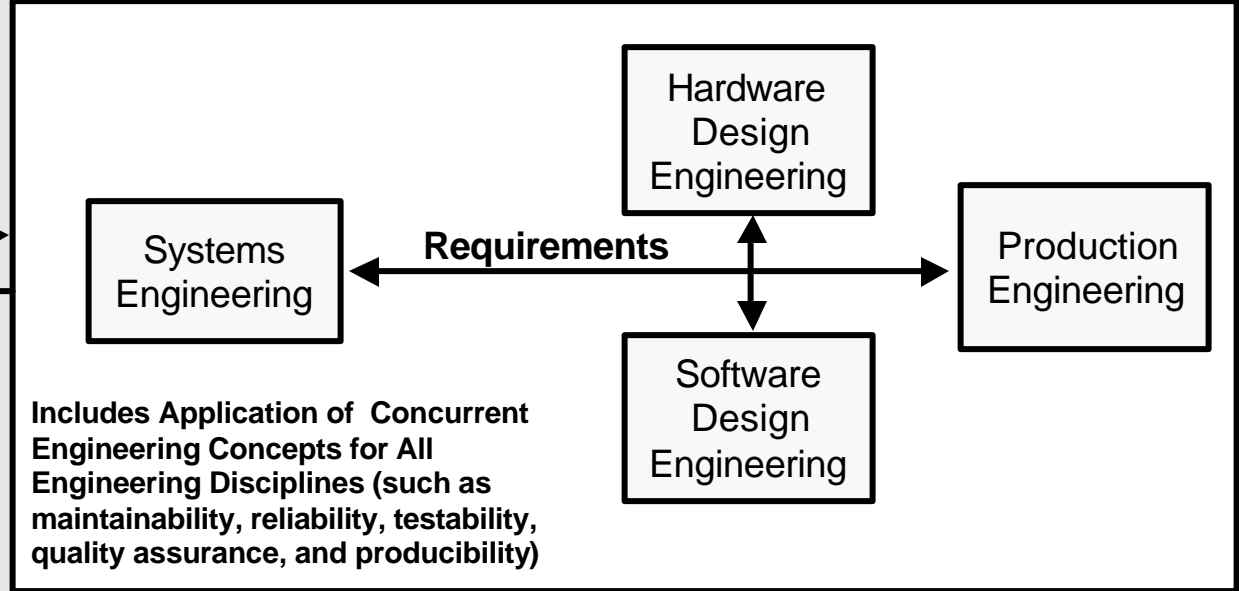
Using, Developing & Support Communities



Project System Body of Knowledge
(Accessed by all personnel as appropriate)

Process, Product and Lessons Learned

Engineering Development Community



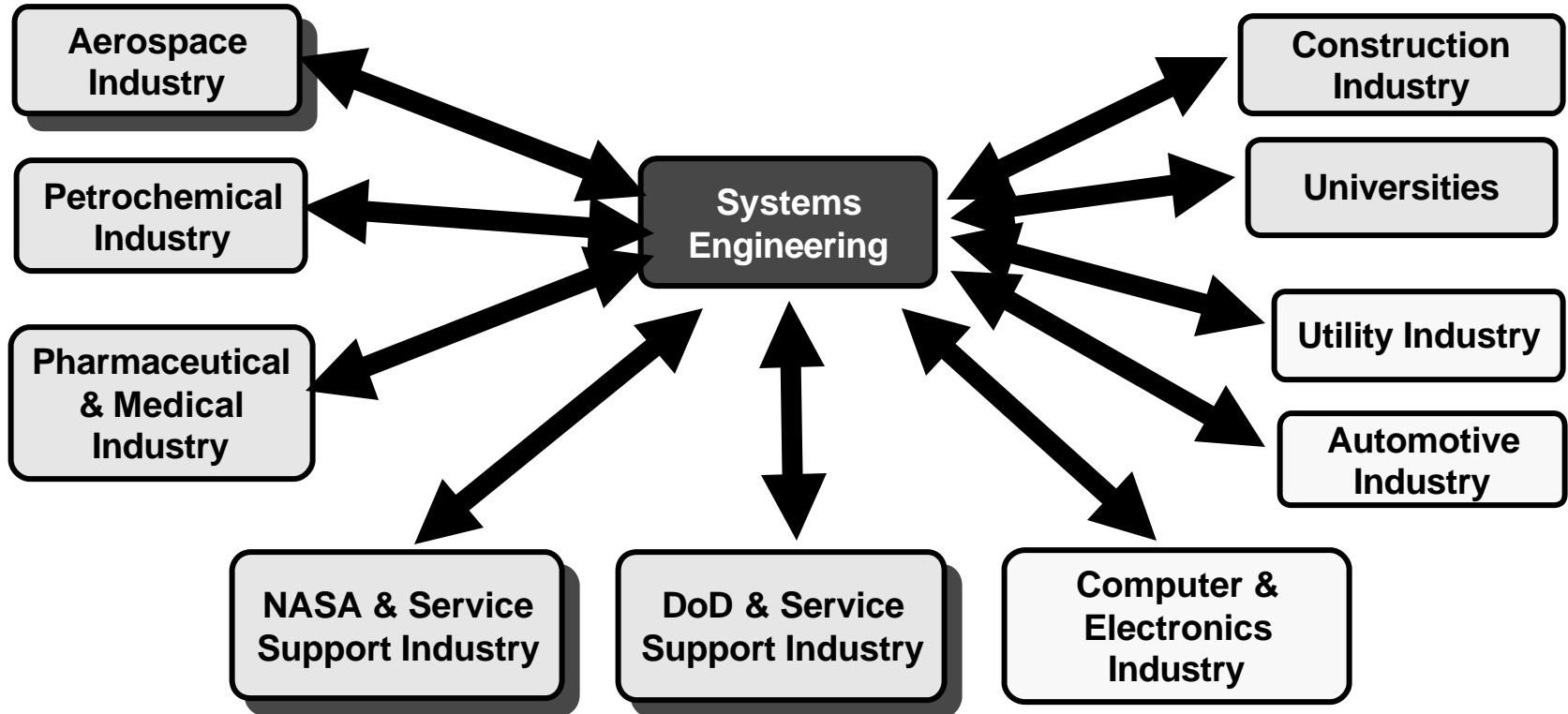


SE Must Apply to the System Life Cycle for All Communities

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- SE Process can be understandable to all, with tailoring templates to change the terminology, emphasis and use of the selected activities
- Company & profession growth requires SE be able to be applied to other industries besides DoD & NASA



A Simplified Life Cycle View Representing the System

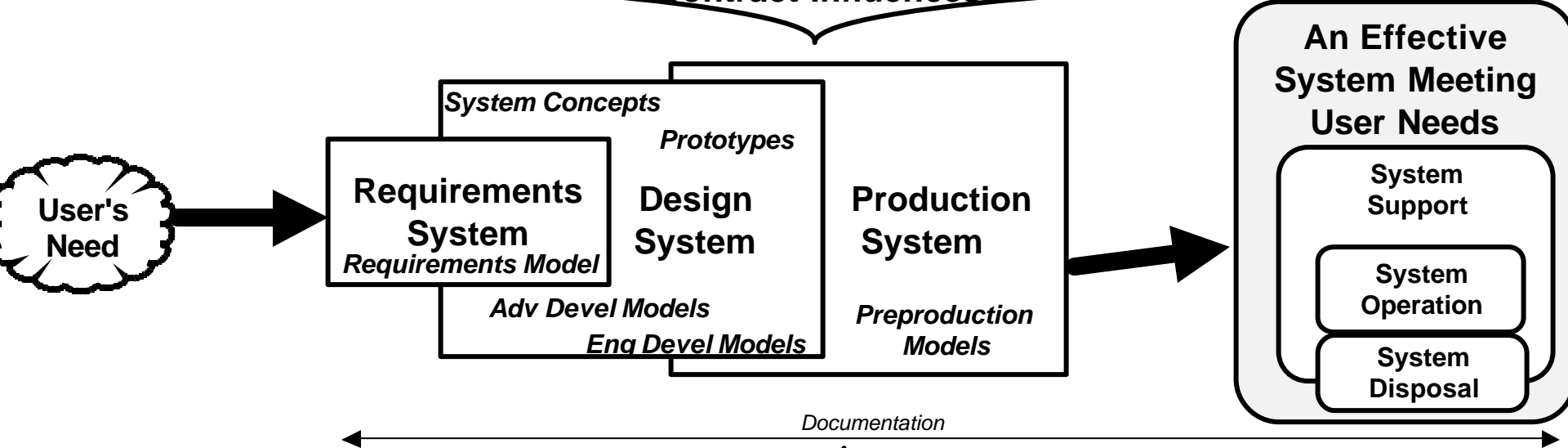
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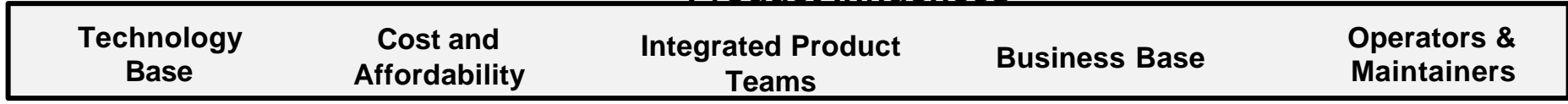


Contract Influences



Documentation

Product Influences



"LUST TO DUST" FOR SE MUST BE UNDERSTANDABLE TO ALL CUSTOMERS AND COMMUNITIES

Conclusions

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- The two parts to systems engineering were identified through the cooperative efforts of >60 NCOSE members over 2 years
- More effort is needed by NCOSE members to further definitize this process into lower levels and to tailor it to each industry
- NCOSE enabled the development of a model of SE which focuses on the needs of all customers
- Systems engineering must be the technical point of responsibility for successful coordination of hardware, software and other elements of the system



Systems Engineering Process Working Group

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26 Jan 1995

Meetings

WG in August 1994 Symposium (1 SEPWG, 5 with other wGs)

12 IGs between Sept 94 to Present at local chapters

WG in January 1995 Business Meeting (1 SEPWG, 9 with other WGs)

23 WG workers, 21 WG observers, 33 requestors (leeches)

- **Accomplishments**

- ⇒ ○ Systems Engineering Process (top level) coordinated among WGs and got consensus
- ⇒ ○ Relationship of chapter to national WG defined; 12 interest groups set up in chapters, hard at work
- Systems Engineering Process Engine purpose got consensus

- **Plans:**

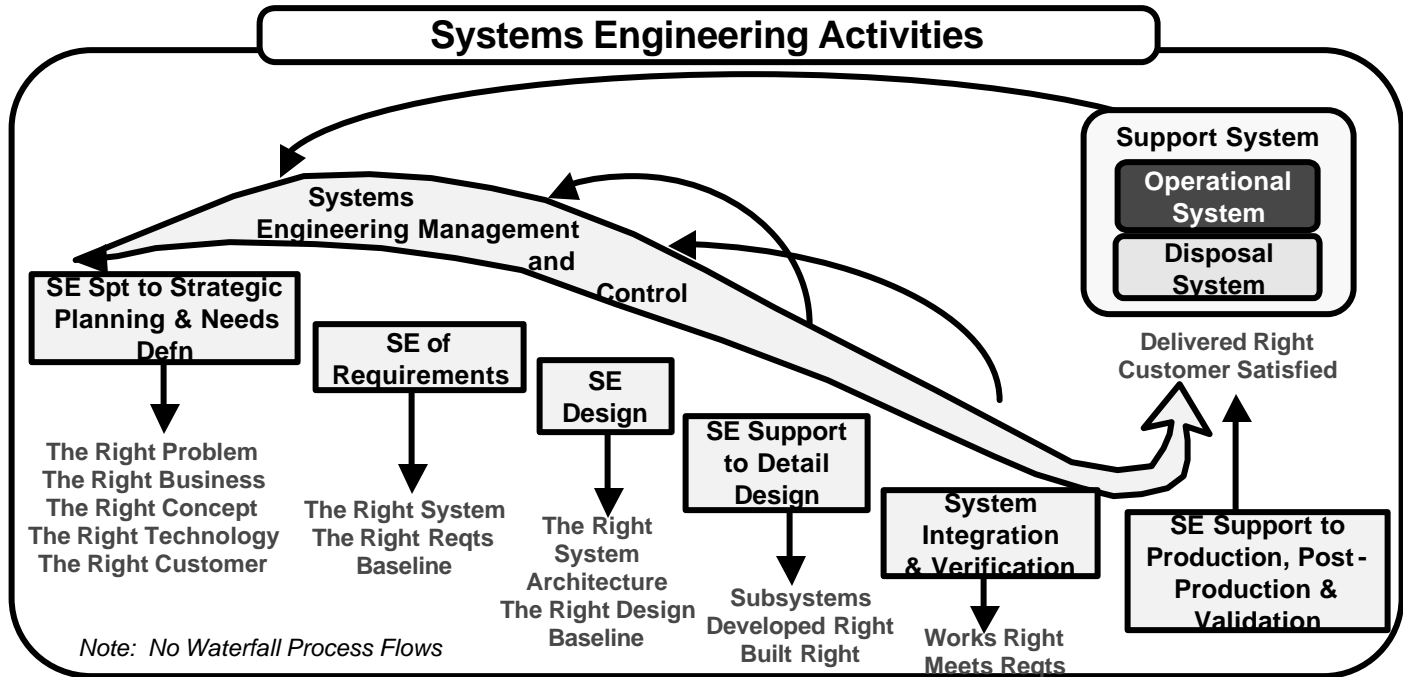
- Systems/SE definition underway - **Terminology WG**
- ⇒ ○ Assisting focus on CAB Need #3
- IGs developing lower level process material (I/O, subprocess elements, entrance and exit criteria, control gates, process logic flows)
- 11 IG/SEPWG papers planned for July 95 symposium
- Coordinate IG material
- IG meetings not tracked by WG, next WG meeting at July 95 symposium



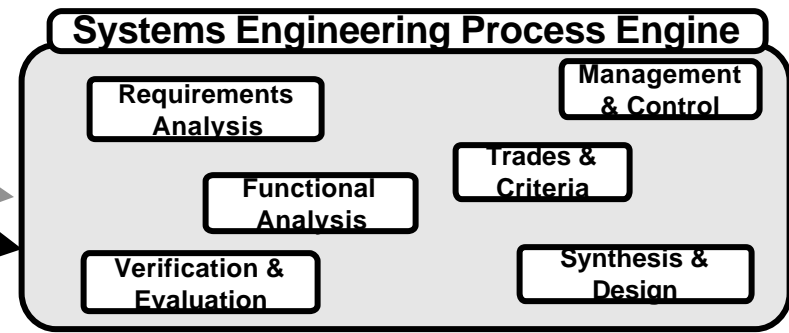
SEPWG Coordinated Process Elements

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The engine is the set of **primitive processes, elemental disciplines, teachable skills and measureable performance areas** that iterate to accomplish the required development activity tasks





SEPWG Response to CAB #3 Need

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- **NEED:** To develop an information package providing program manager's guidelines for applying SE on a program and selected set of qualitative data that demonstrates the cost, schedule, and quality benefits of applying SE or the regrets of not applying SE
- **SEPWG offers:**
 - Method or basis for logical, technical program management using SE
 - Categorization scheme as basis for gathering guidelines and data
 - Provide access to:
 - DSMC SE Management Guidebook
 - USAF Inspector General Report on SE
 - DoD Acquisition Historical Data Base
 - Lessons learned on MLRS, Abrahms tank, F-16
 - NASA historical records/lessons learned (examples):
 - Challenger use of PM/SE
 - Hubble SE/Integ & Test
 - Apollo experience in successful SE
 - Space Station Freedom experiences
 - NE England chapter (originally) planned survey; status unknown



SEPWG Requests from Process Element IGs

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- Inputs and outputs
- Subprocess elements
- Entrance and exit criteria (to/from block)
- Control gates (intermediate to block)
- Process logic flows
- Templates for applying logic flows to specific industry,/company

GOAL: To offer papers for the 1995 July Symposium
(due approx. April 1995 for inclusion in Vol II Proceedings)



SEPWG Using IGs in Chapters to Coordinate WGs

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- Mutli-WG coordinated process in SEPWG effort:
 - Systems engineering support to strategic planning & needs definition with **Mgt Com**
 - SE of Requirements with **Requirements/Process IG**
 - SE Design with **Architecture/Process IG**
 - SE Support to Detail Design (SEPWG only)
 - System Integration & Verification to be done with **Integ/Interf WG**
 - SE Support to Production, Post-Production & Validation (SEPWG only)
 - Systems Engineering Management and Control with **Mgt Com**
 - SE Process Engine with Washington DC chapter
- Other WG coordination
 - **Tools WG** will use SEPWG process elements; SEPWG will try to use Tools notation
 - **CAWG** will use SEPWG process elements; SEPWG will provide process/building blocks to CAWG
 - **Benchmarking WG** will use SEPWG process elements as basis for future surveys; SEPWG will provide subprocess elements
- **Tech WGs** prepare technical material and deliver products IAW tech board guidelines; **Standards WG** takes products, prepares as standards and conducts standards generation process
- Customer tailoring guidelines are needed (for each industry)
- Requirements for tools and methodologies are needed



NCOSE Chapters and Interest Groups Are Contributing

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- The Systems Engineering Elements
 - SE Support to Strategic Planning & Needs Defn - Tom McKendree
 - Systems Engineering of Requirements - Scott Curtis & Ken Kepchar (RMWG)
 - Systems Engineering Design - Bob Olson (SAWG)
 - SE Support to Detail Design - Ron Ireland & John Scruggs
 - System Integration and Verification - John Lazzaro & I&IWG?
 - SE Support to Production, Post-Production & Validation - Charlotte Paul
 - Systems Engineering Management and Control - Dave Cohen
 - Experiences of industry needed - New England Chapter?
 - The Systems Engineering Process Engine - John Snoderly
- Definitions - Terminology WG set up



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Systems Engineering Process Working Group

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26 July 1995



SEPWG Agenda for the Symposium

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- Wednesday, 10 Aug 94, ~9am - Plenary presentation of new SE paradigm
- Wednesday, 10 Aug 94, 5 - 6pm - Side meeting to present SEPWG status summary
- Thursday, 11 Aug 94, 4.45 - 5.45pm - Side meeting to present detailed description of SE paradigm to membership
- Friday, 12 Aug 94, 2.15 - 8pm - Side meeting for SEPWG & potential IG/action reps
 - Discuss & vote on paradigm
 - Develop & agree to IGs, action reps & action plans
- Saturday, 13 Aug 94, 8 - 12N - Side meeting for SEPWG & new IG/action reps
 - Continuation of Friday's meeting



SE Process Working Group Activities Proposed

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-
- Agenda for symposium
 - National Charter
 - Status of and Inputs to the SEPWG
 - Symposium, near and long term goals
 - Approach and papers supporting goals



SE Process Working Group Charter from National

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- Charter:

To refine the Systems Engineering Process elements that are functional to a practicing Systems Engineer; and requirements for benchmarks, methodologies and techniques for the Systems Engineering Process

- Challenge is to:

- Establish effective communications between members
- Describe the SE paradigm
 - SE activities
 - SE Process Engine
- Achieve concurrence on:
 - The 2 level paradigm
 - Definition of each level's concept
 - Description of elements in each level
- Obtain member and interest group participation in definitizing the SE description



Status of the SEP WG

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- National Symposium of 21-22 July 1992 chartered TGCC Process working group to represent the National
- January 1993 - National business meeting - national members met for the first time
 - Charter definitized
 - Special meeting setup
- April 1993 - SEP WG special meeting
 - Leading edge SE developments reviewed and compared
 - Baseline for SE activities and process established
 - Action plan agreed upon
- July 93 - National symposium achieved
 - Coordination among similarly chartered NCOSE WGs
 - Task flow chart for SEP WG
- SEPWG/TGCC has held many meeting from April 1992 to present
- January 94 - SEPWG leadership concurred on process to be shown to members



Leading Edge Development Activities

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- Defense Systems Management College and MIL-STD-499B (draft)
- National Aeronautics and Space Administration (NASA) Systems Engineering Process Improvement Team (SEPIT) by NASA Systems Engineering Working Group
- Naval Air Warfare Center (NAWC) SE Process
- Texas Gulf Coast Chapter (TGCC), Johnson Space Center and Lockheed Systems Engineering activities
- IEEE Systems Engineering Process Working Group
- Lockheed Missiles and Space Company (LMSC)/Space Systems Division (SSD) Systems Engineering Handbook
- AT&T Systems Engineering Process Handbook

There is (yet) no one “best” way to do and view systems engineering!



August 94 Meeting Goals

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- Identify and describe new paradigm to membership
- Obtain concurrence on paradigm baseline (as represented by formal chair paper)
- Identify action reps and IGs for each SE area
- Obtain concurrence on target papers to be presented in July 95
- Draft action plans for each IG/action rep
- Get IGs formed and activities underway in accordance with draft action plans









Systems Engineering Process Working Group Near Term Goals

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- To decide why the SEPWG is doing this, who our customer is and to exchange information  **1/18-20/93, 3/2-4/93**
- To interface with other working groups needing the SE Process and exchange information  **1/20/93 started**
- Compare alternative SE approaches
 - e.g., TGCC, MIL-STD-499B and other SE processes  **4/8/93 started**
- To refine the Systems Engineering Process Engine and its elements  **4/8/93 started**
- To define/refine supporting terminology  **4/8/93 started**
- To determine a common definition of Systems Engineering  **4/8/93 started**



SEPWG Long Term Goals

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- Understand how to apply the SE Paradigm
- Describe the differences in the SE approach relative to the phases of a program
- Identify similarities and differences between SE applied to process and product development for different communities
- Define the relationship between strategic planning, commercial product development and the SE Paradigm
- Define how the SE Paradigm is going to be documented
- Characterize the contents, topics and issues needed in a handbook
- Identify characteristics and issues of prime/subcontractor SE relationships
- Identify requirements for methodologies and tools for performing SE
- Develop benchmark processes

(Restatement needed)



Long Term Results Needed from the SEPWG

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- A description of the Systems Engineering Process
 - Overall
 - Principles, policies and guidelines
 - Multiple levels of detail
 - Control gates and scheduling
 - Guidelines for tailoring to different industries
- Requirements for and/or benchmark processes for SE or SEP
 - Baseline for standard SE process
 - Tailored for different industries
- Requirements for methodologies, techniques and tools for performing SE or SEP
 - Practices and procedures
 - Criteria and conditions
 - Measures of effectiveness
 - Standards, templates and profiles
 - Interfaces
- Common terminologies in SE or SEP across different industries



Process Definition Approach

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- Establish systems engineering process across all industries
 - Briefings from industry personnel
 - Description of their project life cycle, SE Paradigm and key products
 - Draft Systems Engineering Paradigm (superset)
-
- Tailoring guidelines for each industry
 - Establish list of terms across all industries and their definitions
 - Prepare description of Systems Engineering Paradigm
 - Re-assess long term goals, and plan for them

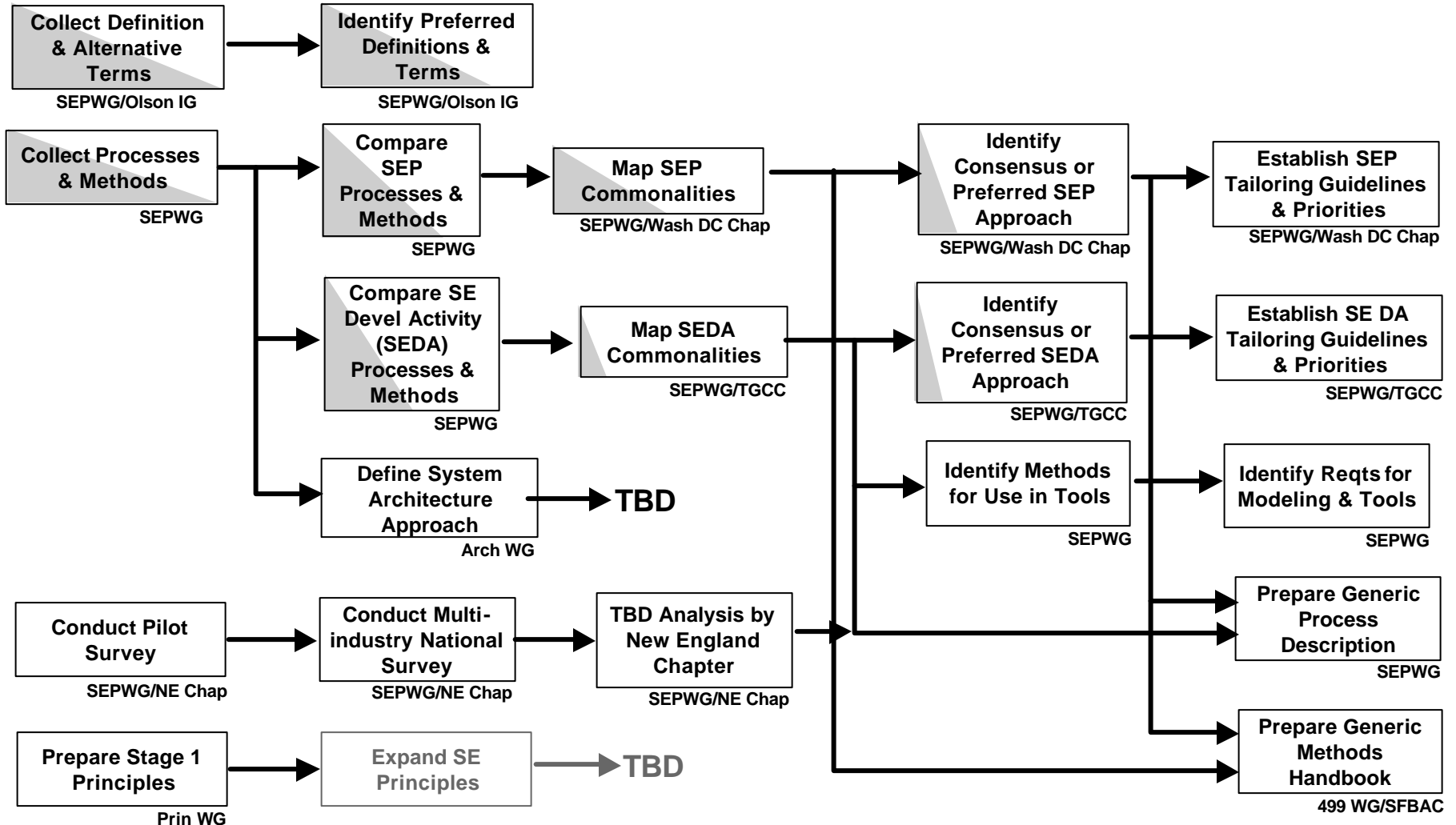


SE Processes & Methods Committee Activity Chart

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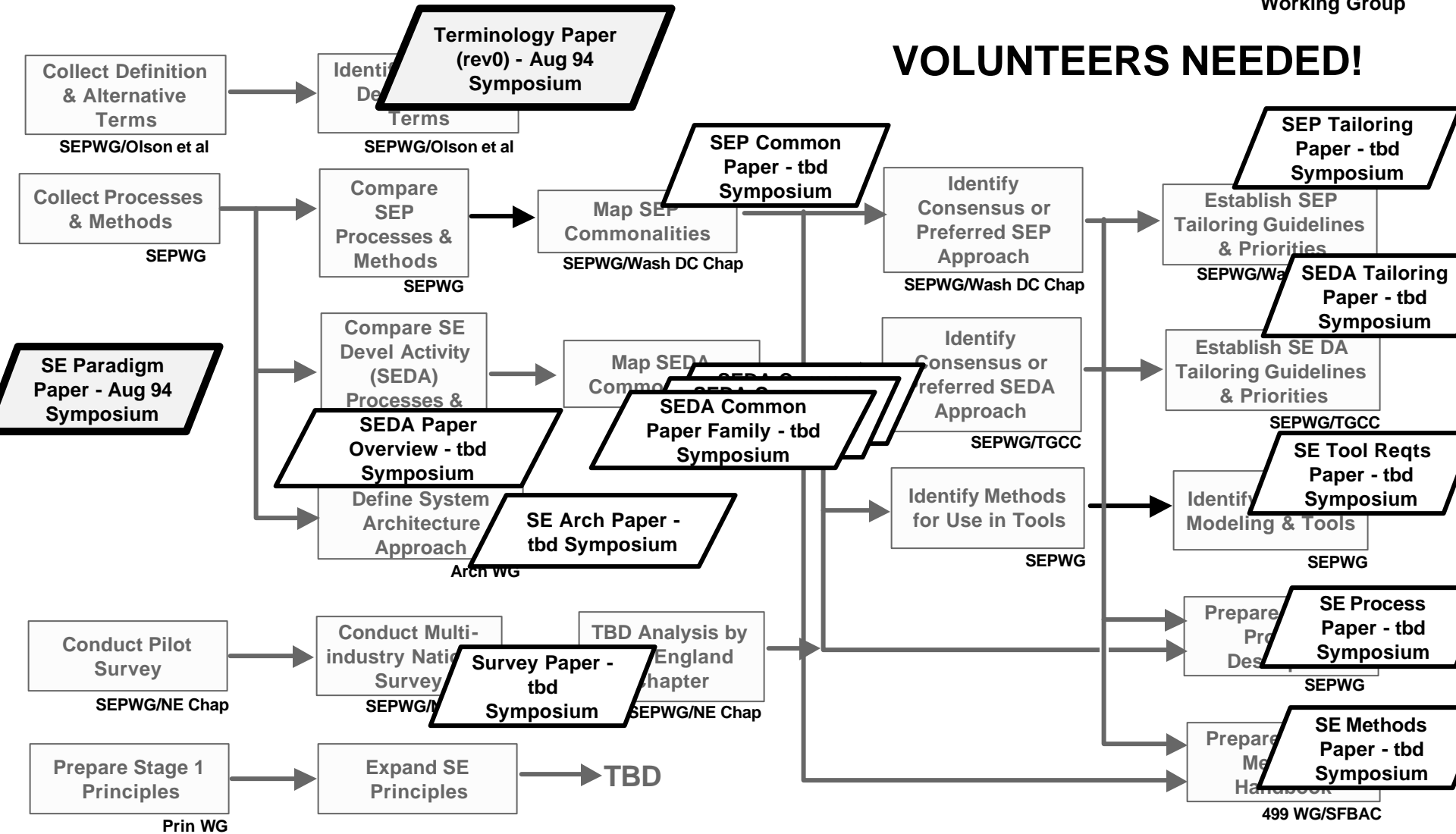
SE Processes & Methods

Possible Papers

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VOLUNTEERS NEEDED!

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Note: Shown under each task is the agency primarily responsible for implementation



Action Plan Summary

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- Task Assignment:
 1. Prepare Systems Engineering Definitions - Bob Olson
 2. Refine the April SE Comparisons by adding additional columns to the activity comparisons - Jonette Stecklein & Roy Mengot
 3. Refine the concept of the SE engine - Les Pieniazek & John Snoderly/Washington IG
 - Primitive processes, elemental disciplines, skills, “personalities”, etc.
 4. Overlay the SEP engine from each source on the respective Acquisition Life Cycle - John Snoderly & Bob Olson
 5. Apply SE Process to Product System Life Cycle - Randy Fleming and Roy Pettis
- Identify IG & action reps and obtain concurrence



NCOSE Chapters and Interest Groups SignUps?

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What

Who

When

- The Systems Engineering activity
 - Block structure and relationships concurrence - **SEPWG**
 - Systems Engineering Support to Strategic Planning & Needs Defn
 - Systems Engineering of Requirements
 - Systems Engineering Design **Sys Arch WG**
 - Systems Engineering Support to Detail Design
 - System Integration and Verification **in part by I&I WG**
 - Systems Engineering Support to Production, Post-Production & Validation
 - Systems Engineering Management and Control
 - Experiences of industry needed - **New England Chapter**
- The Systems Engineering Process Engine
 - Needs completion and concurrence - **Washington DC Chapter**
 - Concept, block structure and elements need concurrence - **SEPWG**
 - Blocks need filling in and concurrence -
 - Definitions - **Sys Arch/SEP Joint Subgroup**
- Customer tailoring guidelines (for each industry) -
- Requirements for tools and methodologies -
- Requirements for and/or benchmark processes for SE or SEP



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New Systems Engineering Paradigm Elements

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11 August 1994



What is the New Systems Engineering Paradigm?

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Recognition that there are:

- Two levels of systems engineering
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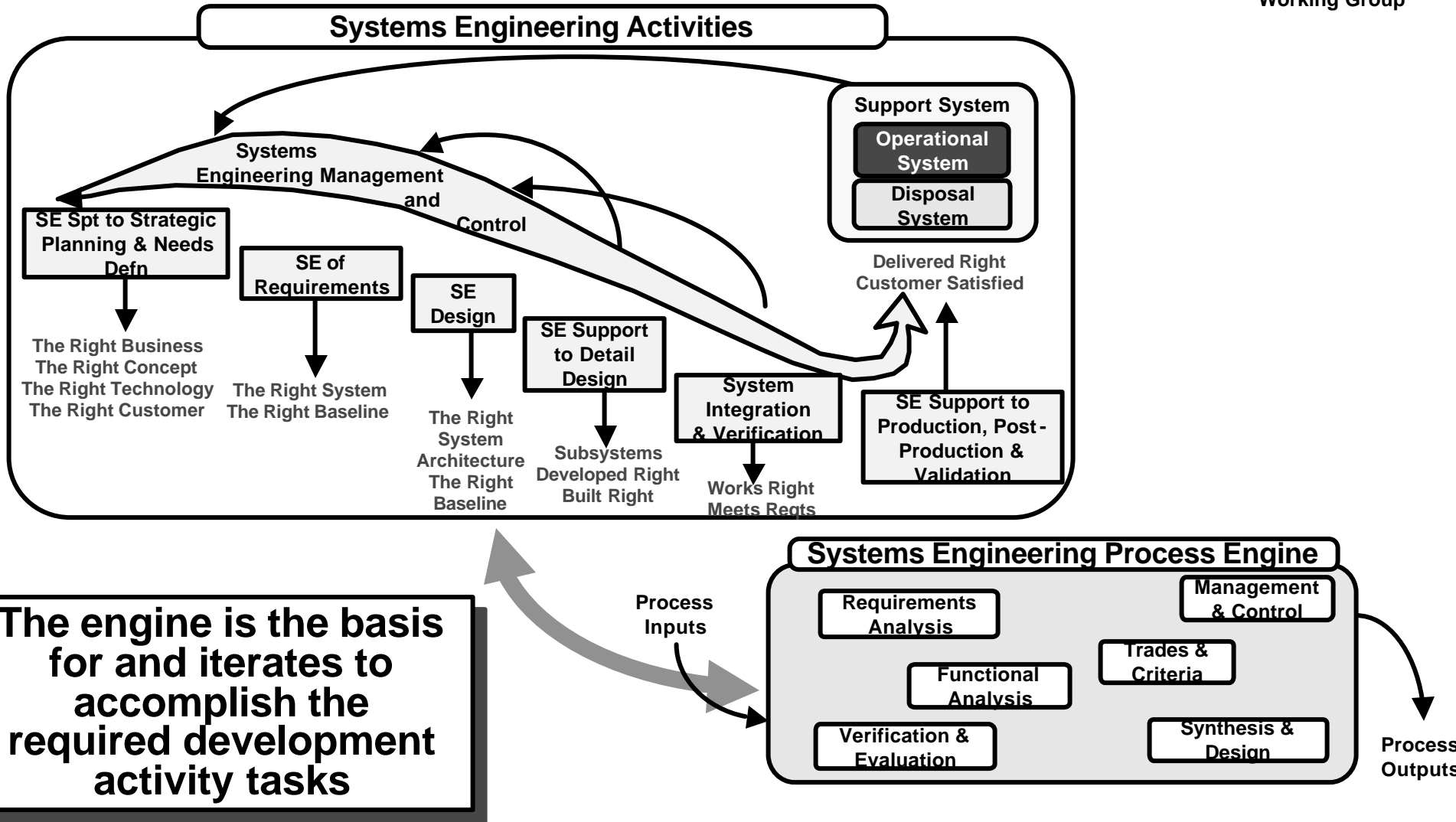
First, Must Consider What is a System



SEPWG Baseline Systems Engineering

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How Can NCOSE Chapters and Interest Groups Contribute?

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- The Systems Engineering activity
 - Blocks need filling in and concurrence - Chapters & IGs
 - Systems Engineering Support to Strategic Planning & Needs Defn
 - Systems Engineering of Requirements
 - Systems Engineering Design
 - Systems Engineering Support to Detail Design
 - System Integration and Verification
 - Systems Engineering Support to Production, Post-Production & Validation
 - Systems Engineering Management and Control
 - Experiences of industry needed - **New England Chapter**
- The Systems Engineering Process Engine
 - Needs completion and concurrence - **Washington DC Chapter**
 - Blocks need filling in and concurrence - Chapters & IGs
- Definitions are needed - **Architecture/SEP Joint Subgroup**
- Customer tailoring guidelines are needed (for each industry)
- Requirements for tools and methodologies are needed



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Systems Engineering activities

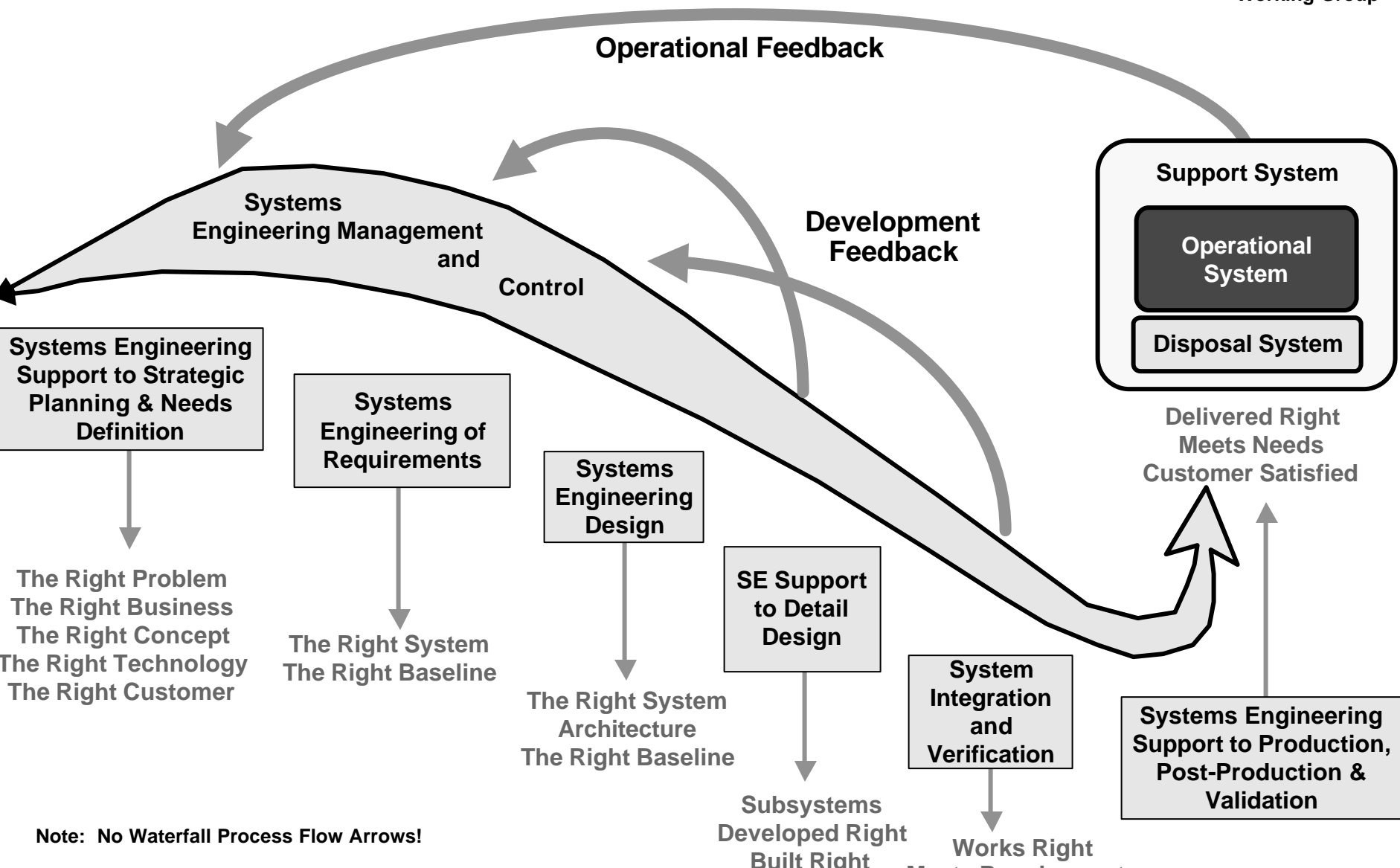


The Vision of the Systems Engineering activities

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Note: No Waterfall Process Flow Arrows!



Where does SE Fit Into the Overall Process?

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1. Acquisition System life cycle phases
 - Set by law and agency regulations
 - Contains project development activities
2. Development System product development activities
 - Contains technical design activities
 - Includes Systems Engineering activities
 - Contains non-technical project support activities
 - Common activities are:
 - Identify Needs, Systems Design, System Evaluation & Selloff, Full Production, Operate, Support and Disposal
3. Systems Engineering Process Engine
 - Contains the “elementary” capabilities for SE
 - Common SE elements are:
 - Requirements Analysis, Functional Analysis, Verification & Evaluation, Synthesis & Design, Management & Control, Trades & Criteria



Systems Engineering Iterates Across Many Development Levels

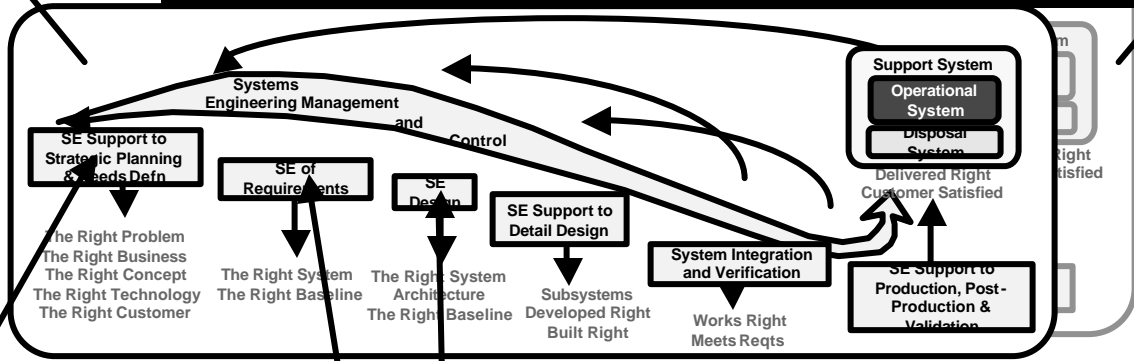
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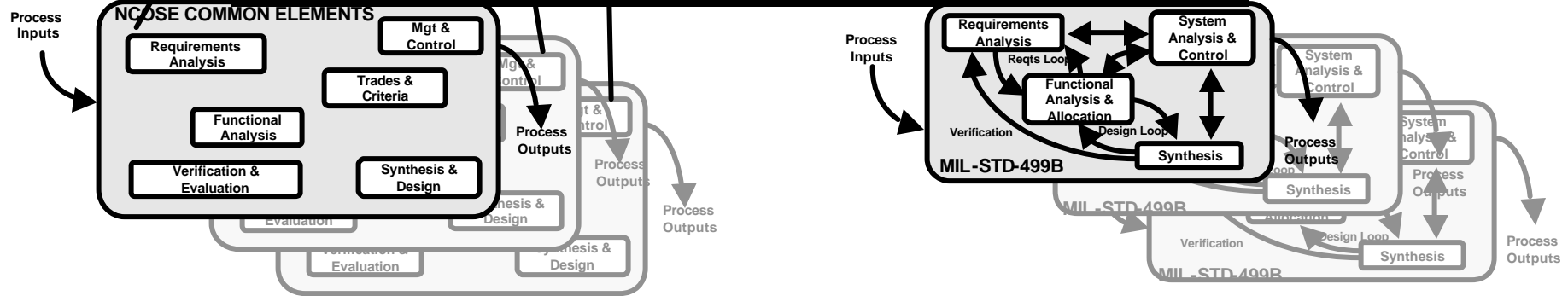
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Acquisition Life Cycle Phases

Systems Engineering activities



Systems Engineering Process Engine





Leading Edge Development Activities

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- Texas Gulf Coast Chapter (TGCC), Johnson Space Center and Lockheed Systems Engineering activities
- IEEE Systems Engineering Process Working Group
- Lockheed Missiles and Space Company (LMSC)/Space Systems Division (SSD) Systems Engineering Handbook
- AT&T Systems Engineering Handbook

There is (yet) no one “best” way to do and view systems engineering!



Development Activity First Level Comparisons

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Common Elements	TGCC/JSC/Lockheed		NAWC Dev Activity	AT&T SE Activity
<ul style="list-style-type: none"> ● Identify Need <ul style="list-style-type: none"> ○ Msn Need Statement ○ Sys Reqts Doc ● Systems Planning ● Research & Technology 	<ul style="list-style-type: none"> ● Right Problem ● Right Business ● Right Concept ● Right Technology ● Right Customer ● Right System 	<ul style="list-style-type: none"> ● SE Support to Strategic Planning ● SE of Requirements 	<ul style="list-style-type: none"> ● Determ Need 	<ul style="list-style-type: none"> ● Marketing
			<ul style="list-style-type: none"> ● System Design <ul style="list-style-type: none"> ○ Reqts Def (A spec) ○ Product Design (B&C Specs) ○ Integ & Test ○ Limited Prodn 	<ul style="list-style-type: none"> ● Right System Architecture ● Right Baseline
<ul style="list-style-type: none"> ● System Eval & Selloff 	<ul style="list-style-type: none"> ● Subsystems Developed Right ● Built Right 	<ul style="list-style-type: none"> ● SE Support to Detail Design ● Sys Integ & Verification 	<ul style="list-style-type: none"> ● Sys Design 	<ul style="list-style-type: none"> ● Engineering
<ul style="list-style-type: none"> ● Full Production 	<ul style="list-style-type: none"> ● Works Right ● Meets Reqts 	<ul style="list-style-type: none"> ● SE Support to Production 	<ul style="list-style-type: none"> ● Detail Design 	
<ul style="list-style-type: none"> ● Operate & Support 	<ul style="list-style-type: none"> ● Delivered Right 	<ul style="list-style-type: none"> ● SE Support to Post- Production & Validation 	<ul style="list-style-type: none"> ● Verification 	<ul style="list-style-type: none"> ● Sales & Service
<ul style="list-style-type: none"> ● Disposal 			<ul style="list-style-type: none"> ● Prod & Deploy 	
			<ul style="list-style-type: none"> ● O&S 	
			<ul style="list-style-type: none"> ● Disposal 	



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Systems Engineering Process Engines



MIL-STD-499B Essential Elements Described

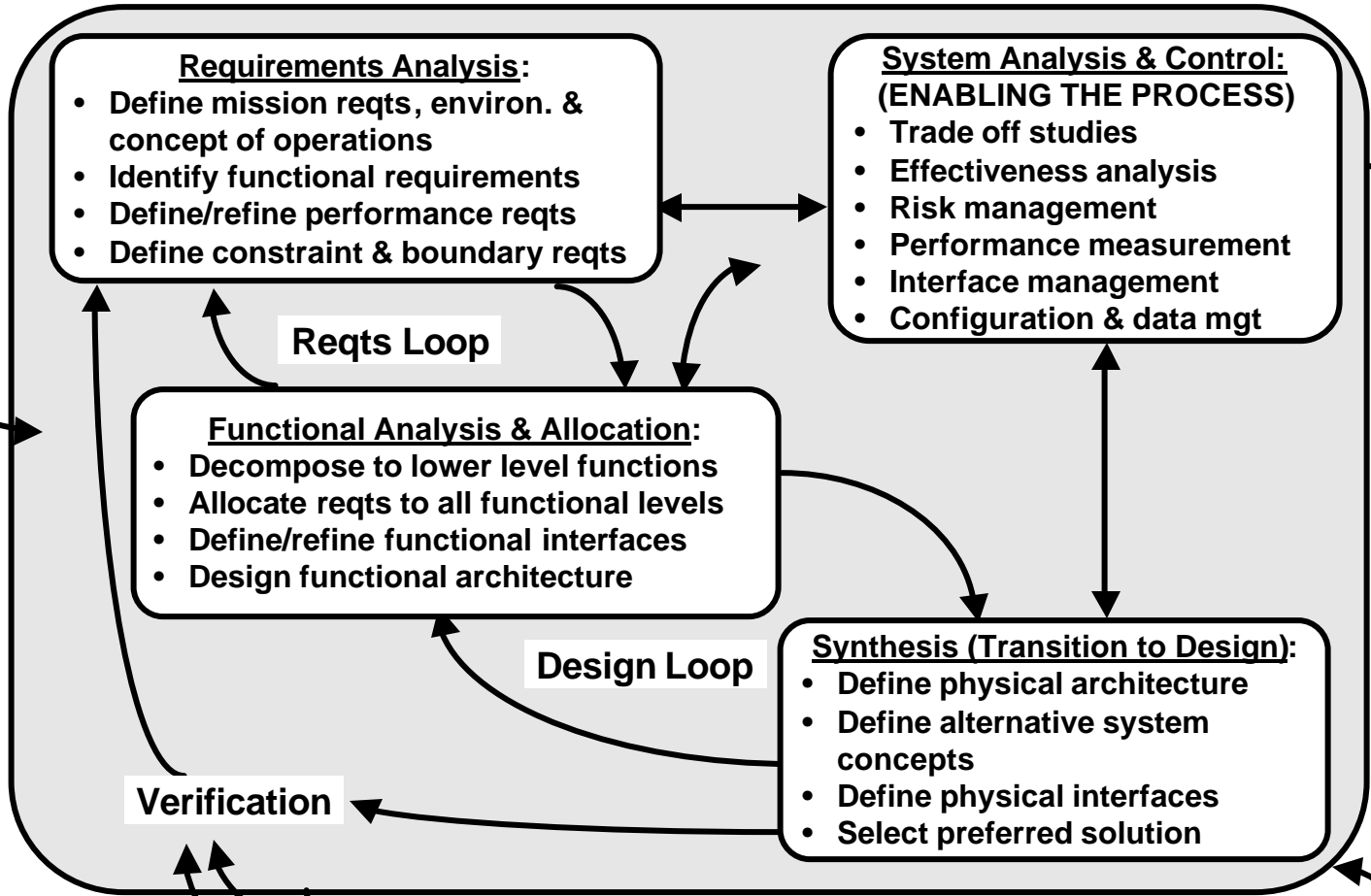
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Customer Needs

- Customer needs, objectives & reqts
 - Missions
 - Measures of Effectiveness
 - Environment
 - Constraints
- Technology base
- Outputs from prior phases
- Program decision reqts
- Specifications and standards



Phase Oriented Product

- Decision support data
- System architecture
- Specifications & baselines

Design (Requirements Implementation)

Production (Design Implementation)



Comparison of SE Process Engines

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Process	Elements	Comparison
499B	Req/Func/Synth/Anal & Control	1,2,5,6,10,13
Mar	Func/Req/Answers/Test	1,5,10,11
IEEE	Loops: Req/Design/Verif	1,9,11
NASA SEPIT	Define/Design/Eval/Decision Spt	3,9,12,14
NASA JPL	Needs/Criteria/Func/Arch/Alloc/Eval	4,5,6,8,10,12
NAWC-WD	Prob Def/Criteria/Altern/Trades/Eval/Doc	3,7,8,12
LMSC/SSD	Req/Trade&Anal/Des&Impl/Verif	1,2,7,9,11

Element in above listing

Gray indicates grouping into common areas

- 1. Req -- 4
- 2. Anal -- 2
- 3. Define -- 2
- 4. Needs -- 1

5. Func -- 3

6. Alloc -- 2

7. Trades -- 2

8. Criteria -- 2

9. Design -- 3

10. Synth,Ans,Arch -- 3

11. Test/Verif -- 3

12. Eval -- 4

13. Control -- 1

14. Decision Spt -- 1

Sequence number

Number of times element repeats in listing



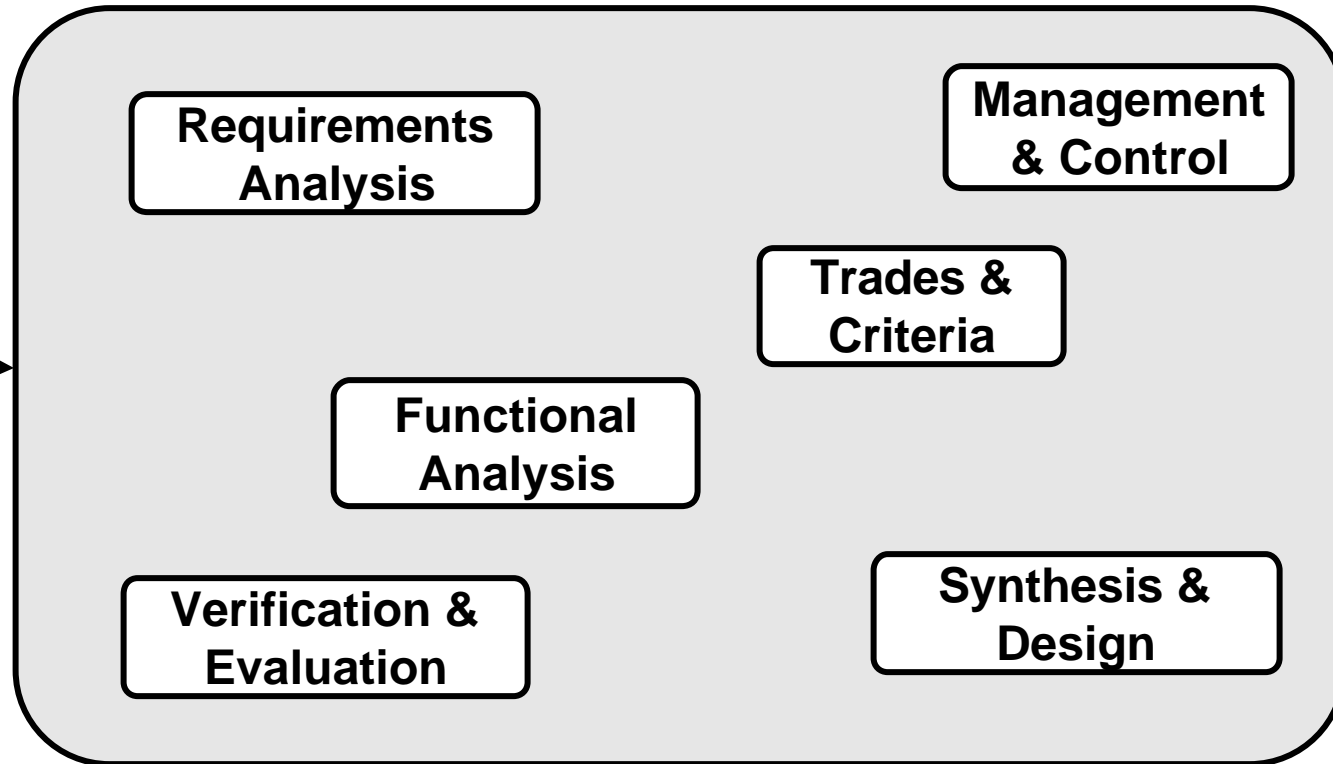
Common Elements of the Systems Engineering Process Engines

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Process
Inputs



Process
Outputs

**Common, Elemental Parts (or Disciplines) Iterate in all
Development Activities**

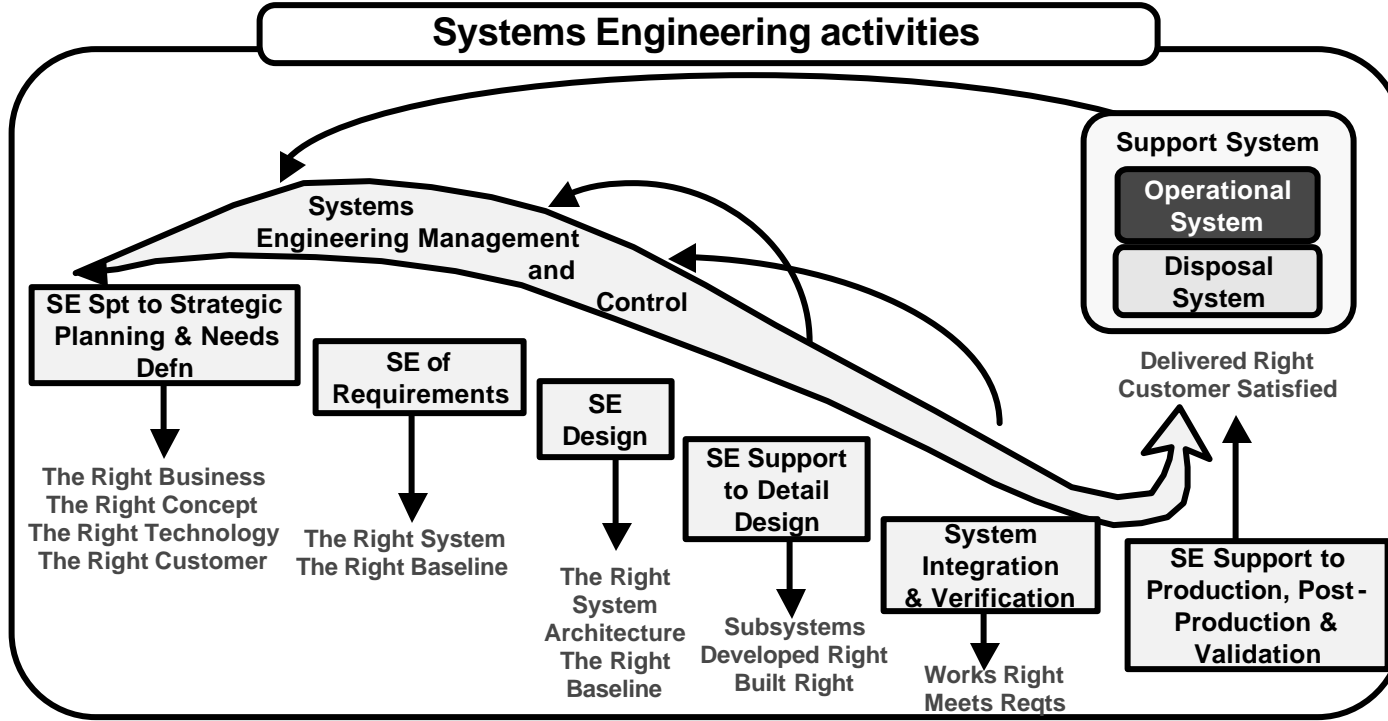


SE Activities Tailor the SE Process Engine

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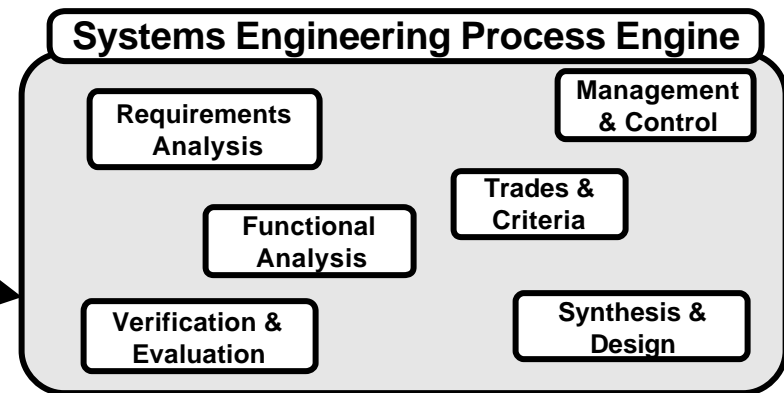
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The engine is the basis for and iterates to accomplish the required development activity tasks

Process Inputs



Process Outputs



Matrix of SE Design Phases

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etc

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499B

NASA
SEWG

NAWC

IEEE

Lockheed

B. Mar

- **SE Support to Strategic Planning & Needs Definition**
 - Spt to Problem Concepts & Needs Anal
 - Support to Business Area Development
 - Spt to Technology and Reqts Analysis
 - Support to Strategic Planning & Target Capture Planning
- **Systems Engineering of Requirements**
 - Problem, Mission and Reqts Analysis
 - Reqts Alloc & Sys Concept Optimization
 - Subsys Reqts Anal & Concept Update
- **Systems Engineering Design**
 - System Design Analysis & Optimization
- **SE Support to Detail Design**
 - Spt Design Element Anal & CI Design
 - Spt Board, LRU and Component Build and Test
- **System Integration and Verification**
 - HW/SW Integration and Checkout
 - Subsystem Integration and Checkout
 - Final System Integration and Checkout
- **SE Support to Production, Post-Prod'n & Validation**
 - Production Process Startup and Anal
 - Spt to Changes to Production Process
 - Support to Changes to Product Design, Use and Maintenance
- **SE Management and Control**
 - Develop and Maintain the SEMP and Enable Other Interfacing Plans
 - Organize System Disciplines, Processes and Activities
 - Control and Coordinate System Disciplines, Processes and Products
 - Direct Technical Tasks Based on System Needs and Hold Responsibility for System Technical Performance

**To Be Developed
After the SEPWG Elements are
definitized.**



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Considerations for an Improved Paradigm of SE



Too Many Definitions of the Systems Engineering Process

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- Electronics Industries Association, SYSB-1, December 1989
 - The methodology of sequential and iterative application of selected scientific and engineering efforts to convert user needs into a system solution that will best satisfy the requirements and constraints in accordance with "agreed to" effectiveness measures reflecting the users needs.
- MIL-STD-499B (Draft), 6 May 1992
 - A comprehensive, iterative problem solving process that is used to: (a) transform validated customer needs and requirements into a life cycle balanced solution set of system product and process designs, (b) generate information for decision makers, and (c) provide information for the next acquisition phase.

Key Points:

User Needs, Produce System, Comprehensive, Iterative

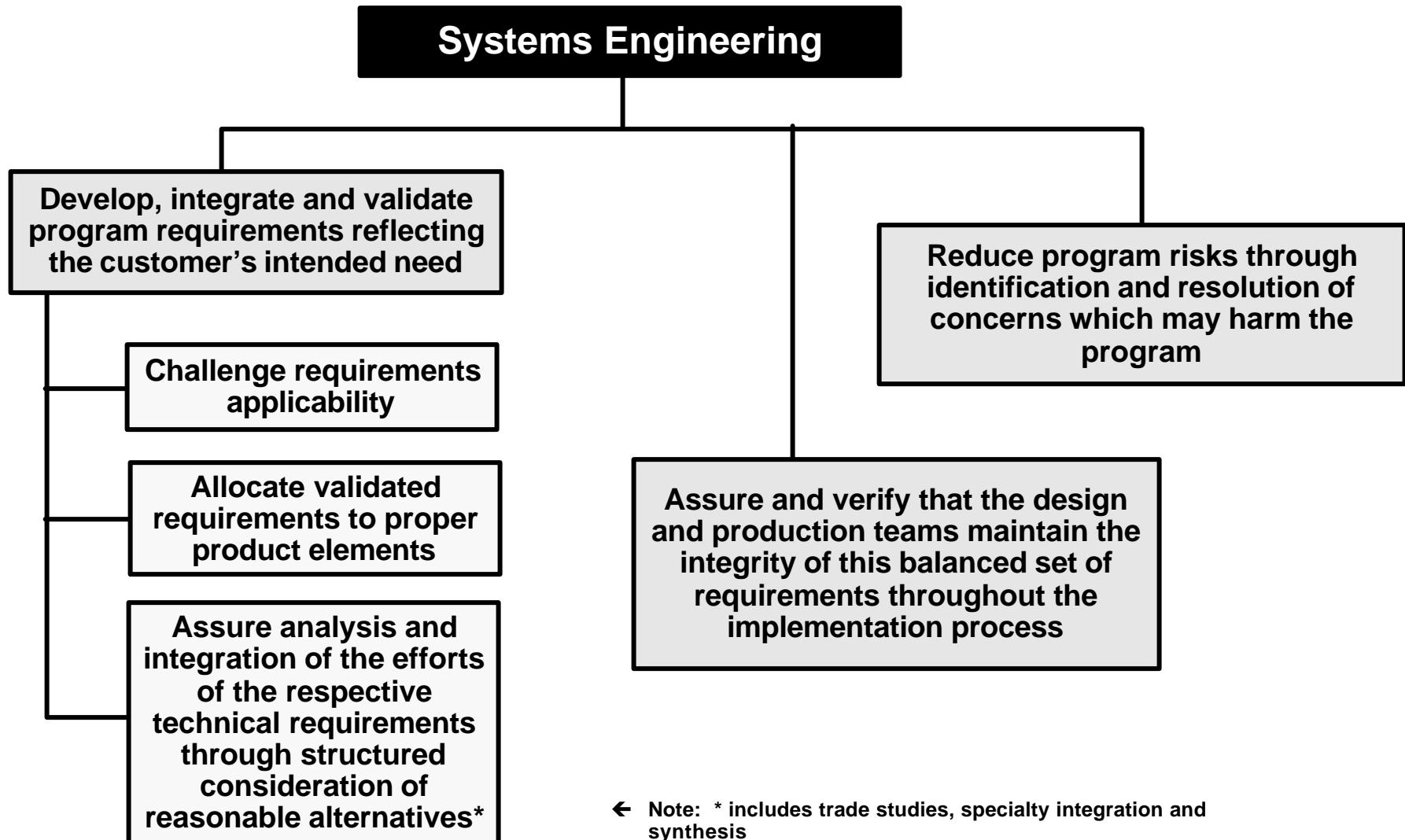
- Dept of Defense Directive 5000.2, Feb 1991, Establishes SE Policies:
 - SE applies throughout the system life cycle
 - Must translate operational need into configured system meeting that need
 - Provide integrated design with equal emphasis on system capability, manufacturing, test and support
 - Ensure compatibility of all functional and physical interfaces
 - Characterize and reduce technical risks
 - The Government manages the SE process, the contractor executes the SE process

A Non-Defense View of Systems Engineering

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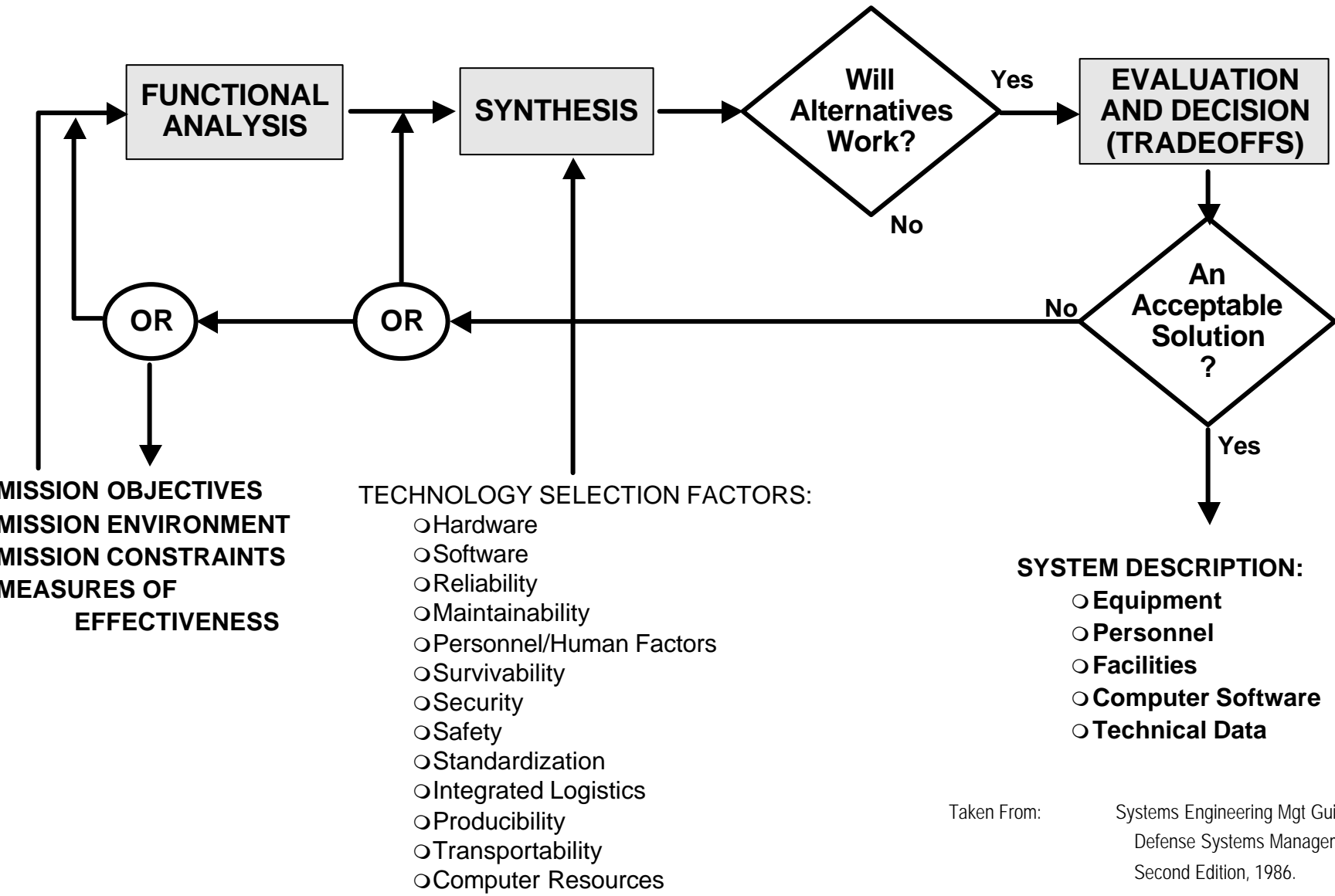


What is the Traditional View of Systems Engineering?

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Taken From: Systems Engineering Mgt Guide
 Defense Systems Management College,
 Second Edition, 1986.



What Skills are Needed in the Systems Engineering Process?

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- Systems Engineering must encompass “personalities” of:
 1. Systems Manager
 2. Systems Engineer (Traditional)
 3. Systems Architect
 4. Systems Analyst
 5. Systems Integrator
 6. Systems Tester/Test Manager

**for an effective system, integrating all disciplines and products,
with demonstrated long term operability and utility**

- Systems Engineering must also provide "personality" of:
 7. System Teacher

**for effective process and infrastructure definition and
development**



NCOSE Chapters and Interest Groups SignUps?

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What

Who

When

- The Systems Engineering activity
 - Block structure and relationships concurrence - **SEPWG**
 - Systems Engineering Support to Strategic Planning & Needs Defn
 - Systems Engineering of Requirements
 - Systems Engineering Design
 - Systems Engineering Support to Detail Design
 - System Integration and Verification
 - Systems Engineering Support to Production, Post-Production & Validation
 - Systems Engineering Management and Control
 - Experiences of industry needed - **New England Chapter**
- The Systems Engineering Process Engine
 - Needs completion and concurrence - **Washington DC Chapter**
 - Concept, block structure and elements need concurrence - **SEPWG**
 - Blocks need filling in and concurrence -
 - Definitions - **Arch/SEP Joint Subgroup**
- Customer tailoring guidelines (for each industry) -
- Requirements for tools and methodologies -
- Requirements for and/or benchmark processes for SE or SEP



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A Structured Analysis of SE Activities



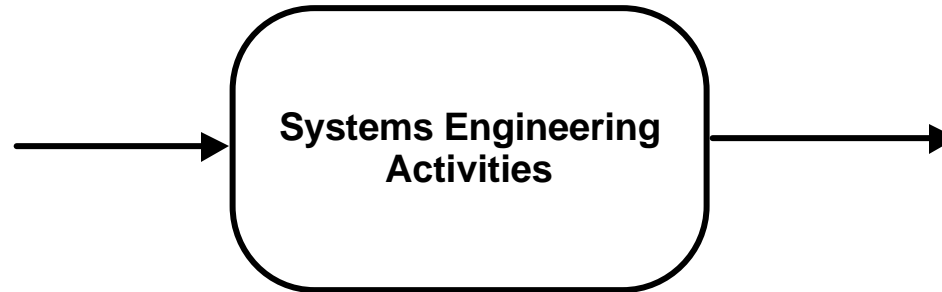
Levels 0 and 1 of the Systems Engineering Activities

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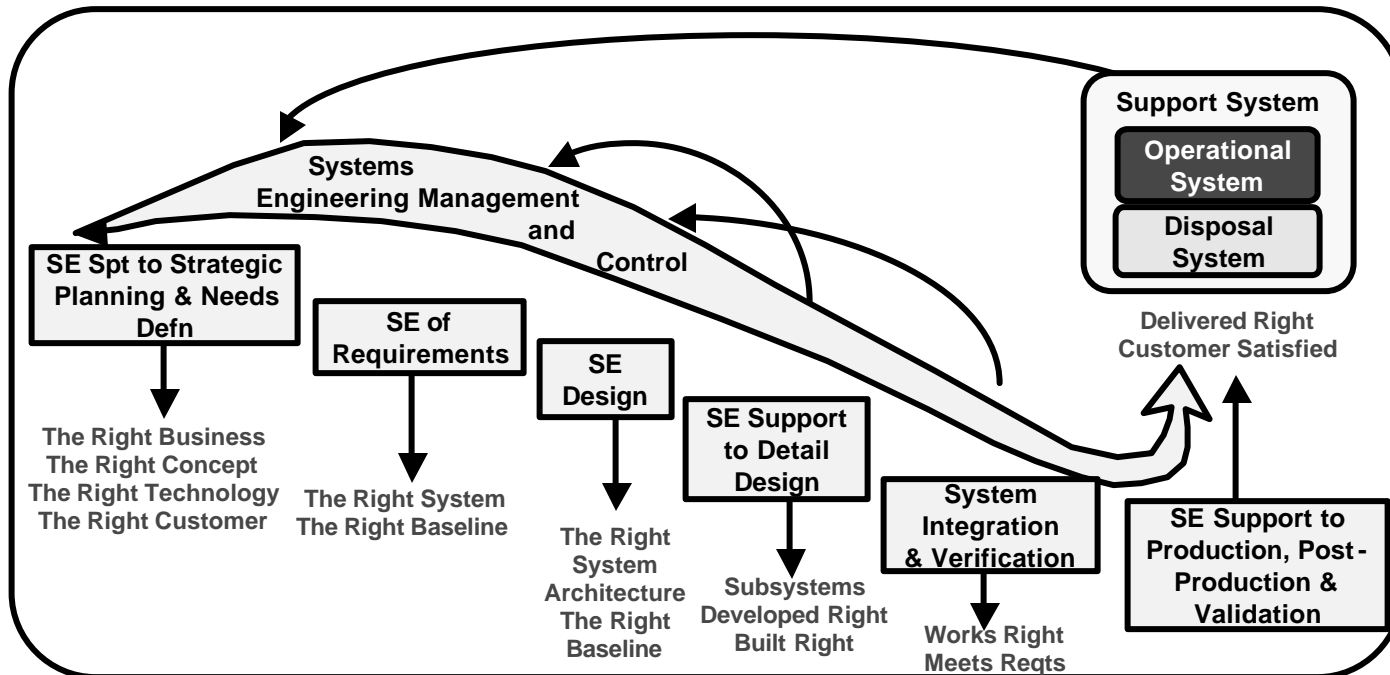
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Level 0:



Level 1:





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SE activities at Level 2 Shown in More Detail



Why Systems Engineering Support to Strategic Planning?

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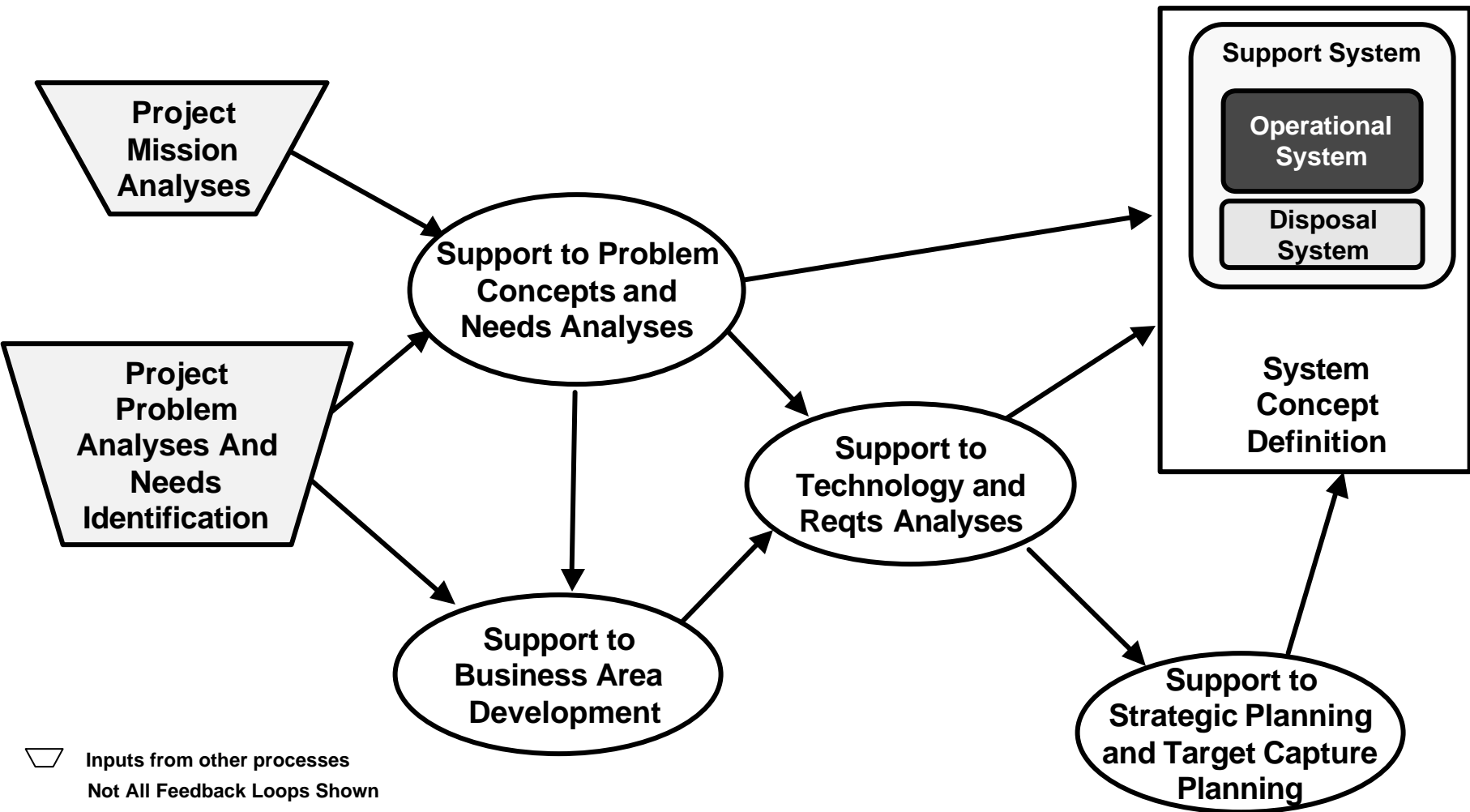
- Strategy is defined as “The overall plan and actions required for large scale operations”
- Systems Engineering must:
 - Analyze and engineer alternative technical approaches before one selected
 - Analyze and engineer alternative technical concepts before one selected
 - Analyze and engineer alternative systems before one selected
 - Provide technical support to strategic planning process
 - Provide holistic technical support covering all subsystems, technologies and disciplines in integrated manner
- Thus, Systems Engineering must provide technical support to strategic activities, i.e., Strategic SE.
- Government - wants it cheaper; Industry - wants bigger profit

Overview Systems Engineering Support to Strategic Planning & Needs Definition

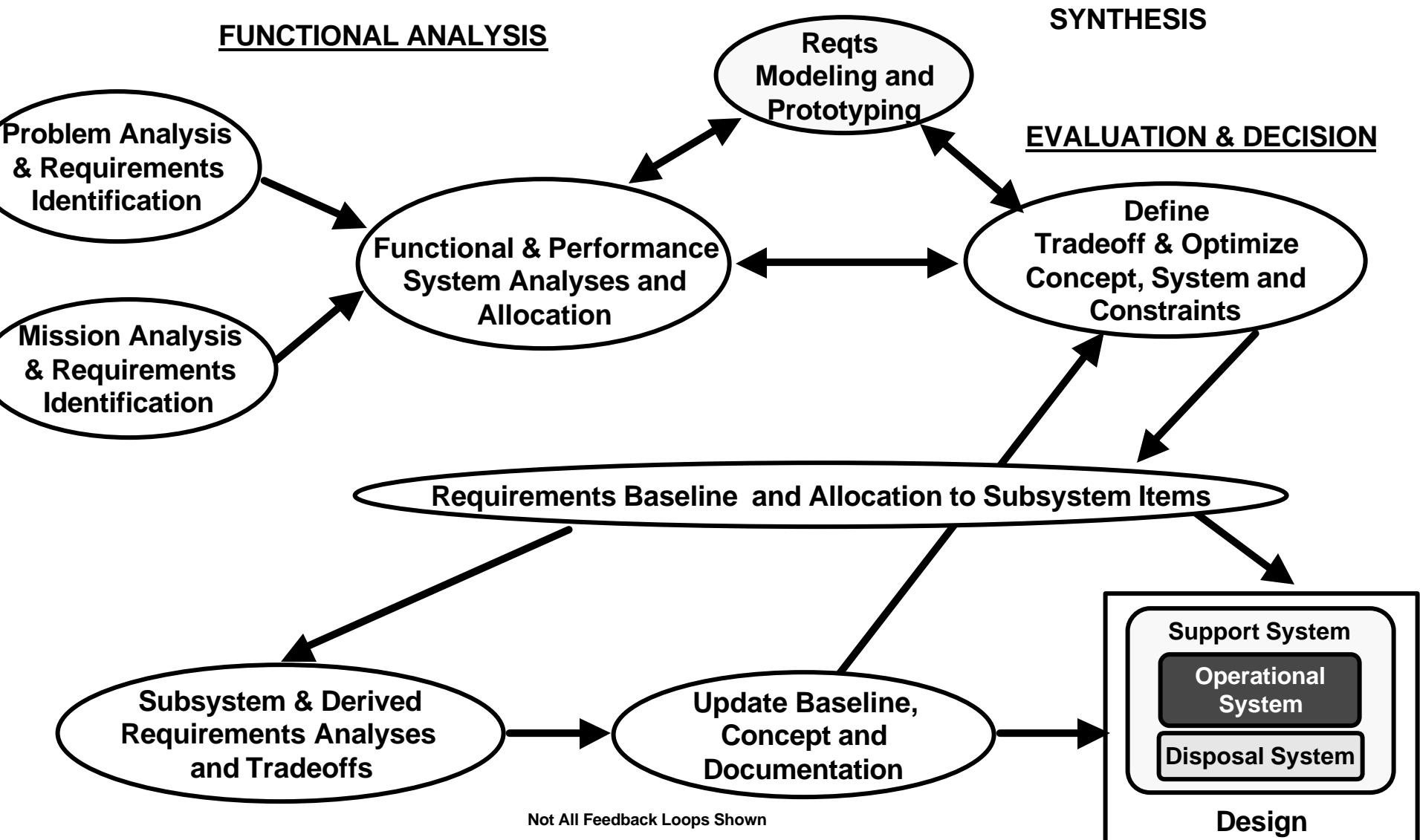
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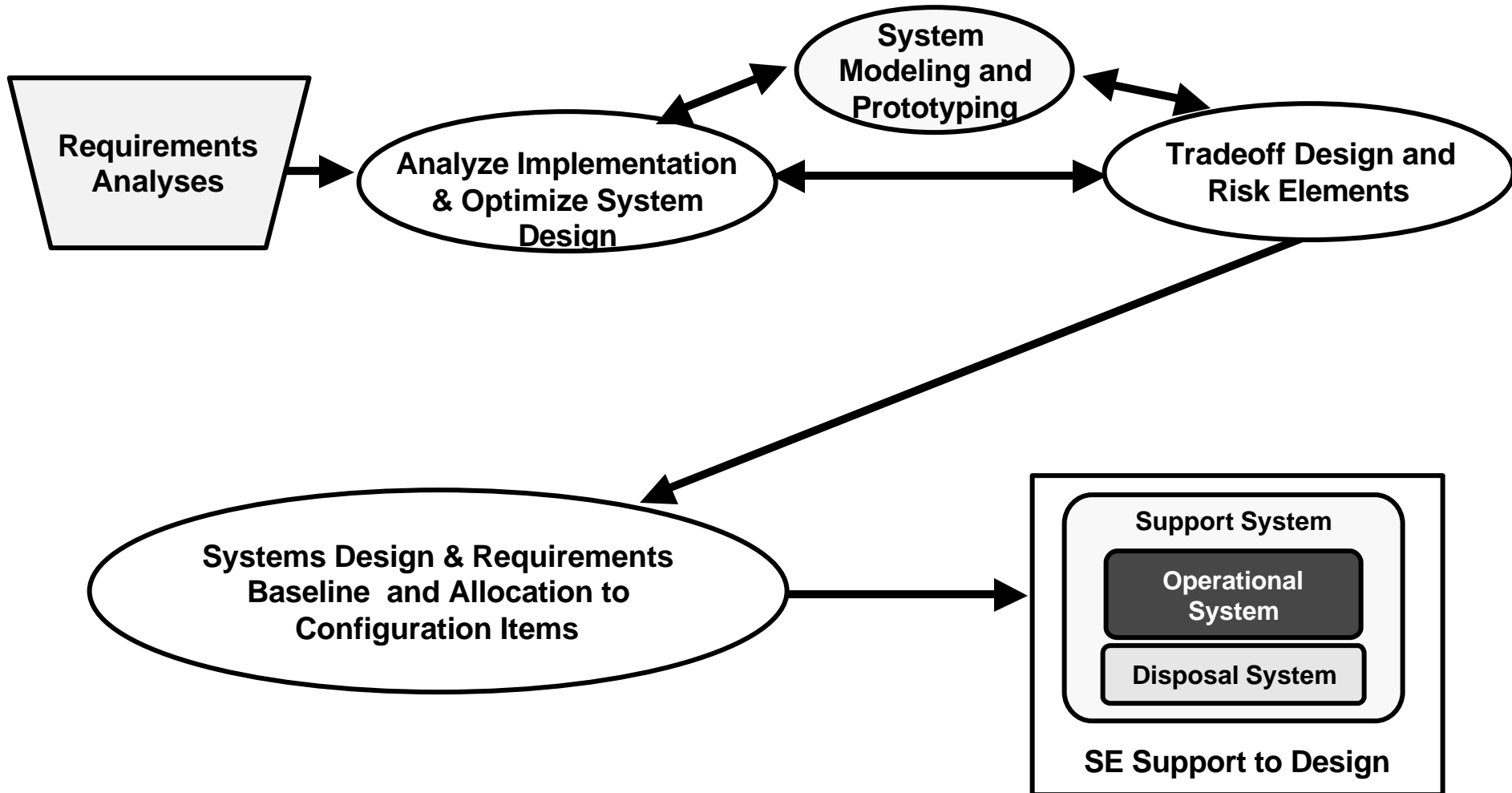
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Overview - Systems Engineering of Requirements



Overview - Systems Engineering Design

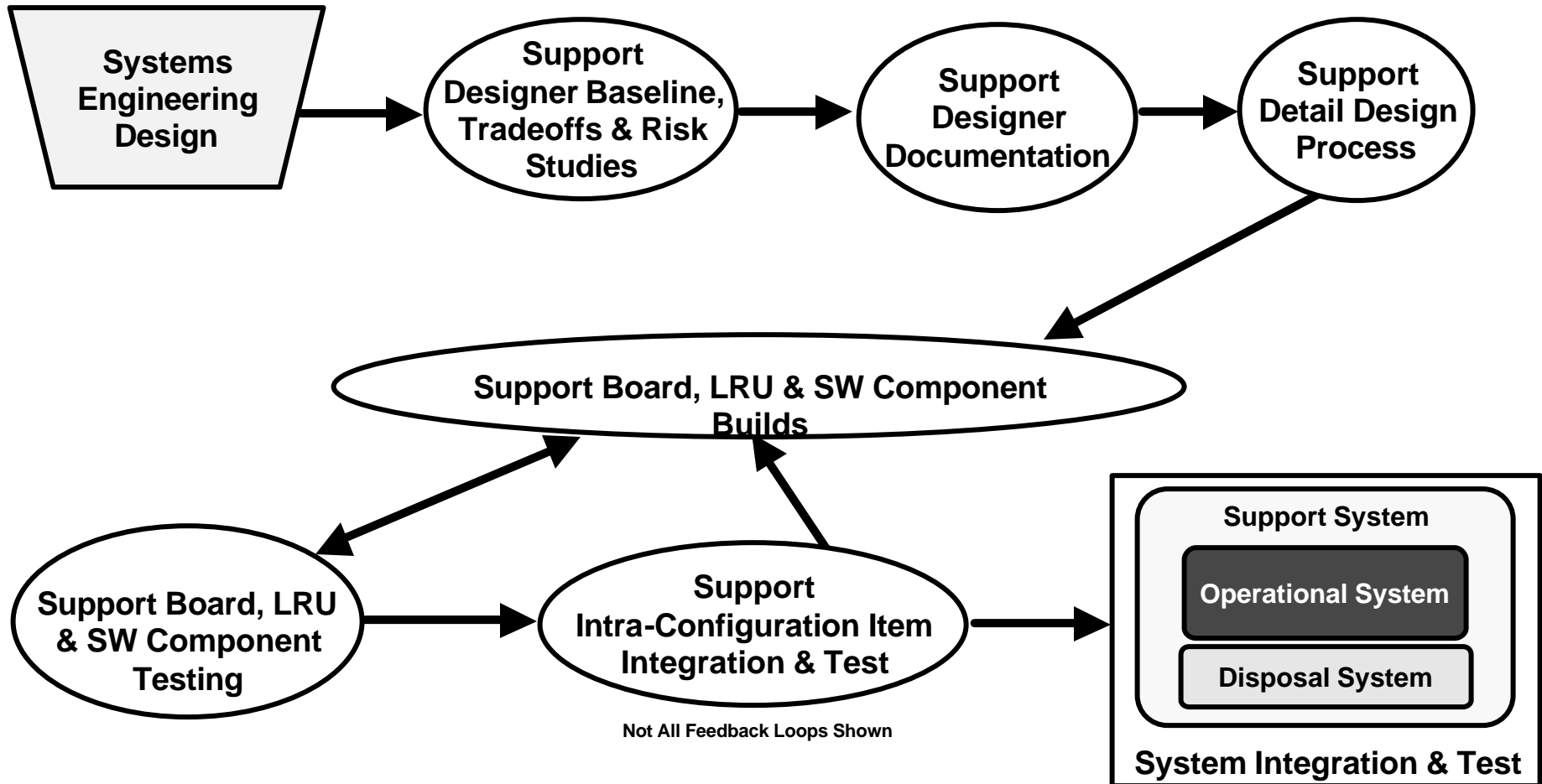


Overview - SE Support to Detail Design

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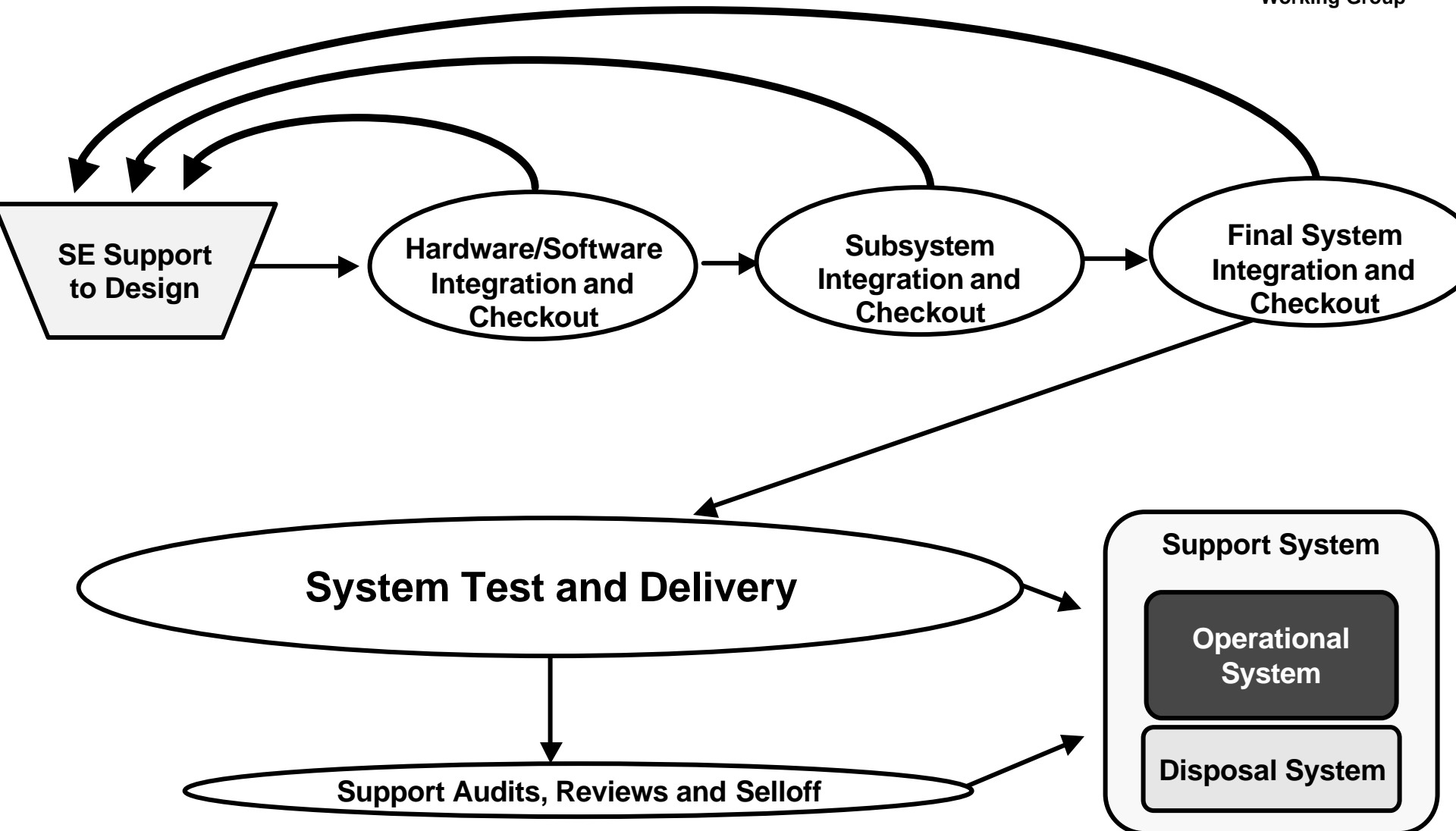


Overview - System Integration and Verification

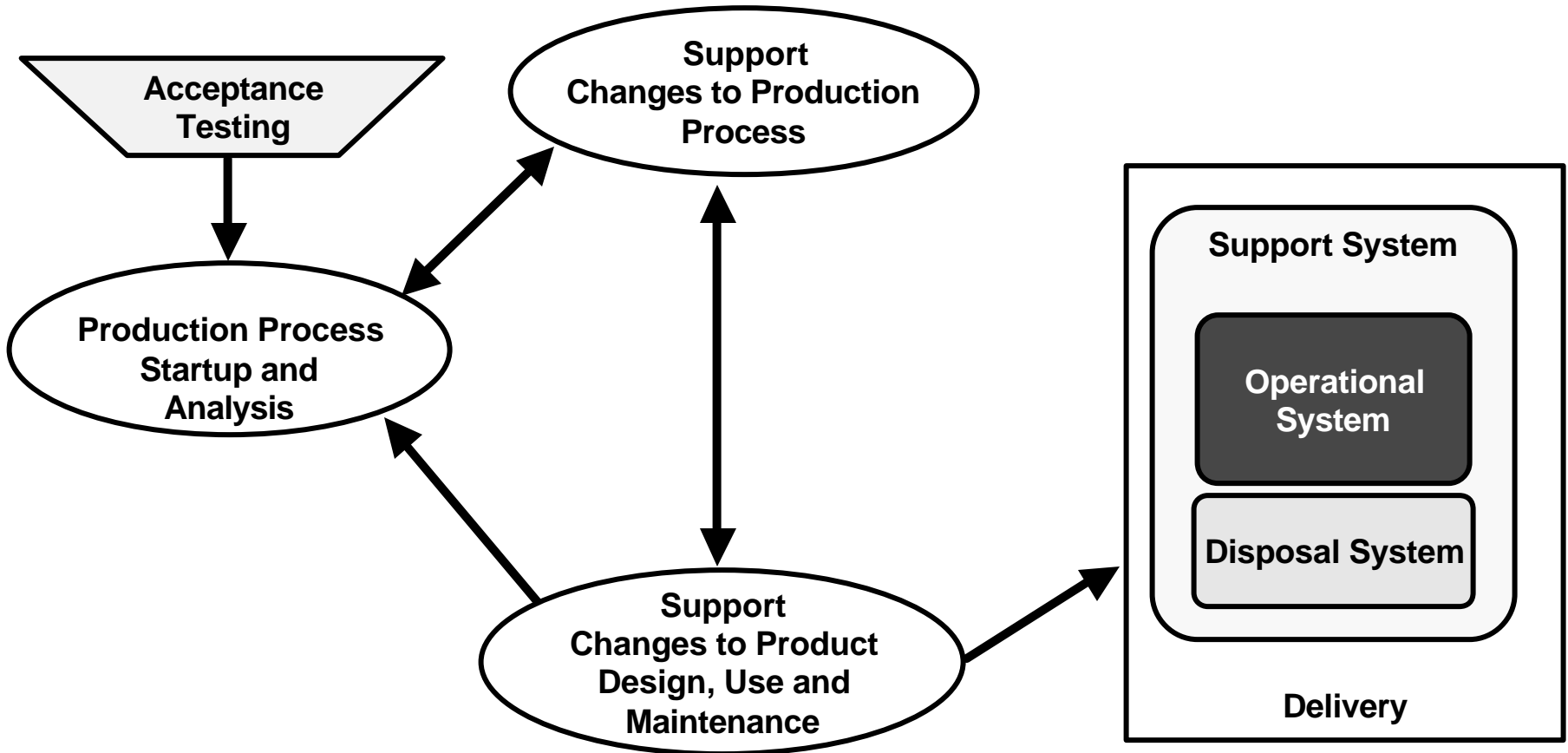
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Not All Feedback Loops Shown



Not All Feedback Loops Shown

This only completes the Development Systems Engineering

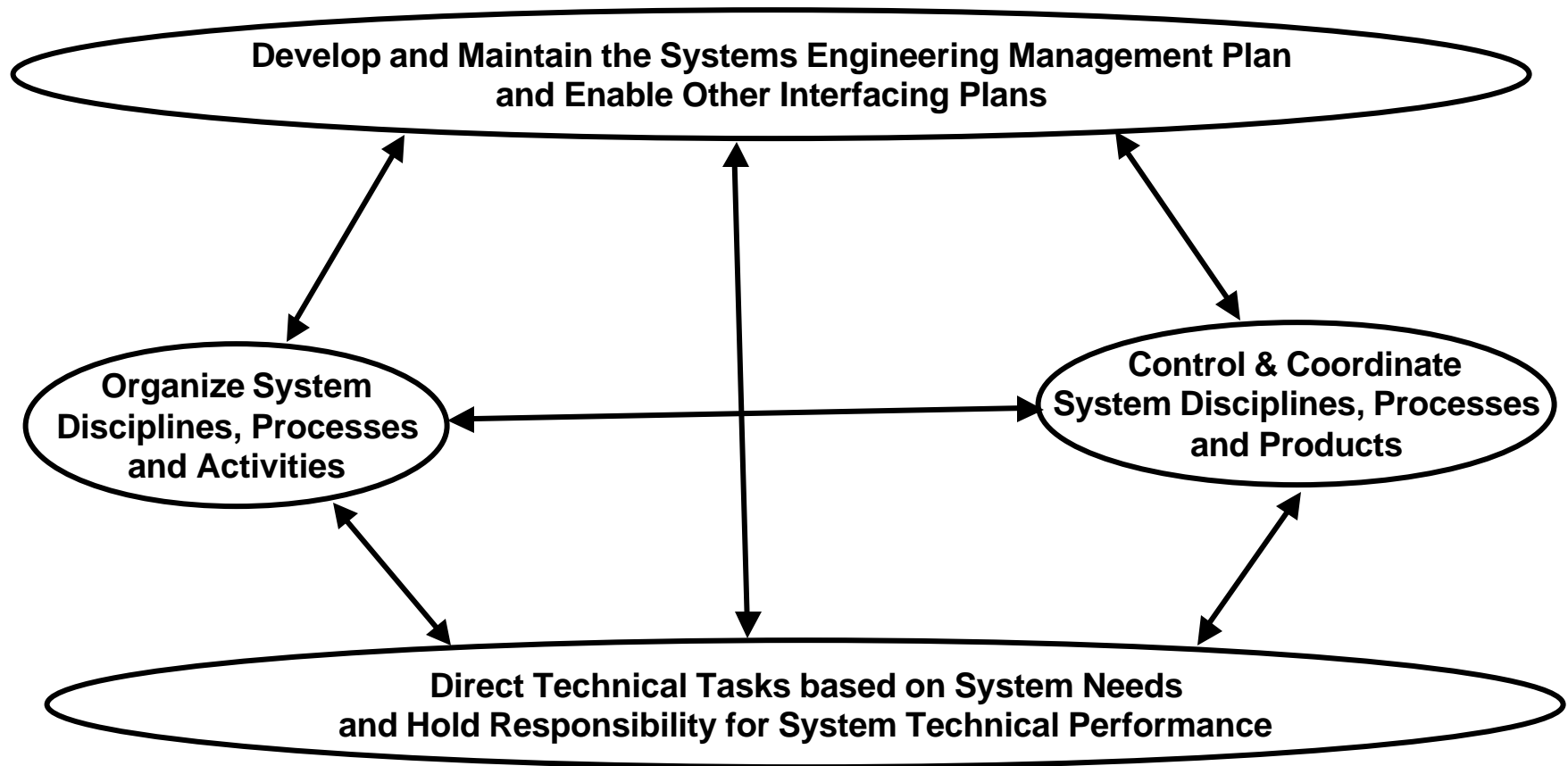


Overview - Systems Engineering Management and Control

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SE Activities Level 3

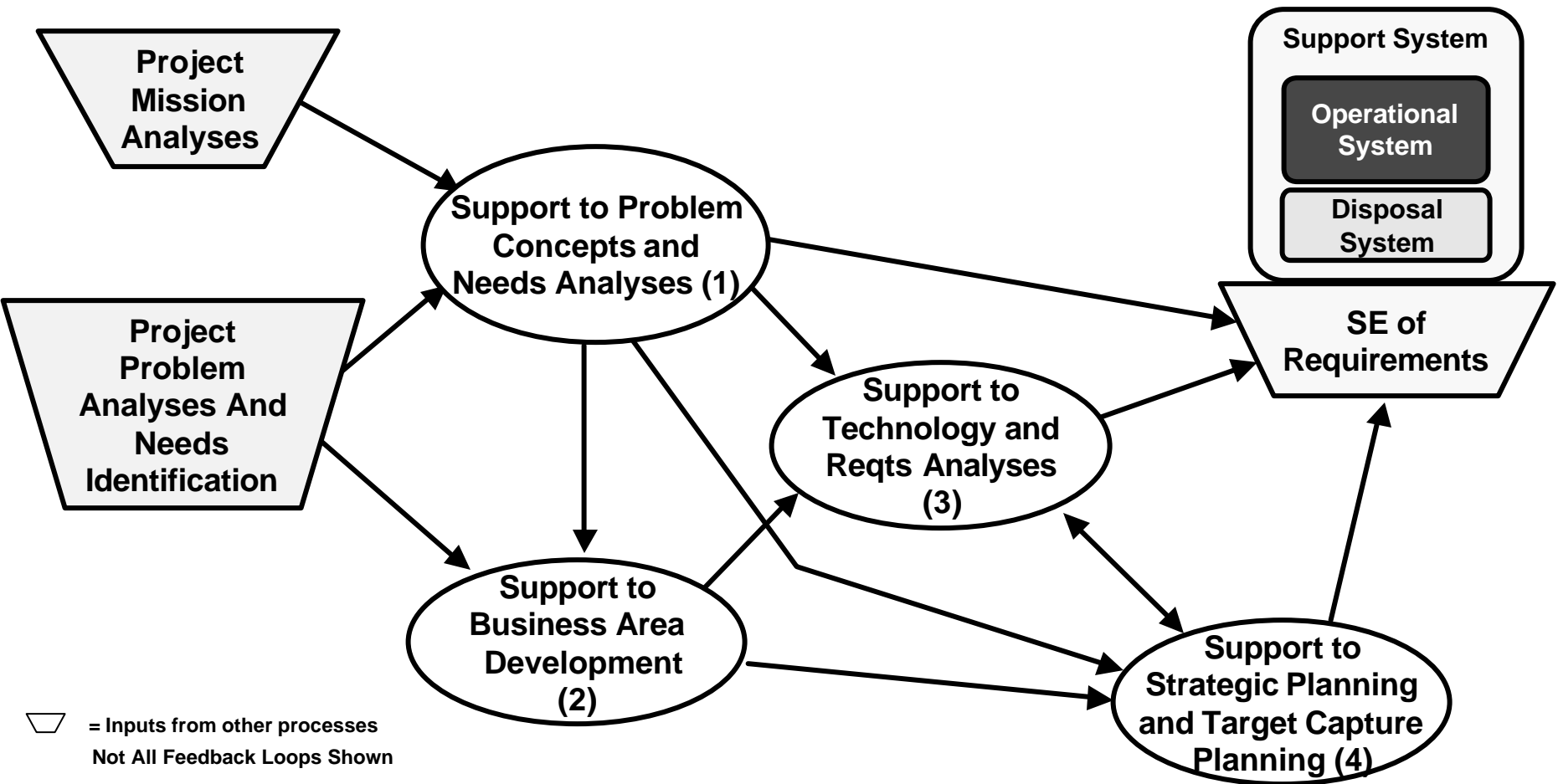
Systems Engineering Support to Strategic Planning & Needs Definition

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SE Support to Strategic Planning & Needs Defn - Part 1

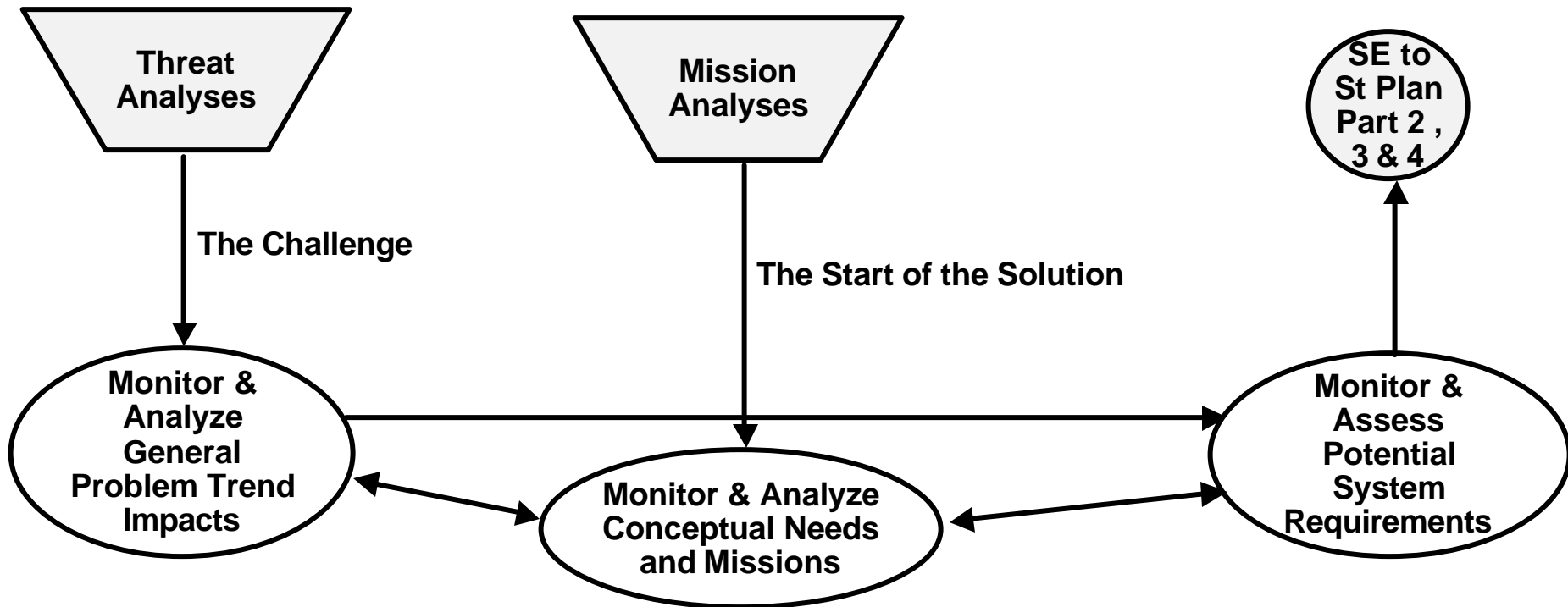
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Support to Problem Concepts & Needs Analysis

L3



Not All Feedback Loops Shown

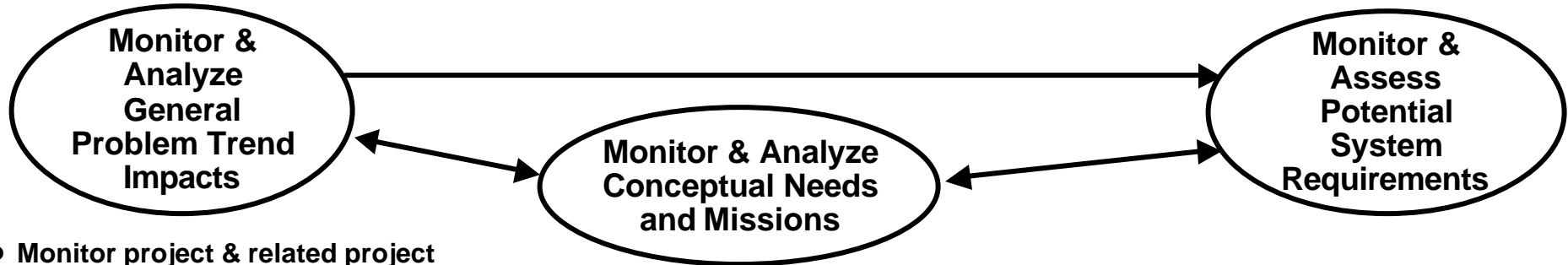
Support to Problem Concepts & Needs Analysis- Tasks

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- Monitor project & related project problem assessments
- Analyze project problem issues & commonalities
- Identify related problems impact for other business
- Coordinate problem simulations
- Define problem trends & impact on old business
- Define new business needs based on problem trends
- Define new technologies & old technology changes needed
- Perform mission operations analyses based on problem
- Analyze problem risks to systems, platforms and missions

- Monitor project mission analyses
- Perform non-project mission analyses
- Identify potential concepts
- Identify synergistic missions impact for alternative concepts
- Coordinate mission simulations
- Define mission trends impact on old concepts
- Define new concept needs based on mission trends
- Define needs of missions for new systems
- Perform mission operations analyses based on concepts

- Analyze related system funding profiles & requirements
- Monitor projects' system needs, problems & missions
- Understand key system requirements & issues
- Identify other potential projects with similar needs
- Identify & prioritize needs for technology from system viewpoint
- Assess & influence potential specifications and SOWs
- Recommend opportunities to pull new project business or contracts

SE Support to Strategic Planning & Needs Defn - Part 2

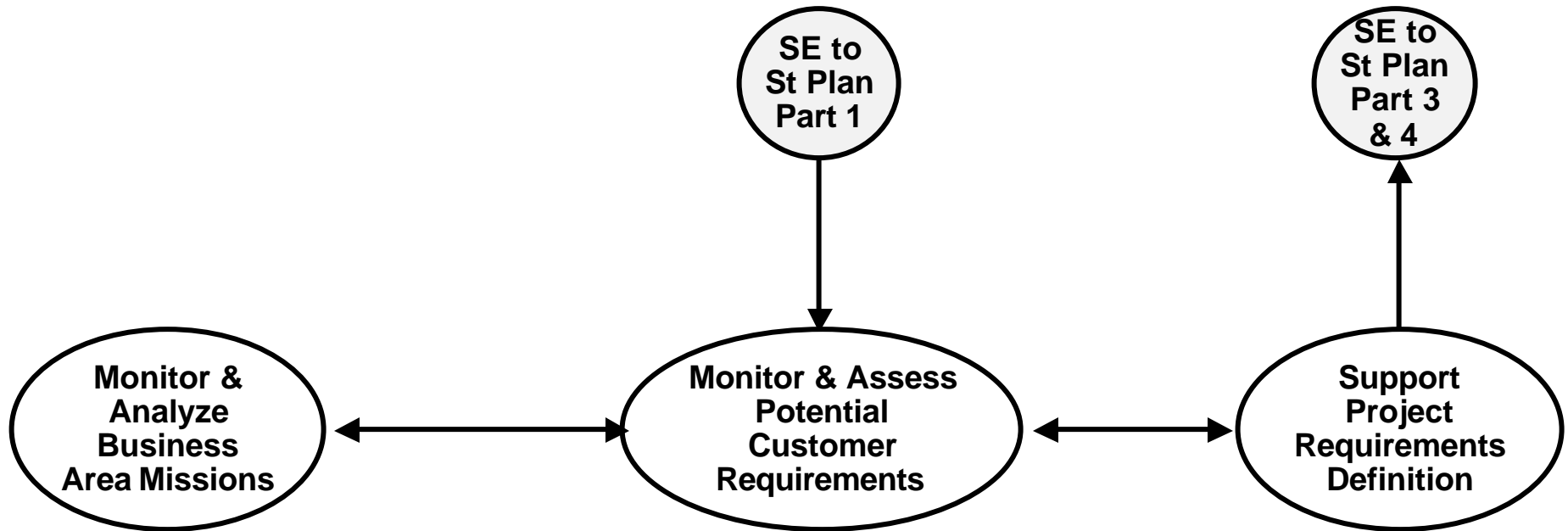
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Support to Business Area Development



Support to Business Area Development - Tasks

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- Monitor project mission analyses
- Perform business area mission analyses
- Identify potential synergistic concepts to broaden business base
- Identify potential mission impacts for other business areas
- Define mission trends impact on old business
- Define new business needs based on mission trends
- Define new customer needs based on mission trends

- Analyze customer funding profiles & requirements
- Monitor projects' customers needs, problems & missions
- Understand key requirements & issues of customers
- Identify other potential customers with similar needs
- Identify & prioritize needs for technology from customer viewpoint
- Assess & influence potential specifications and SOWs
- Recommend business opportunities to pull new business or contracts

- Analyze RFQ/RFPs, SOWs, Terms & Conditions, etc for Requirements
- Define requirements for proposals for project
- Identify previous equipment & related technology
- Assess risk of customer technical approach (for performance, schedule & funding)
- Define & assess alternatives

SE Support to Strategic Planning & Needs Defn - Part 3

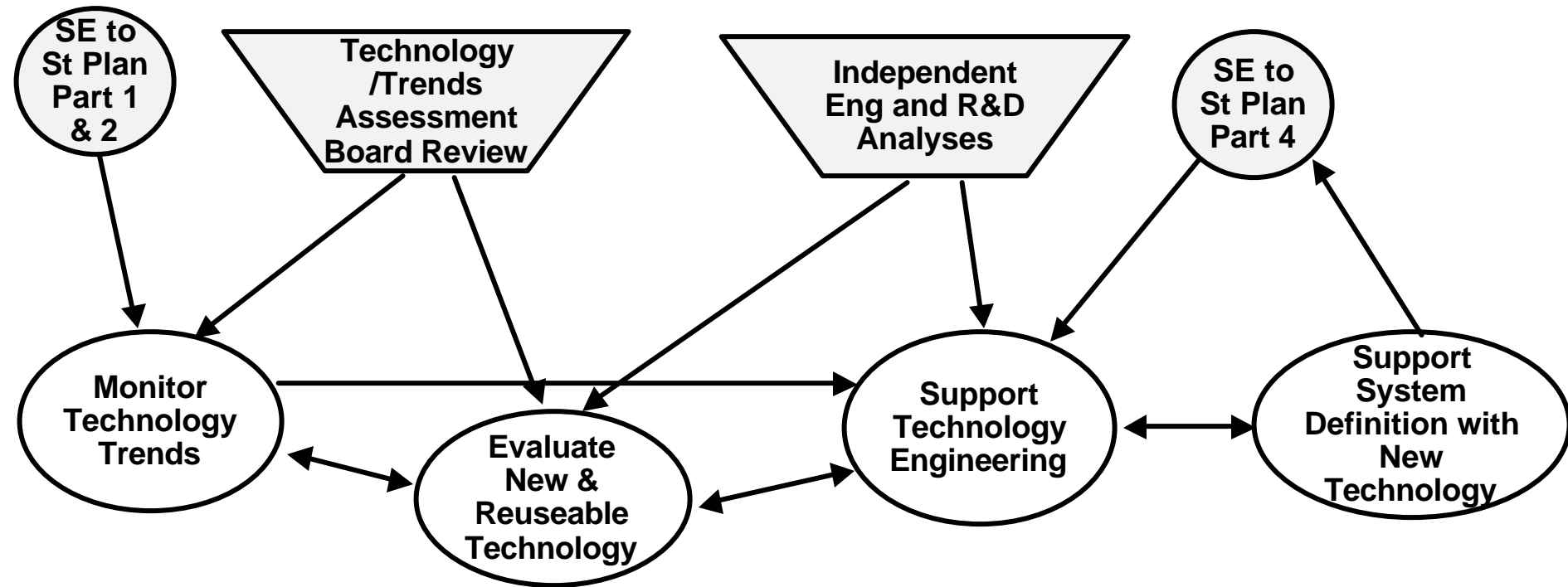
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Support to Technology & Requirements Analysis

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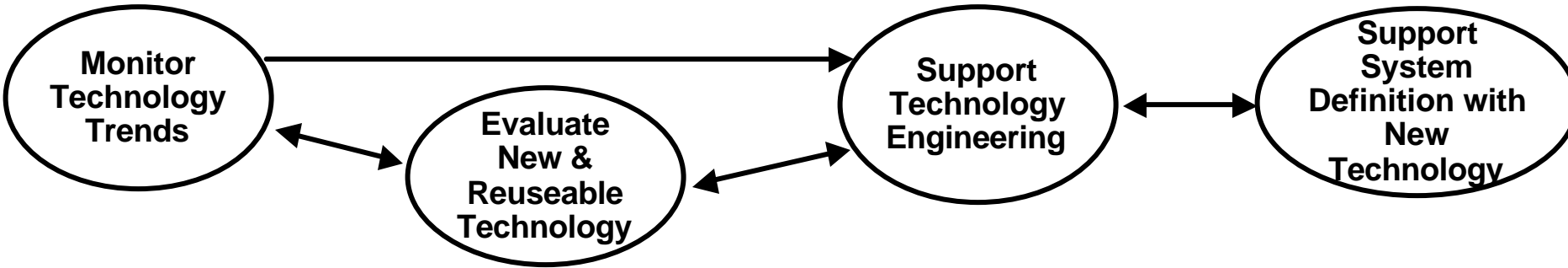
Support to Technology & Requirements Analysis- Tasks

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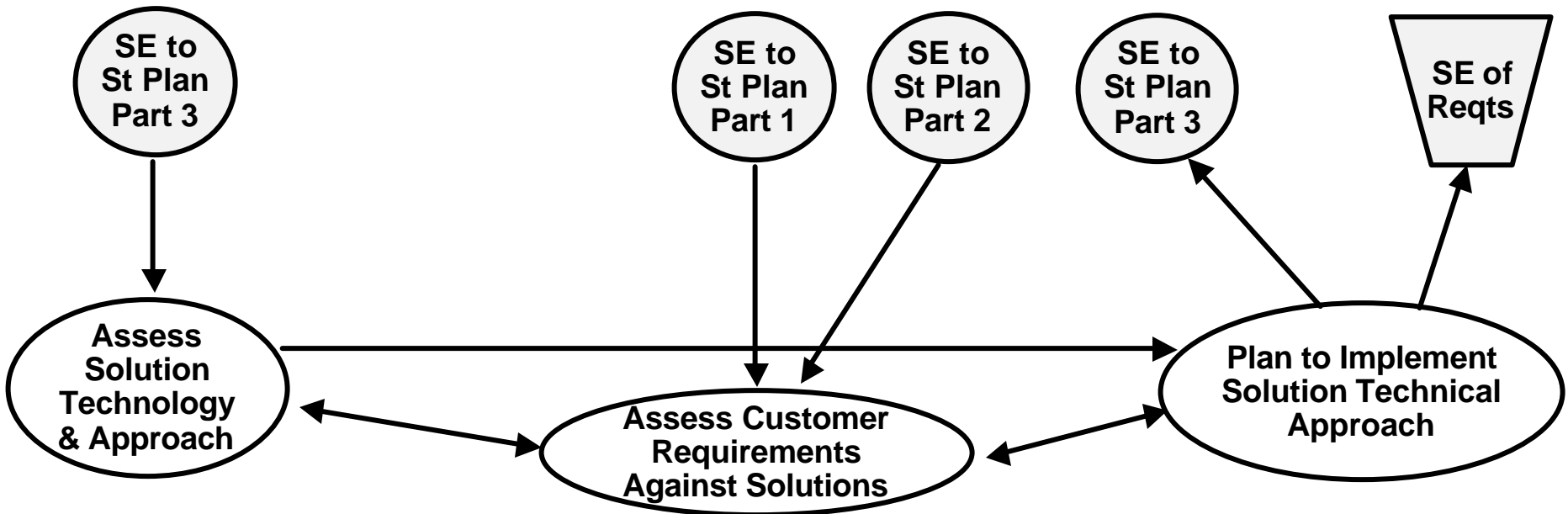
- Analyze technology trends
- Identify technology shortfalls & opportunities
- Support technology trend assessment analyses
- Support Centers for Technology analyses
- Monitor tool technology
- Identify needs for new technology & specify
 - prime equipment
 - support equipment
 - development tools
- Monitor IR&D, CR&D, Coop R&D, etc analyses & results

- Establish technology assessment criteria
- Model new technologies in simulations
- Develop technology position papers & white papers
- Analyze technology utilization & cost factors
- Identify & tradeoff technology issues
- Determine make-buy alternatives & recommend
- Assess technology risk
- Evaluate utility of R&D outside of own organization
- Establish technology availability
- Evaluate new uses for existing technology
- Recommend technologies to push

- Support IR&D planning & performance
- Support CR&D planning & performance
- Support R&D by other organizations with potential application
- Plan for technology risk reduction
- Plan for & support technology insertion

- Prepare system approaches & plans
- Develop schedules for new technology
- Support efforts to establish new projects
- Support efforts to establish new & alternative concepts & systems
- Develop operating concepts for new or alternative systems

Support to Strategic Planning & Target Capture Planning



Support to Strategic Planning & Target Capture Planning - Tasks

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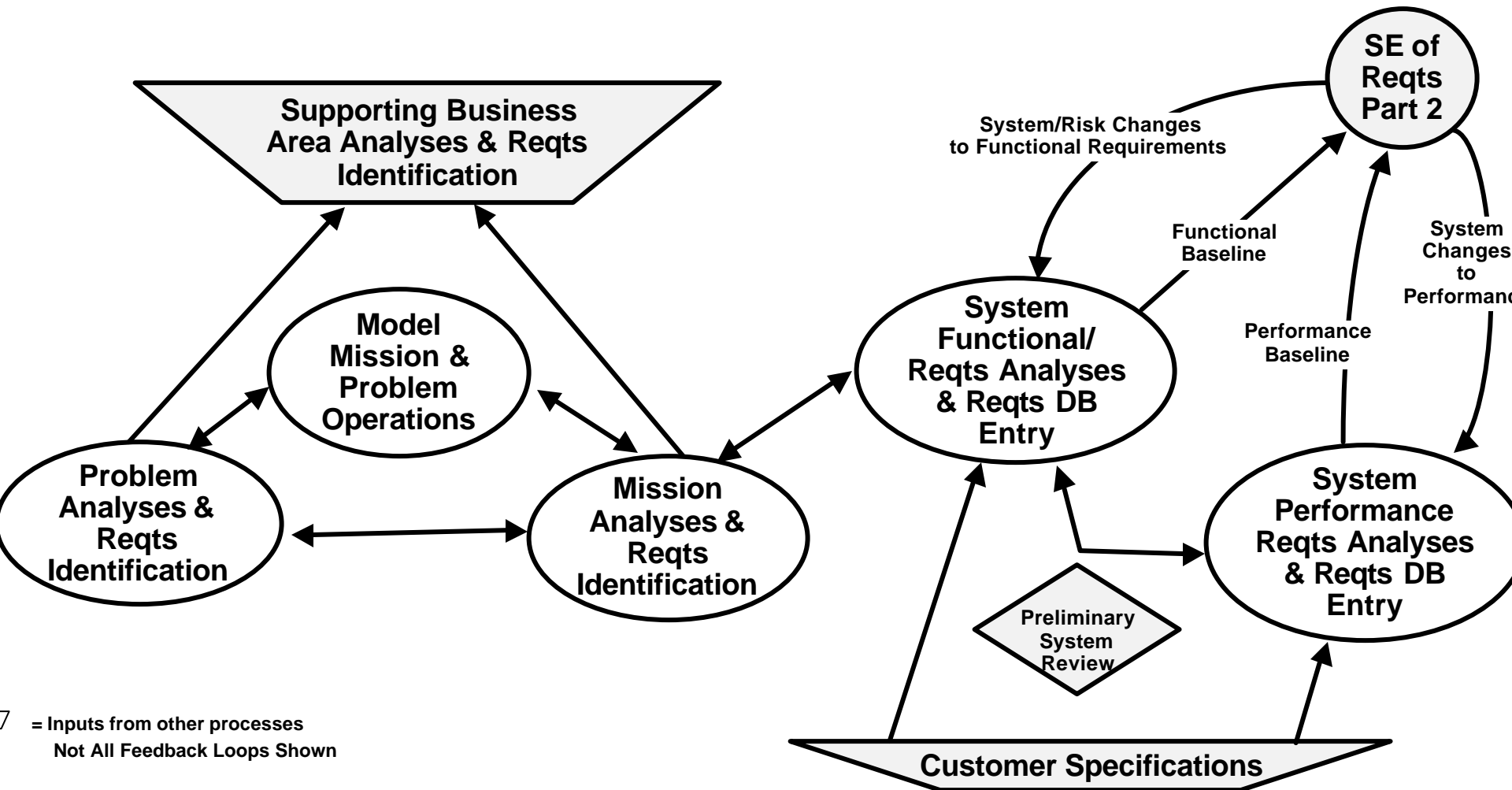


- Assess maturity & time to implement solution technology
- Identify & evaluate cost drivers for the technology
- Identify & evaluate commonality & reuseability of elements of the technology
- Identify & evaluate use of standard methodologies & tools
- Develop evaluation criteria for alternative technology approaches
- Estimate technology performance
- Model technology in simulations
- Develop decision criteria
- Develop analytical techniques
- Develop approaches to increase productivity

- Understand customer requirements
- Assess previous use of similar technology (by customer)
- Assess availability of technology
- Develop solution system architecture for customer
- Assess solution vs requirements in simulations
- Assess affordability of solutions

- Develop technical roadmaps
- Identify objectives for IR&D, CR&D, etc and analyses
- Define priorities for IR&D, CR&D, etc
- Develop pro-forma plans & documentation
- Develop system strategies, concepts, alternatives, constraints & recommendations
- Develop budget strategies & financial alternatives
- Define system development & technical approaches
- Develop implementation strategy
- Prepare target capture documentation inputs
- Prepare proposal inputs

Problem, Mission & Requirements Analysis



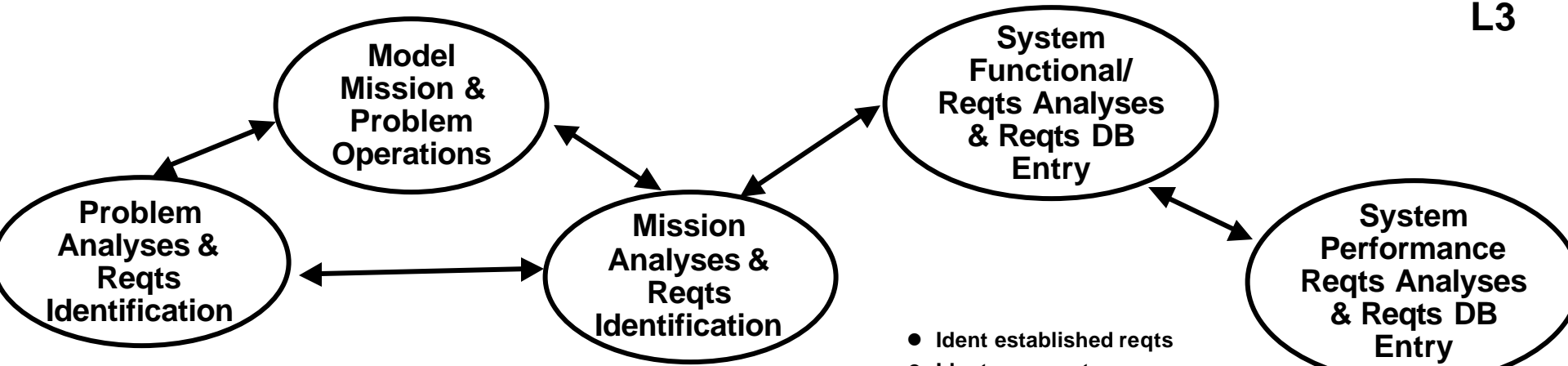
Problem, Mission & Requirements Analysis - Tasks

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- Analyze problems & customer operations
- Develop
 - Problem & process defn
 - Event sequences
 - Process timelines
 - False alarm defn

- Model operational environment with problems & missions
- Develop simulations
- Validate simulations

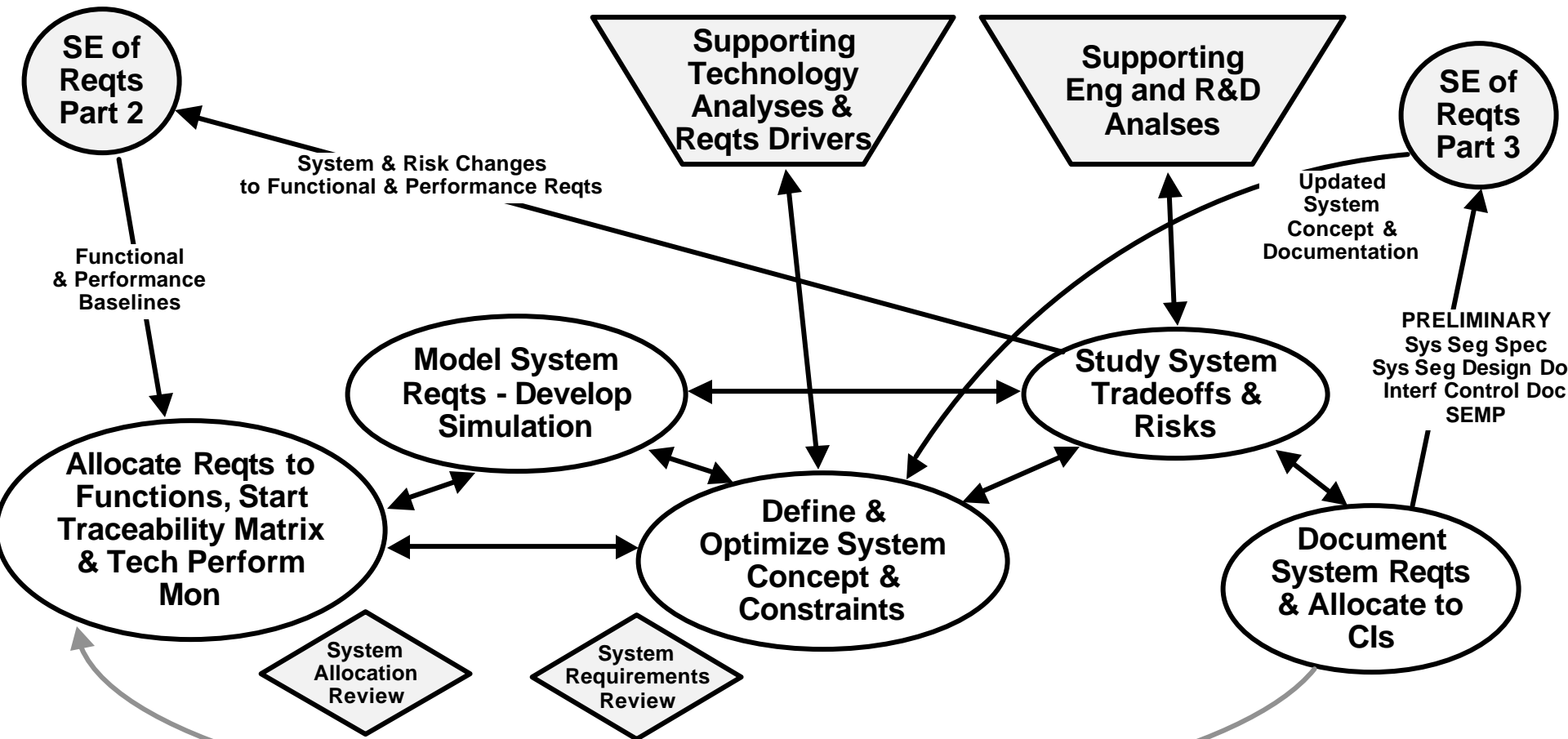
- Analyze operating profiles & scenarios
- Analyze environ factors
- Analyze customer utilization
- Analyze mission timelines
- Analyze mission operations plans
- Analyze mission effectiveness
- Analyze supportability factors:
 - Testability
 - Producibility
 - Maintainability
 - Reliability
 - Tooling
- Identify maintenance concepts

- Ident established reqts
- Ident new reqts
- Ident:
 - Primary functions
 - Support functions
- Ident functional flows & interfaces
- Ident subfunc reqts
- Ident field service reqts
- Analyze maintenance concepts
- Analyze supportability:
 - Testability
 - Producibility
 - Maintainability
 - Reliability
 - Tooling
- Coordinate & verify reqts
- Estab reqts data base (DB)
- Enter qualitative reqts

- Analyze parametric reqts:
 - Sensitivity
 - Throughput
 - Input/Output
 - Size & Weight
 - Heat dissipation
 - Power & range
 - etc.
- Analyze timelines
- Analyze "ilities" impact on sys effectiveness
- Analyze R&M performance reqts
- Enter quantitative reqts

Not All Feedback Loops Shown

Requirements Allocation & System Concept Optimization



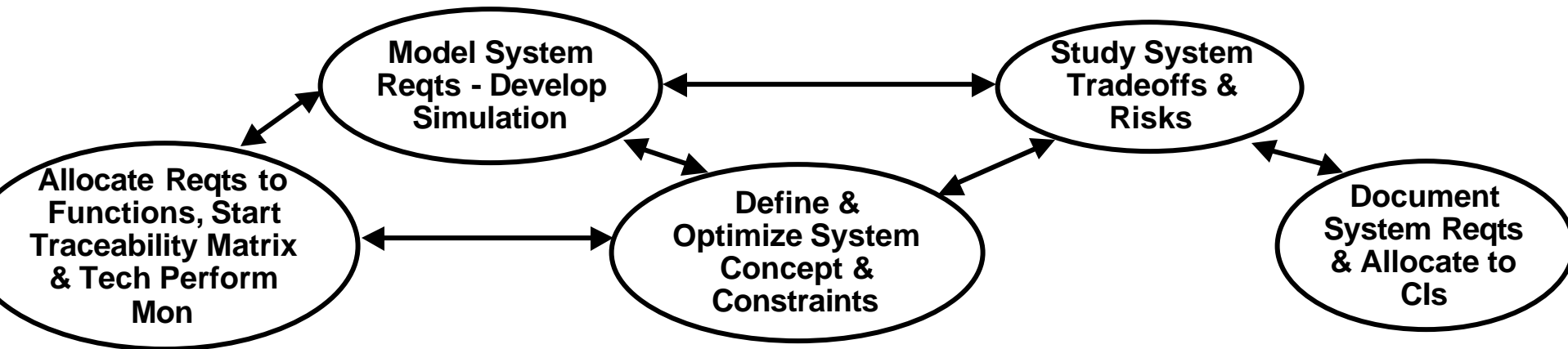
Requirements Allocation & System Concept Optimization - Tasks

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- Prepare allocated func & perform baseline for:
 - Prime elements
 - Support elements
 - Test elements
- Define tech perform measures
- Identify traceability elements of reqts DB
- Coord & verify reqts

- Model reqts of system
- Develop simulations
- Validate simulations
- Investigate func & perform reqts in simulated environment

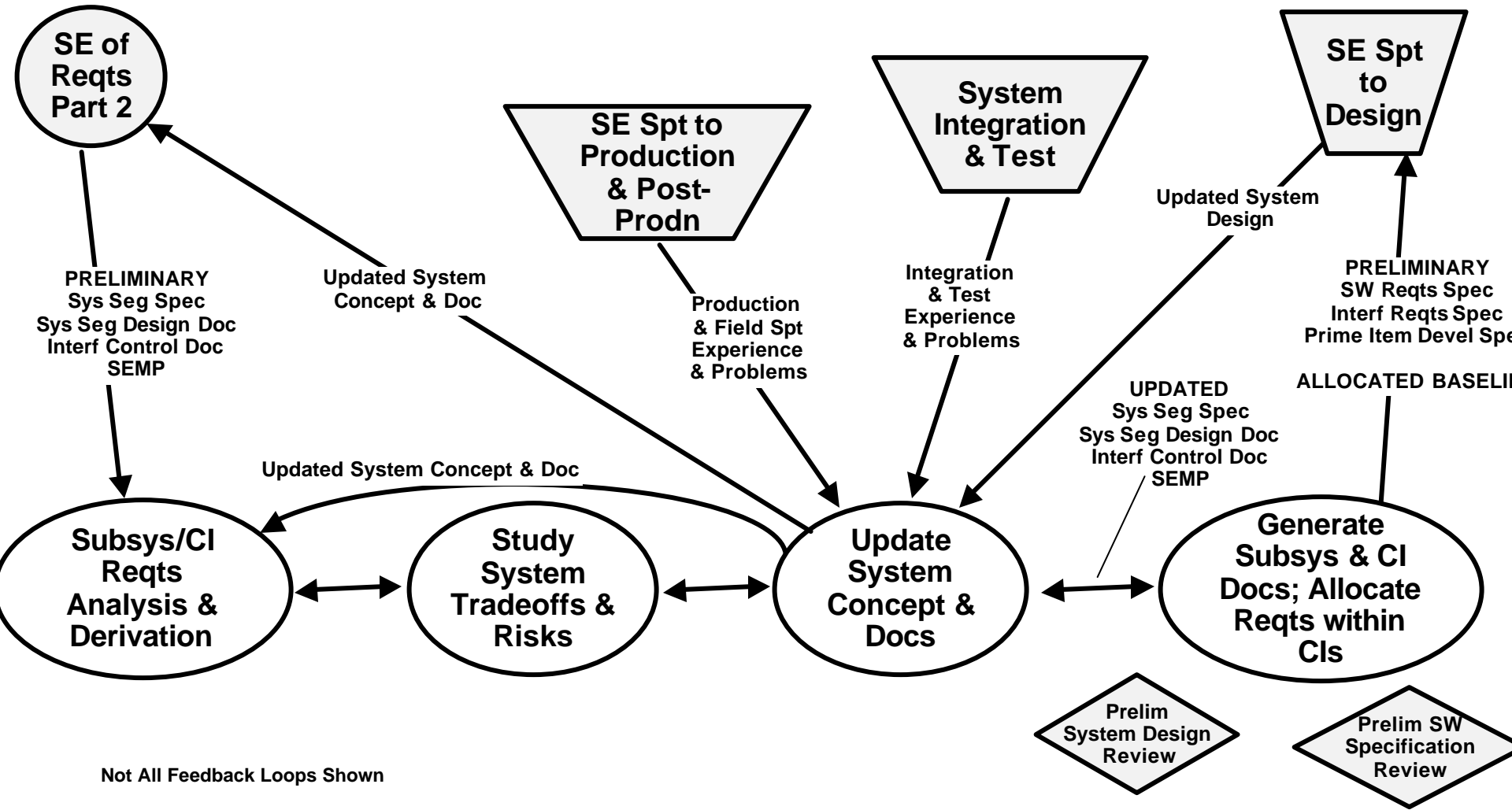
- Assess system simulation
- Develop CWBS
- Build spec tree
- Develop system architecture
- Check impact of new technol
- Check impact of updated sys concept & doc
- Refine sys interfaces
- Assess sys trades impact on sys concept
- Assiss risk impact on sys concept
- Define system: Prime, Support & Test Elements
- Assess shortfalls in sys concept or reqts
- Definitize config items (CI)

- Ident needs for sys studies
- Ident sys analysis methodology
- Ident tech sys issues & assumptions
- Assess perform & cost alternatives
- Assess Prime, Support & Test func & perform tradeoffs
- Analyze logistics spt
- Generate SEMP

- Prepare sys specs
- Prepare allocated sys reqts baseline
- Define Prime, Support & Test CIs and/or their reqts

Not All Feedback Loops Shown

Subsystem Requirements Analysis & Concept Update



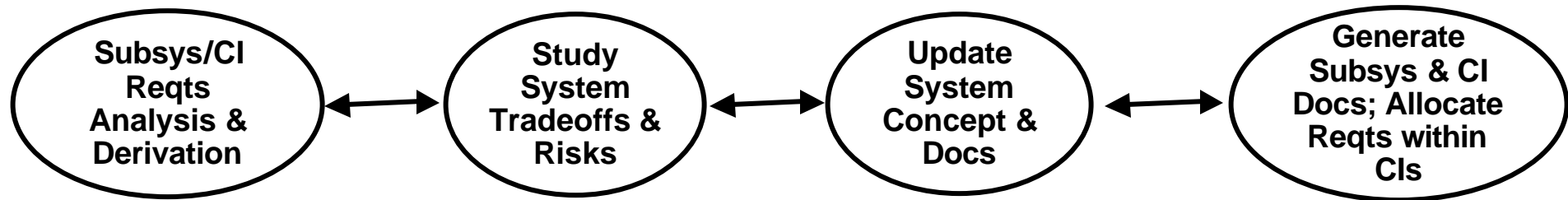
Subsystem Requirements Analysis & Concept Update - Tasks

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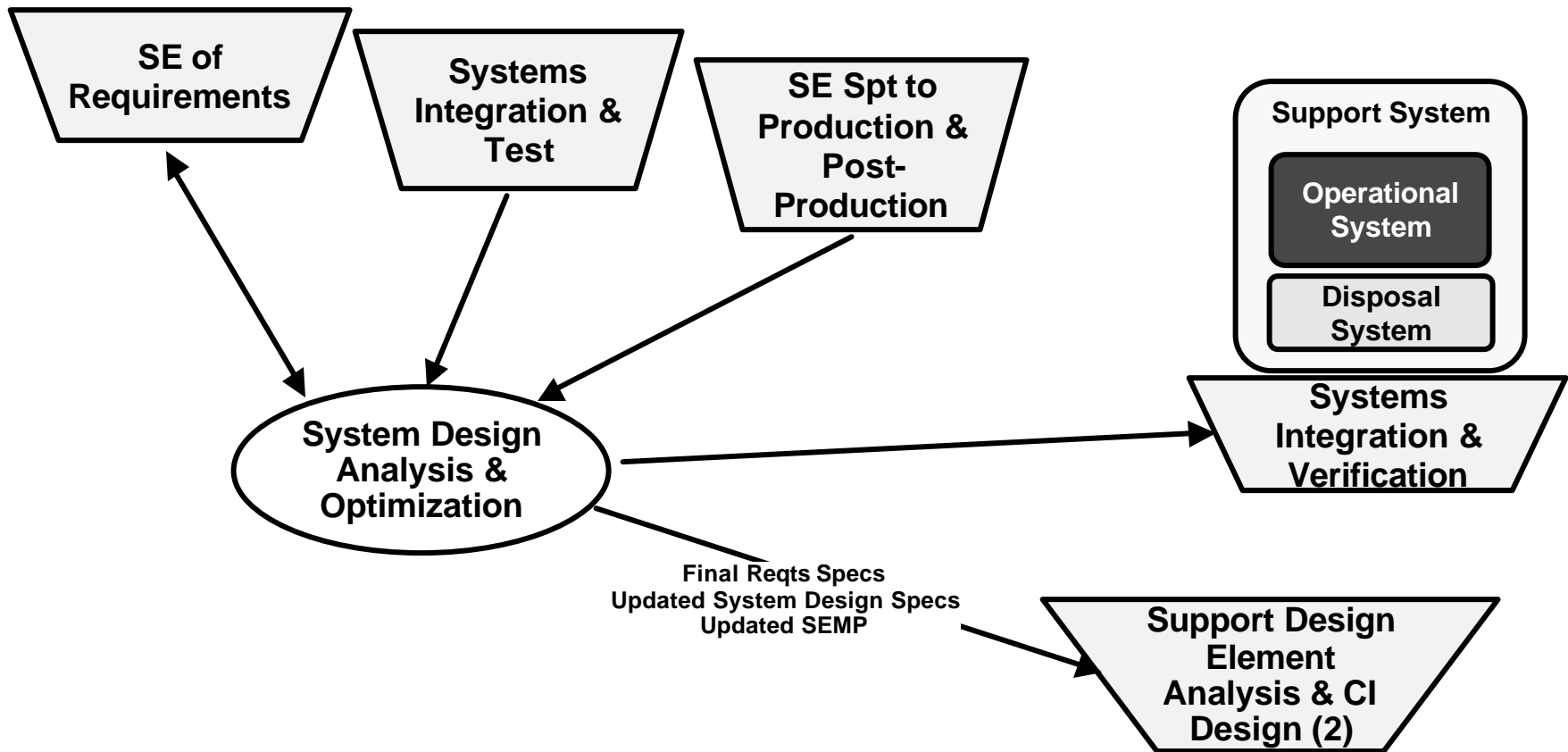
- Check impact on subsys & changes to system
- Derive lower level func & perform reqts for:
 - Prime subsys/CIs
 - Support subsys/CIs
 - Test subsys/CIs

- Ident needs for subsys or CI studies
- Ident analysis methodologies
- Ident tech issues & assumptions
- Assess perform & cost alternatives
- Assess subsys & CI logistics reqts

- Assess subsys & CI reqts
- Assess subsys & CI trades
- Assess subsys & CI risks
- Determine scope of impact beyond subsys & CI
- Establish need for change to sys concept or documents
- Update sys concept or documents
- Check sys design against sys concept & sys reqts
- Update SEMP

- Prepare prelim subsys reqts specs
- Generate prelim docs for design eng allocation
- Prepare allocated CI reqts baseline for:
 - Prime subsys/CIs
 - Support subsys/CIs
 - Test subsys/CIs
- Analyze lessons learned

Not All Feedback Loops Shown



= Inputs from other processes
Not All Feedback Loops Shown



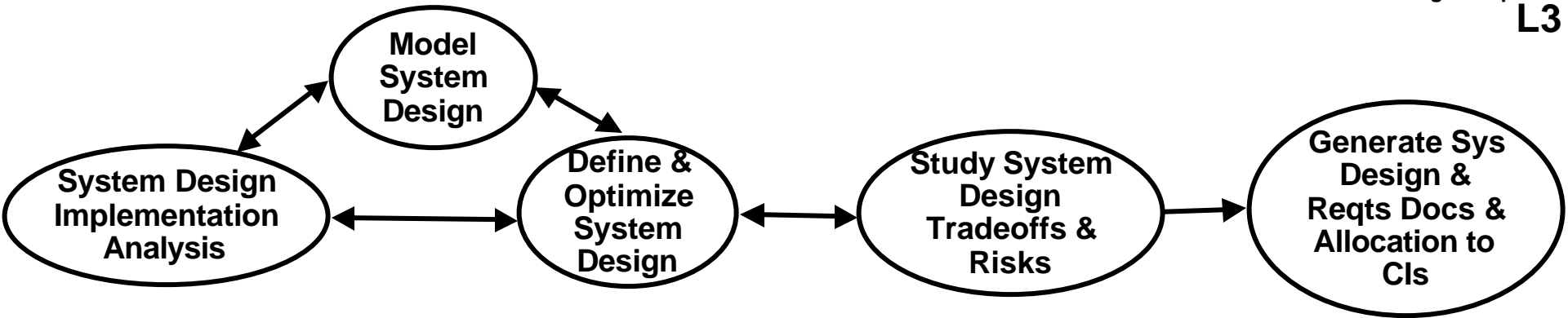
System Design Analysis & Optimization - Tasks

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- Establish design breakdowns
- Etab design parameters
- Etab design timelines
- Etab design operation
- Etab design to unit production cost goals
- Etab allocation of design tasks to design team members/vendors

- Model system as designed
- Develop simulation
- Validate simulation

- Assess design simulation
- Refine sys architecture
- Design sys interfaces
- Assess design trades impact on sys design
- Assess risk impact on sys design
- Assess design of Prime, Support & Test elements
- Assess shortfalls in sys design
- Ident sys test needs
- Update SEMP

- Ident needs for design & implementation studies
- Ident analysis methodology
- Ident tech issues & assumptions in design or reqts
- Assess alternatives, results & drivers
- Assess potential reqts changes
- Assess design trades for Prime, Support & Test elements
- Do sys design to unit production cost analysis
- Do design logistics support analysis

- Prepare prelim sys design specs
- Finalize sys & CI reqts specs
- Prepare allocated CI design baseline
- Allocate design to unit production cost goals to subsys & CIs

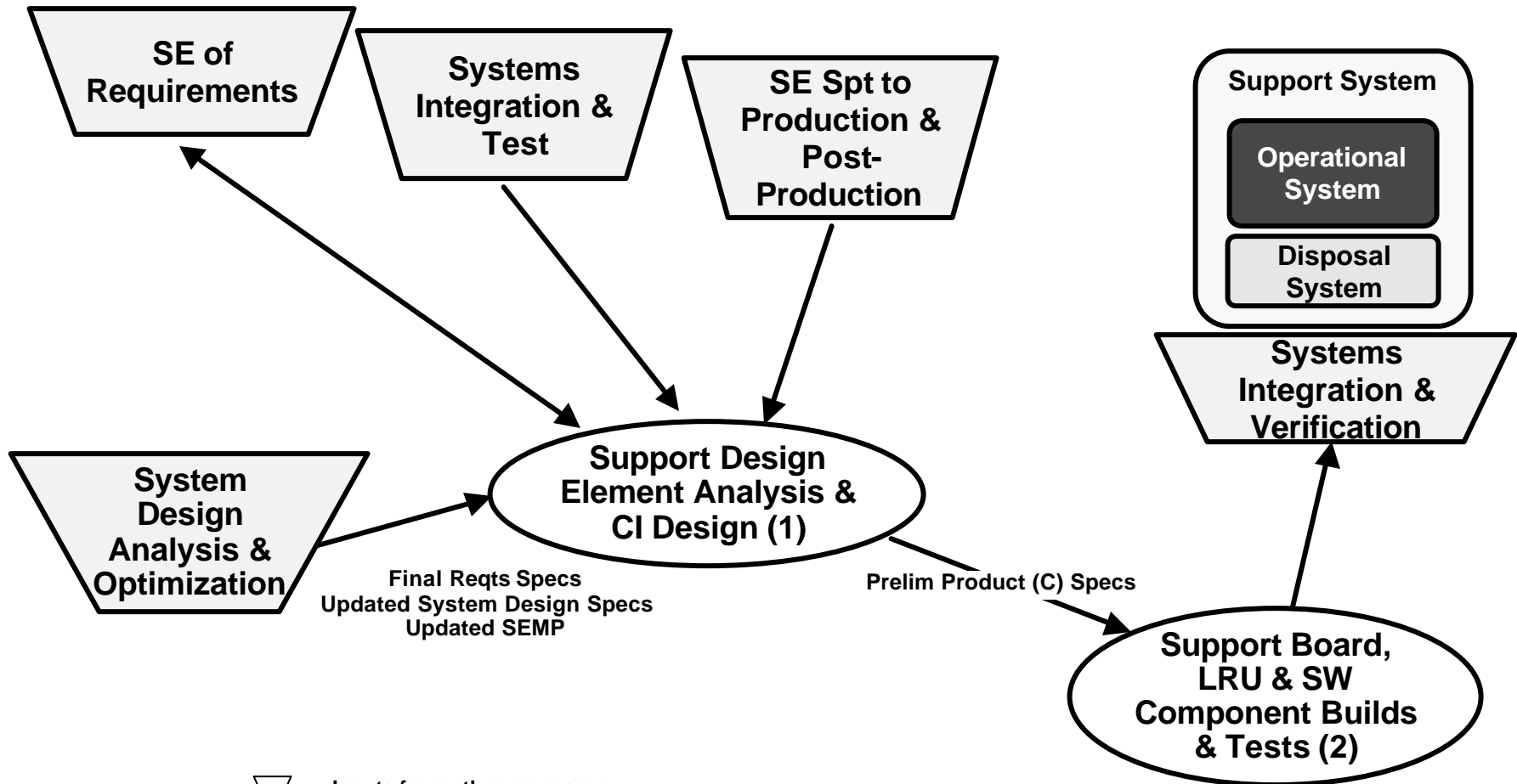
Not All Feedback Loops Shown

Systems Engineering Support to Detail Design

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= Inputs from other processes
Not All Feedback Loops Shown

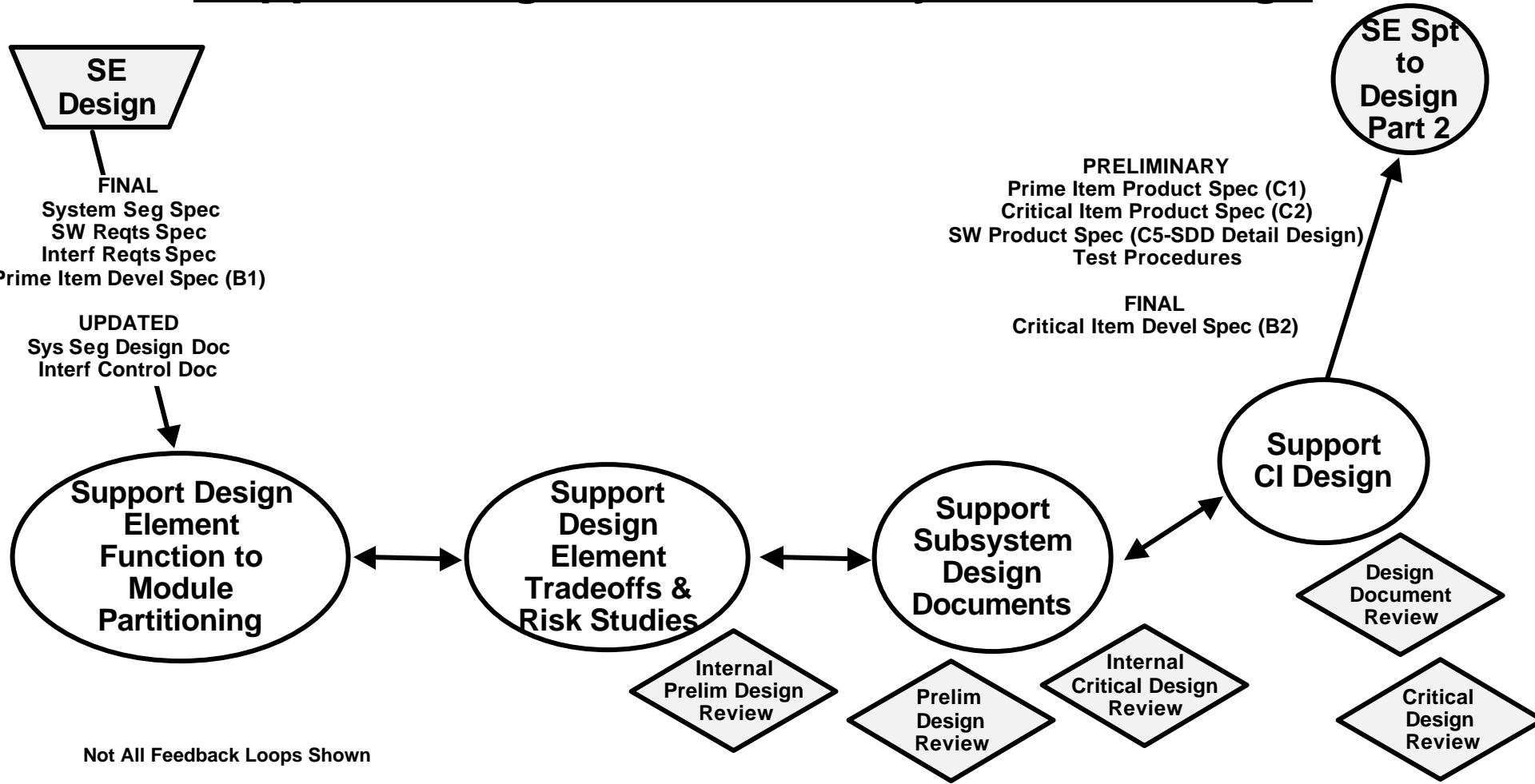
SE Support to Detail Design - Part 1

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Support Design Element Analysis & CI Design



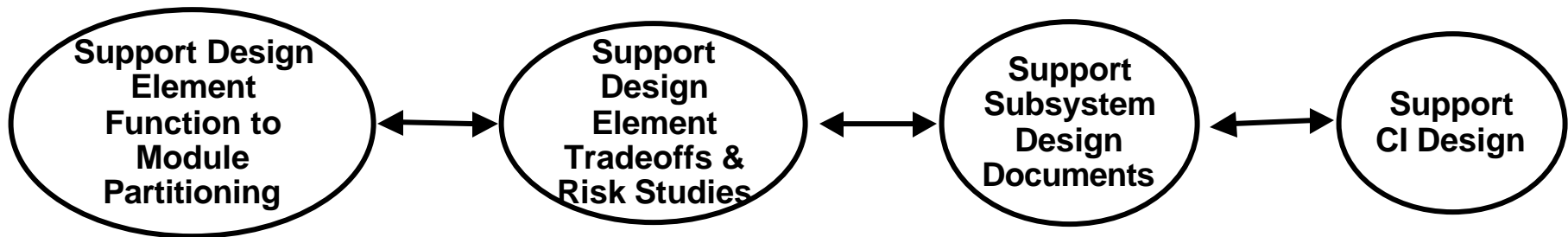
Support Design Element Analysis & CI Design - Tasks

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- Attend design reviews
- Assess design element impact on sys design
- Monitor design performance
- Define design element baseline
- Verify module reqts partitioning

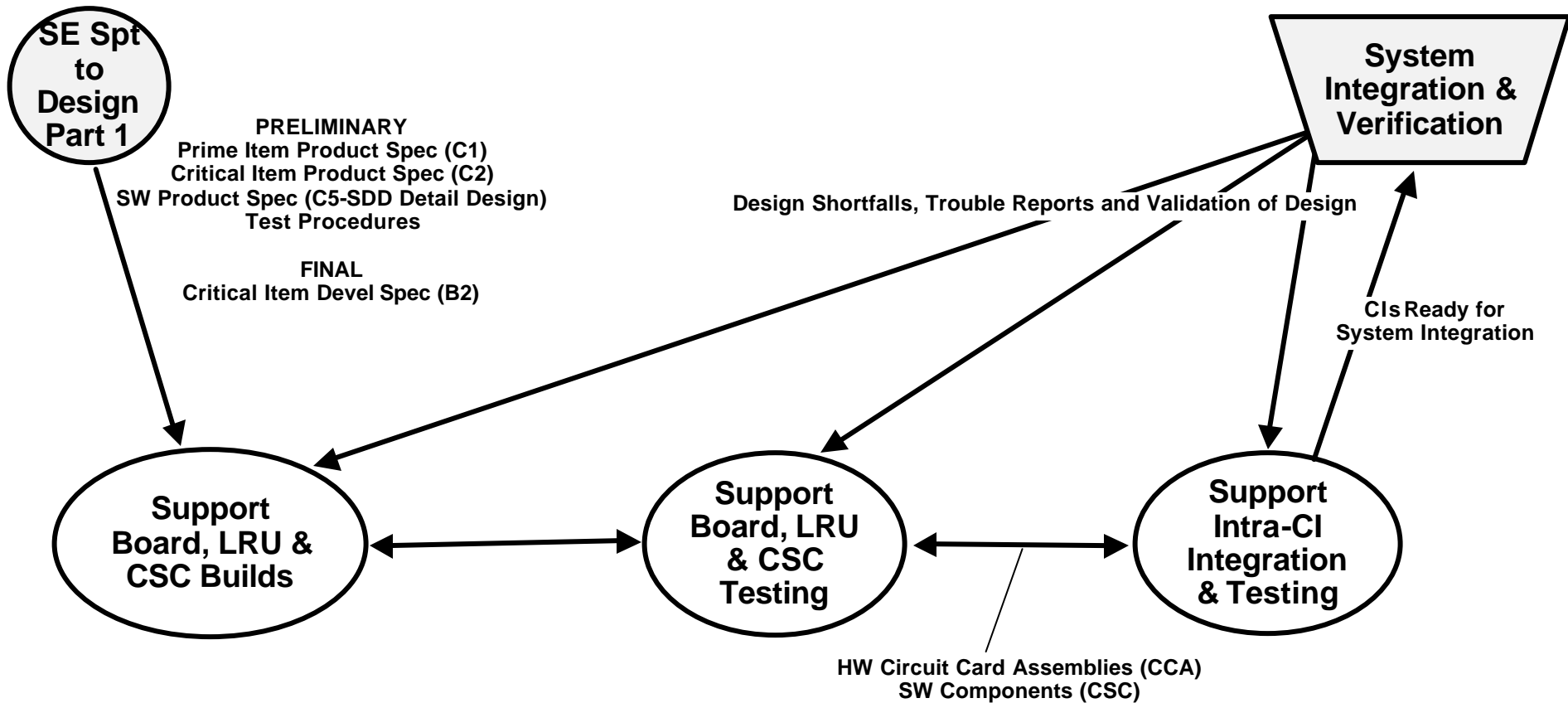
- Review design element trades planning, process & results
- Assess analysis methodology, assumptions, issues & alternatives
- Assess potential design element changes
- Assess design element supportability & testability

- Support prelim build-to product specs
- Finalize critical item devel specs
- Verify product specs

- Attend design reviews
- Assess design element impact on sys design
- Monitor design performance
- Define design element baseline
- Verify lower level design reqts

SE Support to Detail Design - Part 2

Support Board, LRU & SW Component Builds & Tests



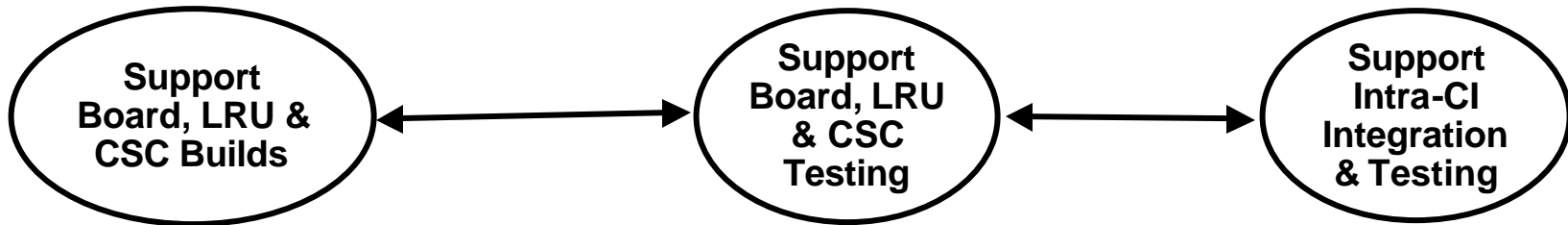
Support Board, LRU & SW Component Builds & Tests - Tasks

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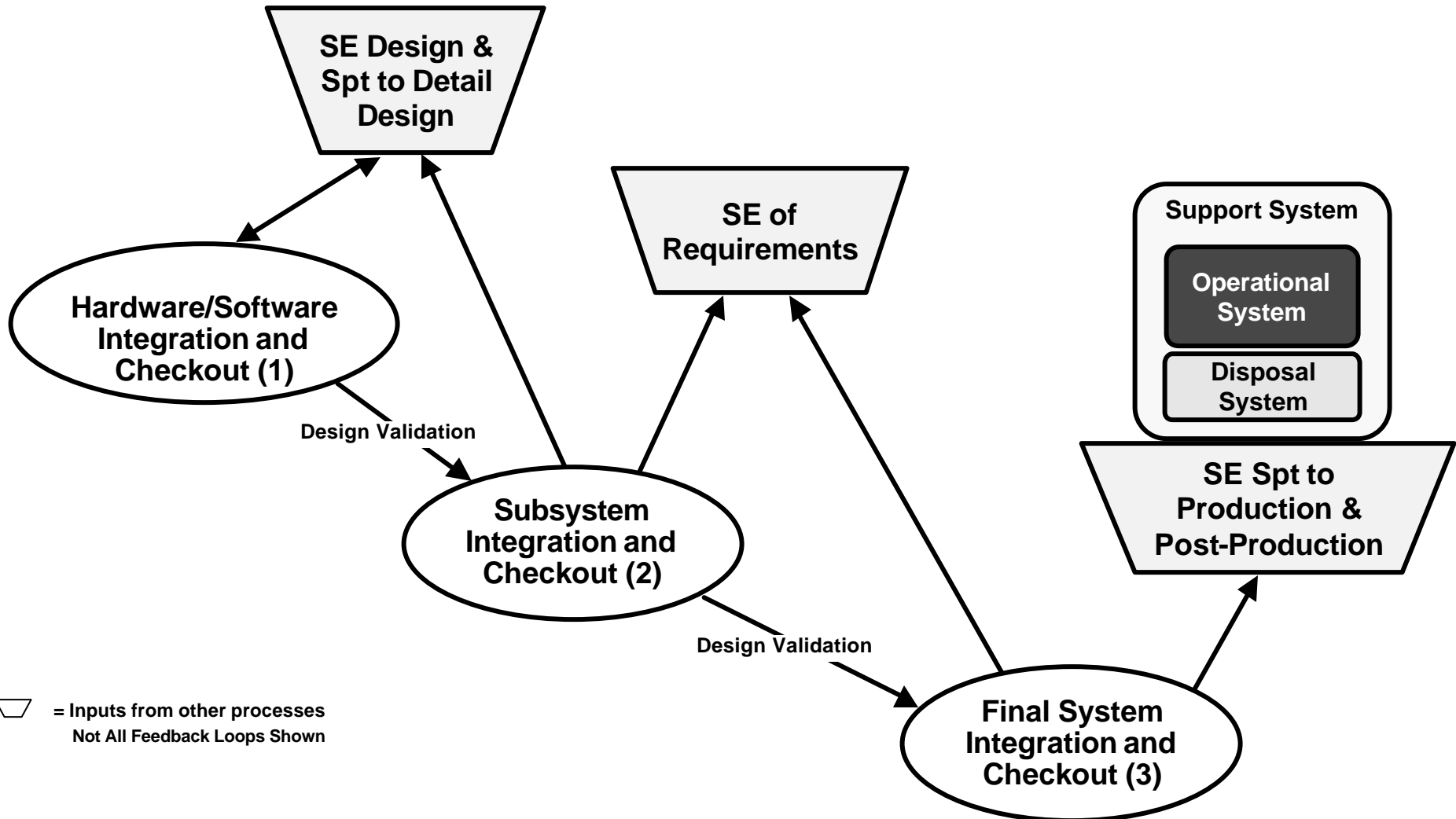
- Attend build reviews
- Verify LRUs and CSCs ready for test
- Monitor design eng fixes of trouble reports
- Monitor build performance
- Verify consistency of HW & SW builds

- Review test plans
- Monitor testing
- Verify test results
- Verify LRUs and CSCs ready for integration

- Review integration plans
- Monitor integration reviews
- Review test plans
- Monitor testing
- Verify test results for:
 - Prime subsys/CIs
 - Support subsys/CIs
 - Test subsys/CIs
- Verify CIs ready for system integration
- Verify specialty eng test results (“ilities”)
- Analyze lessons learned

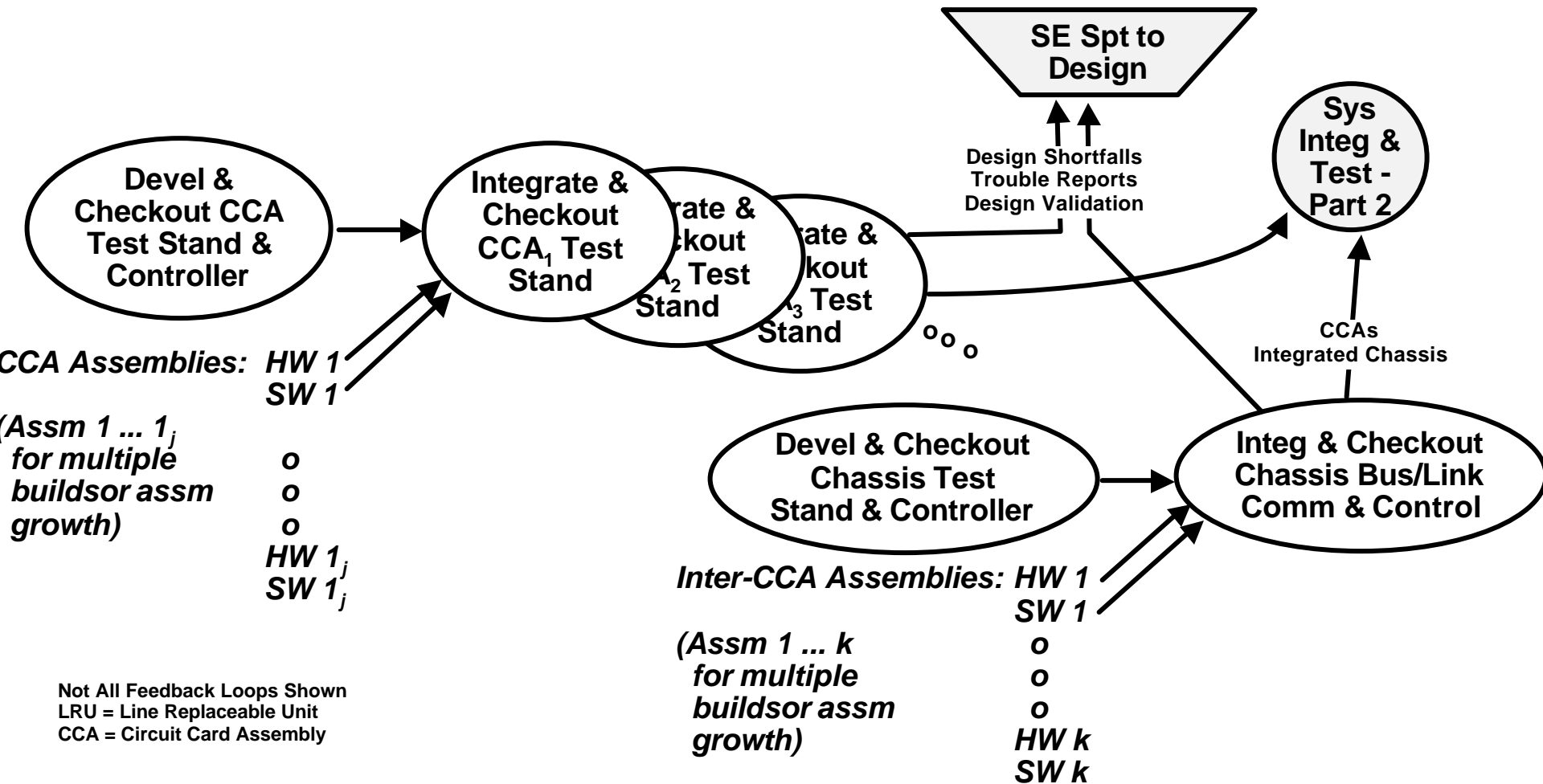
Not All Feedback Loops Shown

System Integration and Verification



Hardware/Software Integration & Checkout

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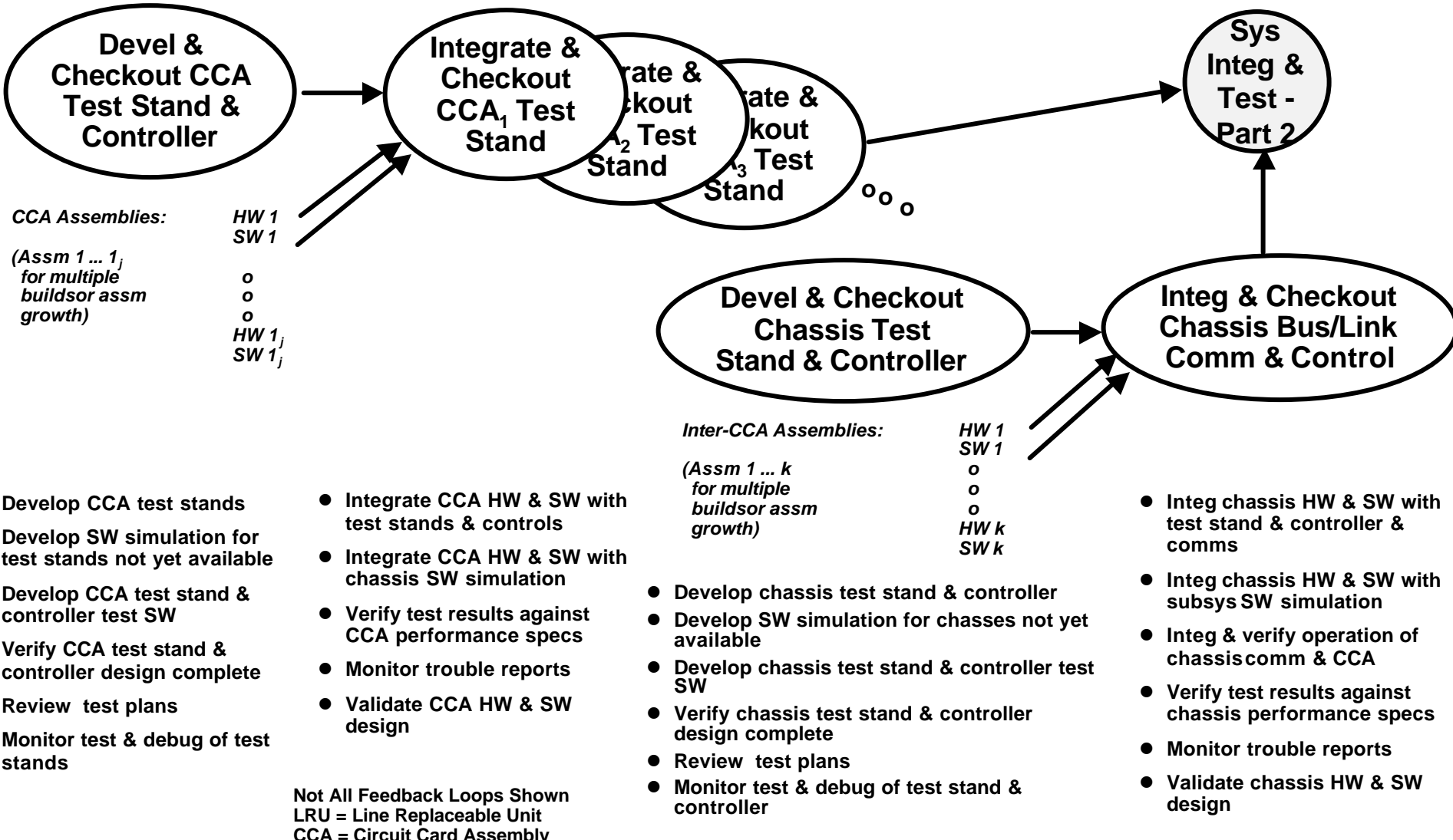
Hardware/Software Integration & Checkout - Tasks

SEP WG

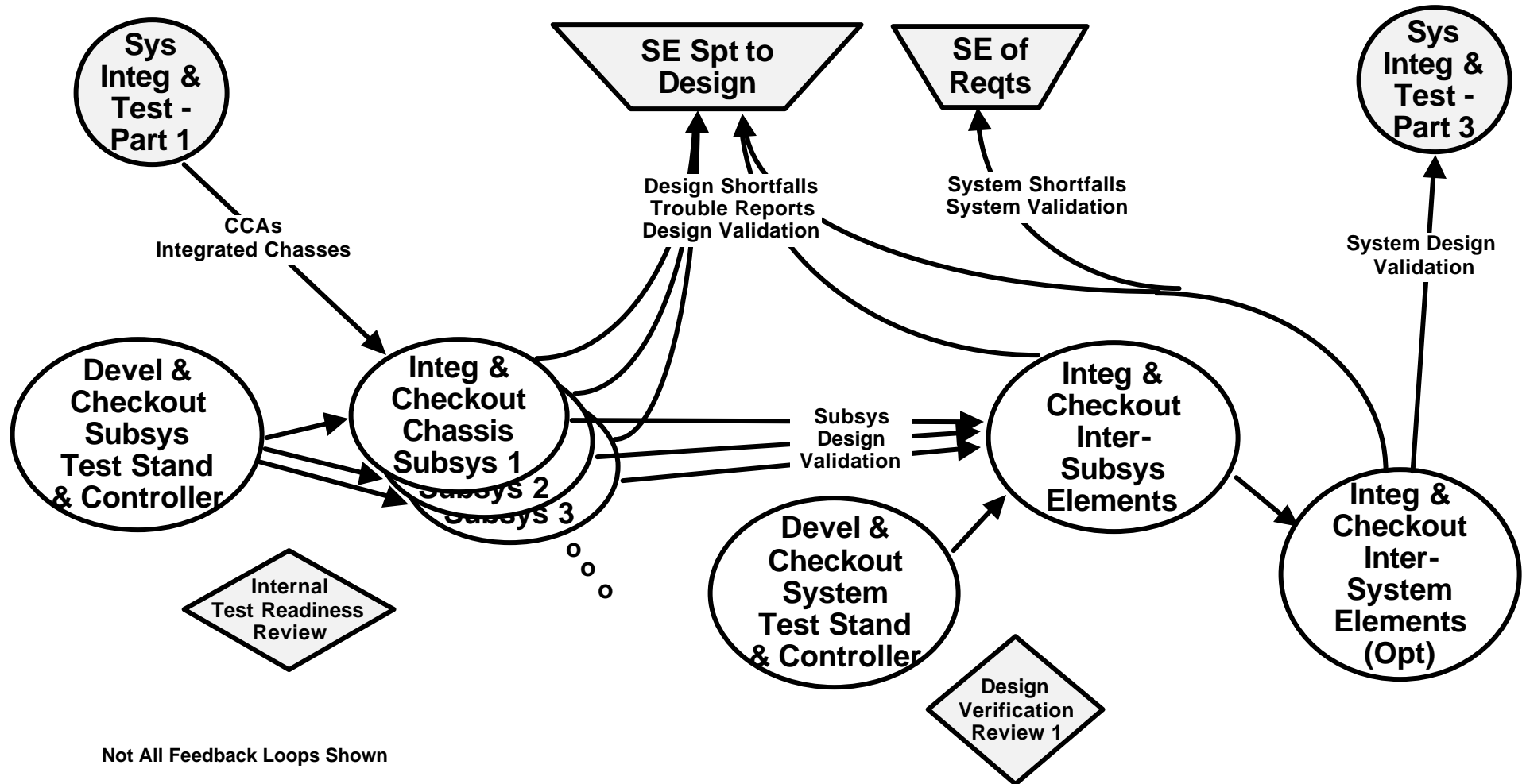
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Subsystem Integration & Checkout

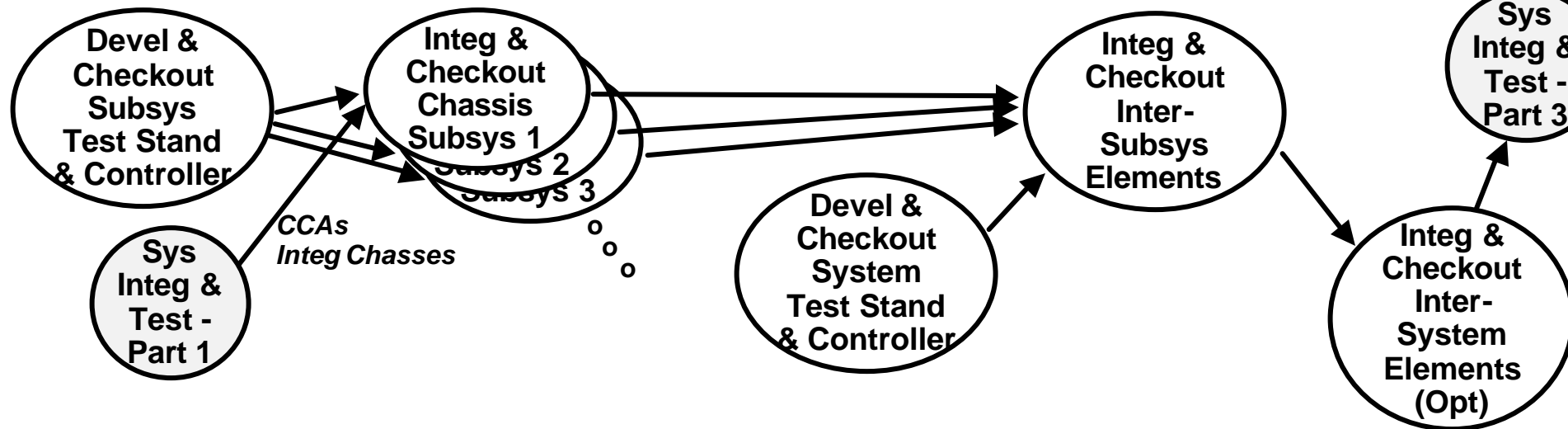


Subsystem Integration & Checkout - Tasks

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- Develop subsys test stands
- Develop SW simulation for subsys not yet available
- Develop subsys test stand & controller test SW
- Verify subsys test stand & controller design complete
- Review test plans
- Monitor test & debug of test stands

- Integrate chassis subsys HW & SW with test stands & controls
- Integrate chassis HW & SW with subsys SW simulation
- Verify test results against performance specs
- Monitor trouble reports
- Validate chassis subsys HW & SW design

- Develop sys test stands
- Develop SW simulation for sys not yet available
- Develop sys test stand & controller test SW
- Verify sys test stand & controller design complete
- Review test plans
- Monitor test & debug of test stands

- Integrate subsys HW & SW with test stands & controls
- Integrate subsys HW & SW with sys SW simulation
- Verify test results against performance specs
- Monitor trouble reports
- Validate sys HW & SW design

- Integrate sys HW & SW with sys test stands & controls or actual system
- Verify test results against performance specs
- Monitor trouble reports
- Validate platform system design

System Integration & Verification - Part 3

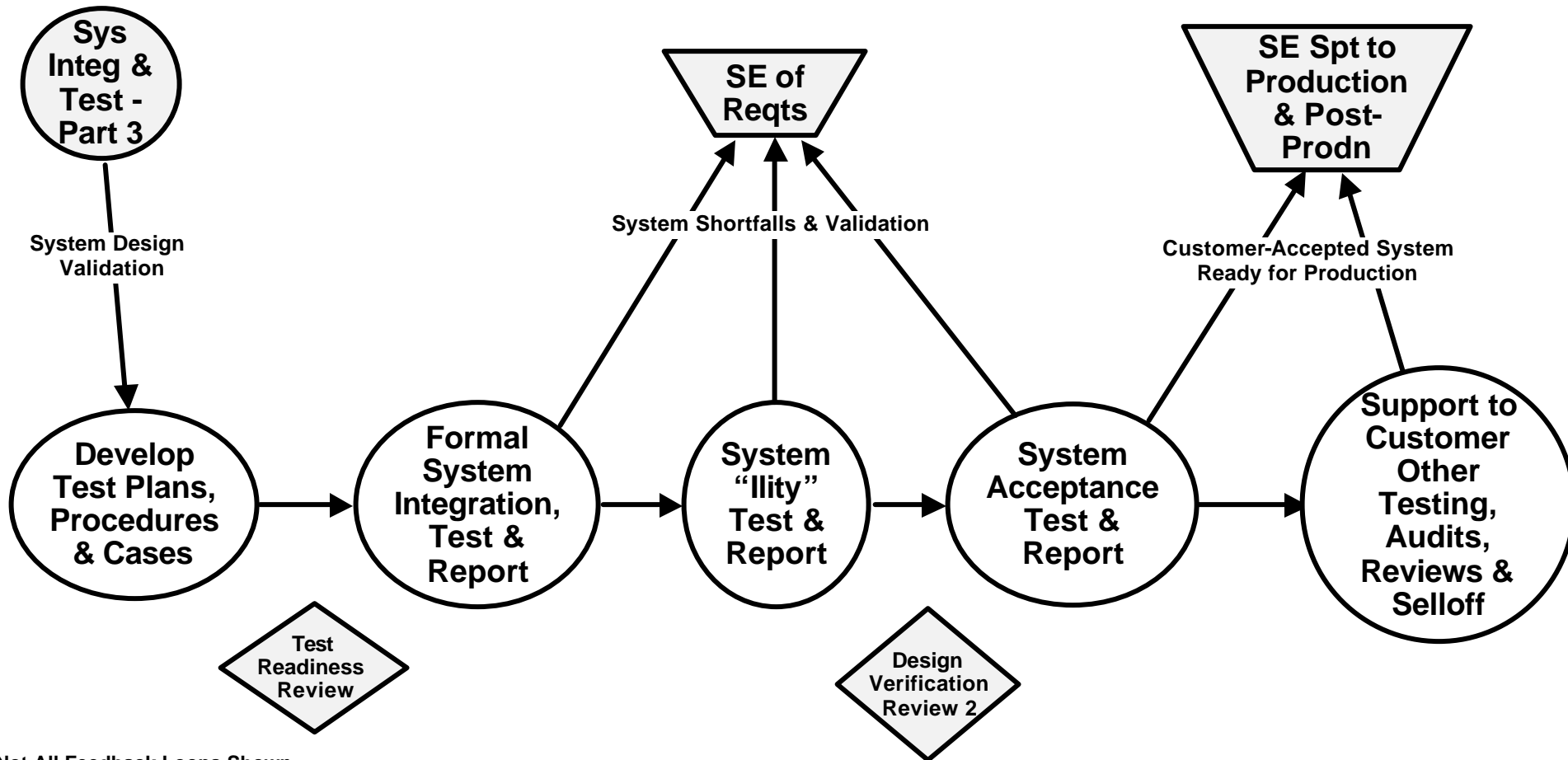
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Final System Integration & Test



Not All Feedback Loops Shown



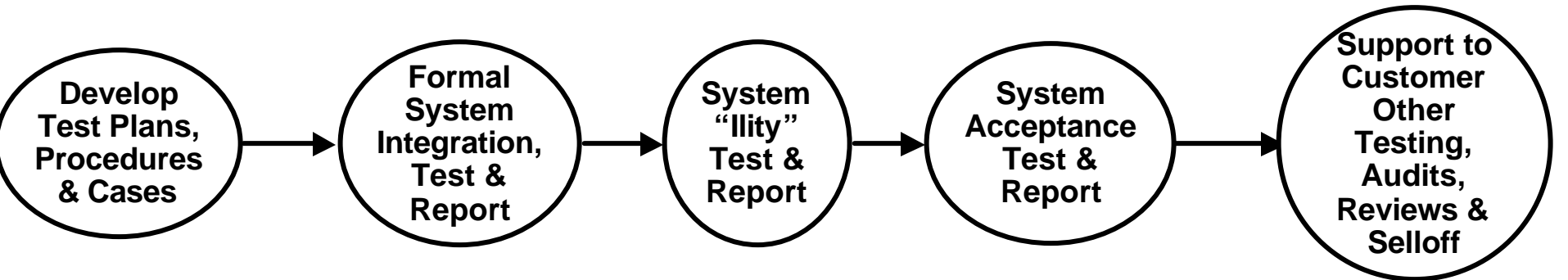
Final System Integration & Test - Tasks

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- Develop formal integ test plan & procedures
- Develop "ility" test plans & procedures
- Develop acceptance test plan & procedures
- Define test cases & conditions
- Prepare for major review

- Conduct system integ testing
- Verify system meets performance specs
- Verify system meets acceptance test criteria
- Monitor trouble reports

- Monitor system "ility" tests
 - Environ Qual
 - Reliability
 - Manufacturing
 - EMI/EMC
- Verify system meets performance specs
- Monitor trouble reports

- Conduct system acceptance test
- Verify system meets performance specs
- Monitor trouble reports
- Analyze lessons learned

- Support func config audit (FCA)
- Support physical config audit (PCA)
- Support formal qual review (FQR)
- Support production readiness review (PRR)
- Support customer test & eval

Not All Feedback Loops Shown



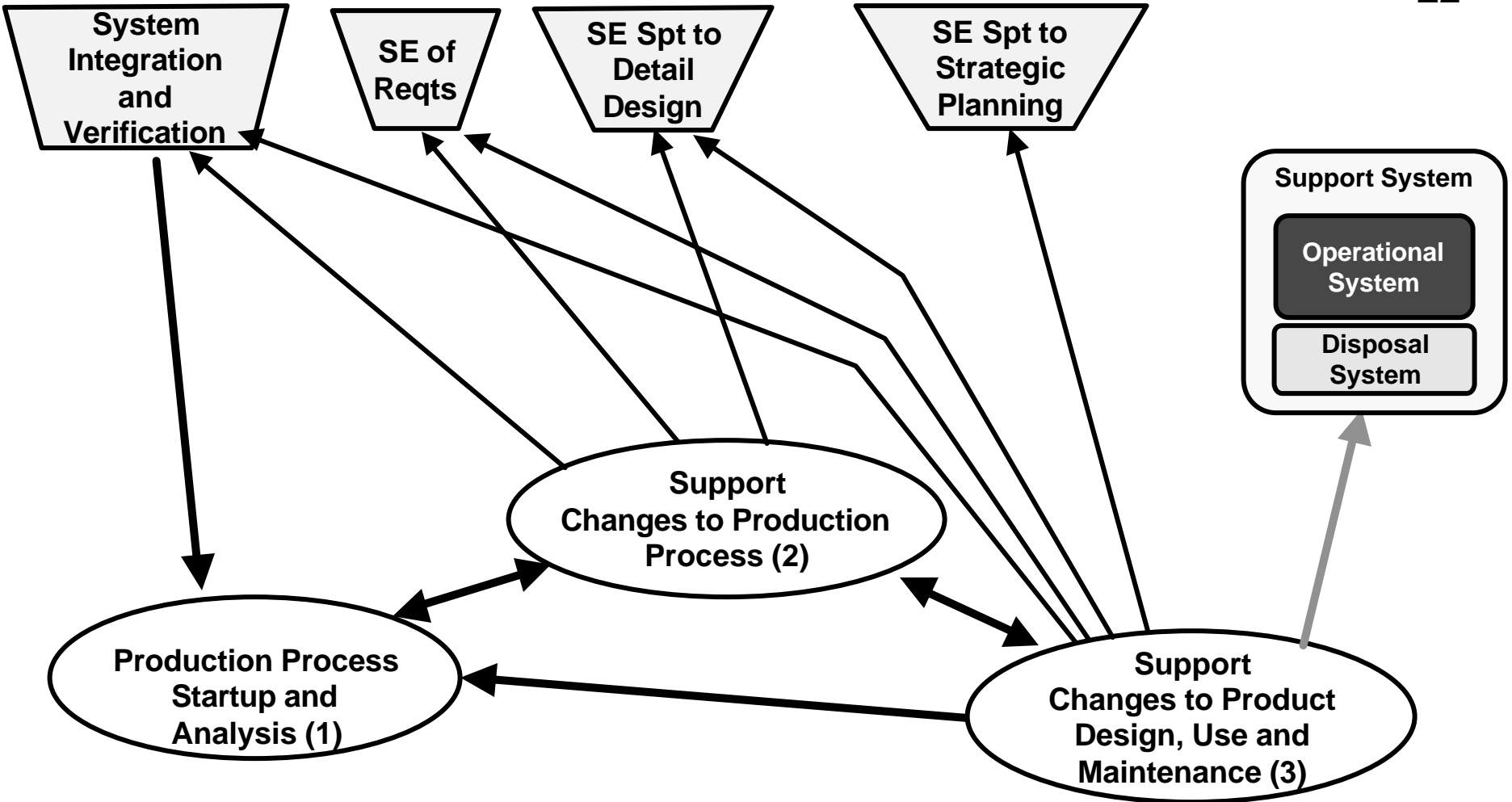
Systems Engineering Support to Production, Post-Production & Validation

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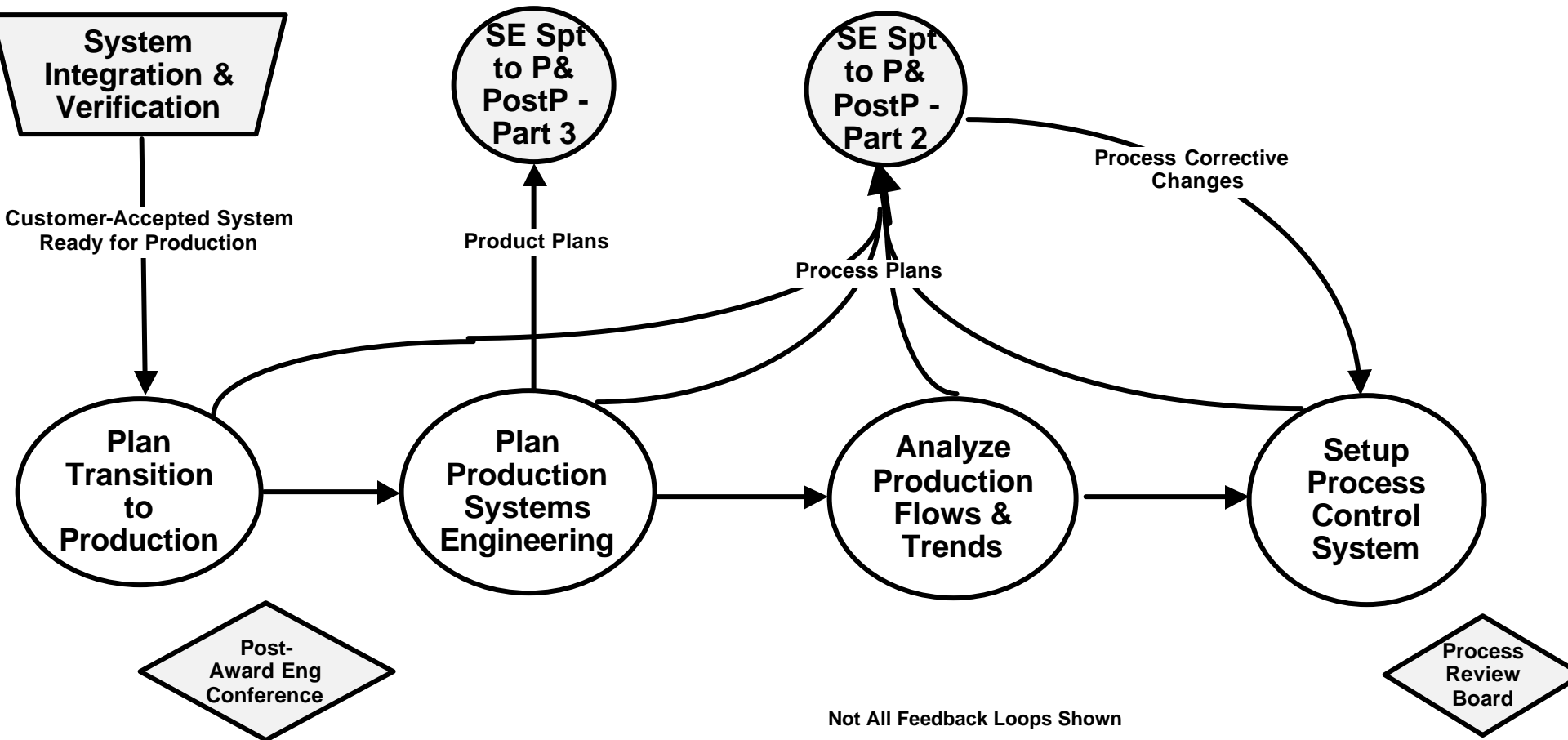
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Not All Feedback Loops Shown

Production Process Startup & Analyses



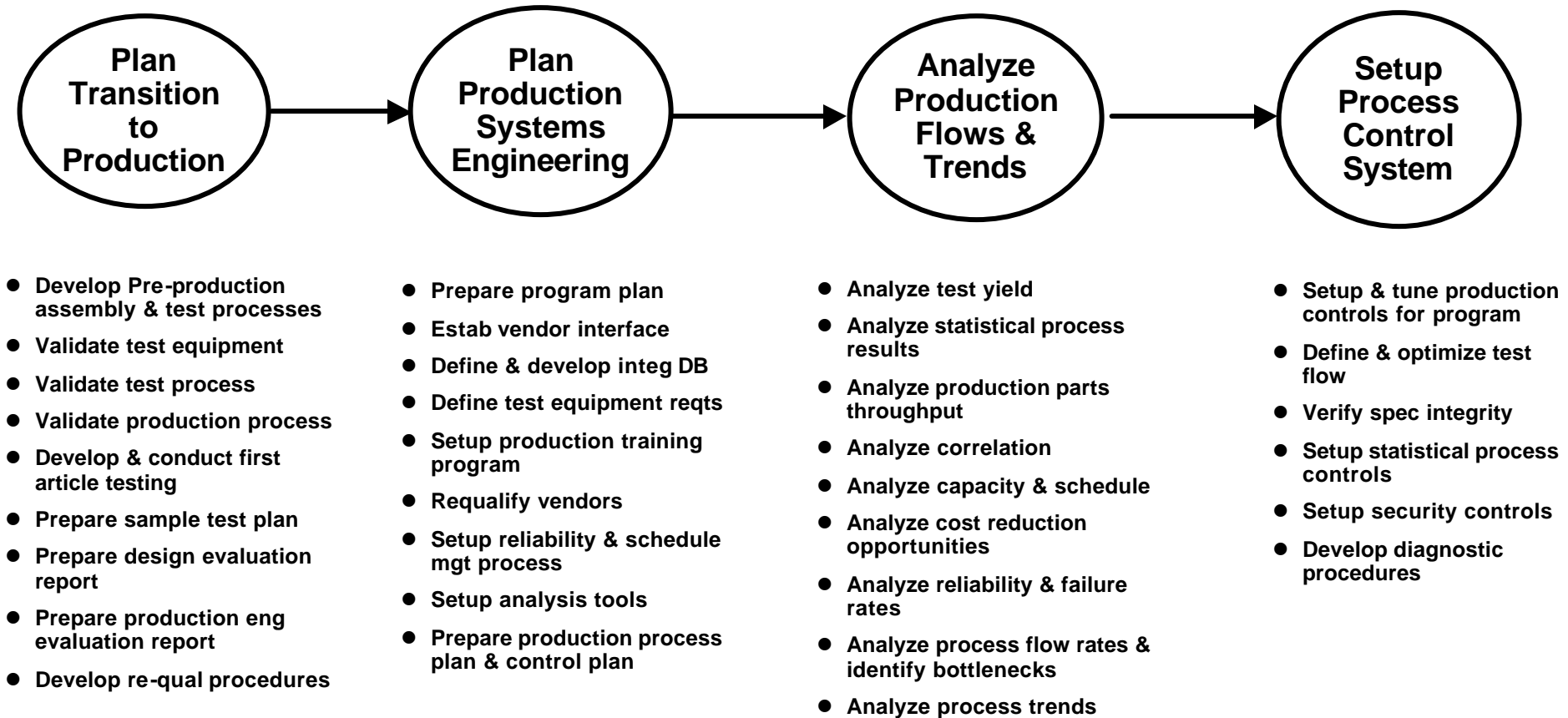
Production Process Startup & Analyses - Tasks

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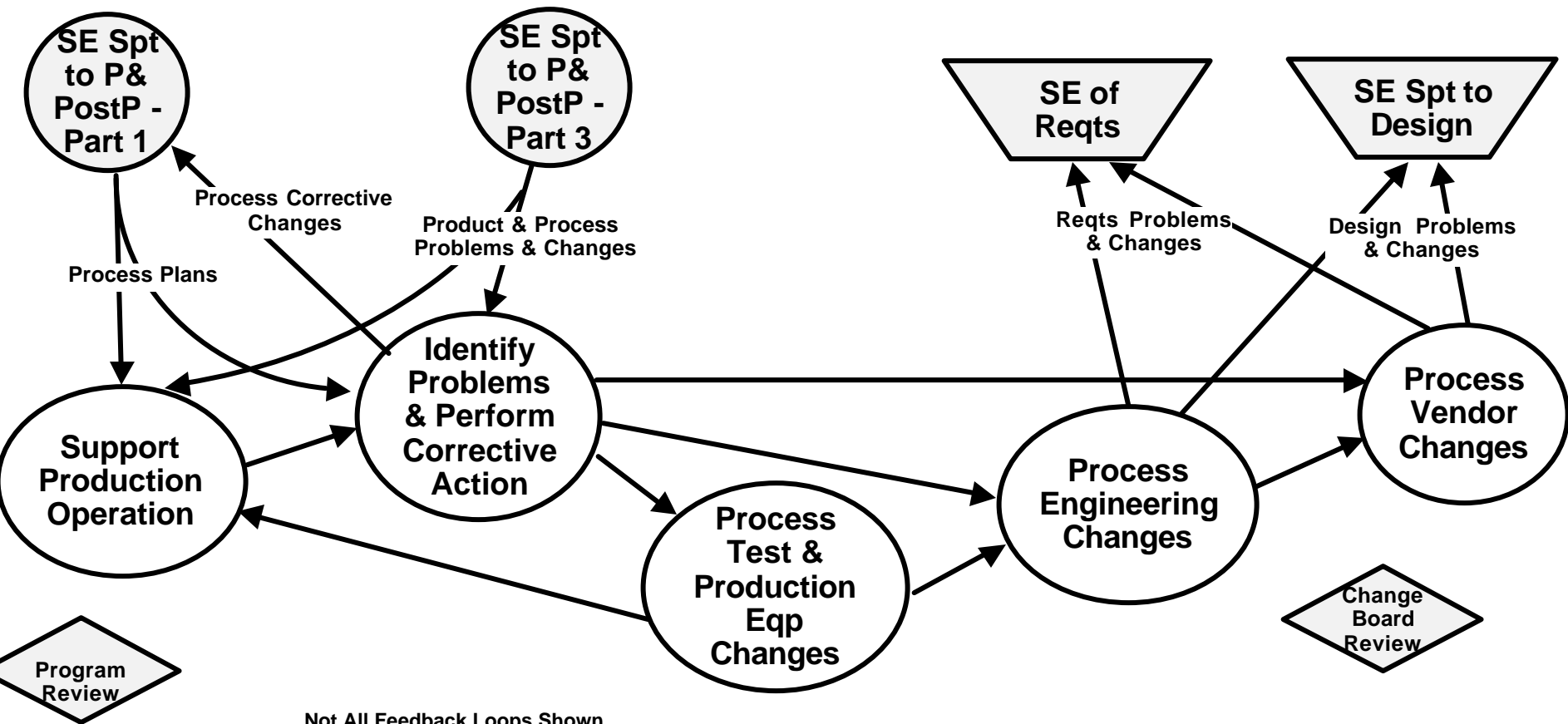
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Not All Feedback Loops Shown

Support Changes to the Production Process



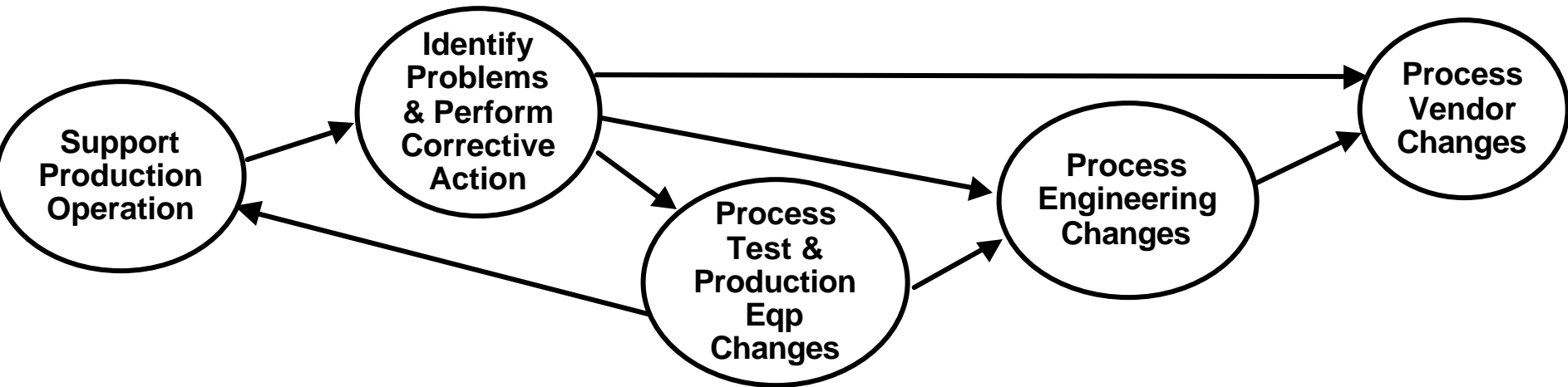
Not All Feedback Loops Shown

Support Changes to the Production Process - Tasks

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- Develop production work-arounds
- Perform confirmation testing
- Evaluate obsolete parts
- Conduct sample testing
- Attend change reviews
- Support production of:
 - Prime equipment
 - Support equipment

- Ident response to obsolete parts
- Ident corrective actions
- Ident Problem parameters
- Analyze problem parameter tradeoffs
- Coord with customer
- Ident criteria for re-eng vs. procedure change acceptability

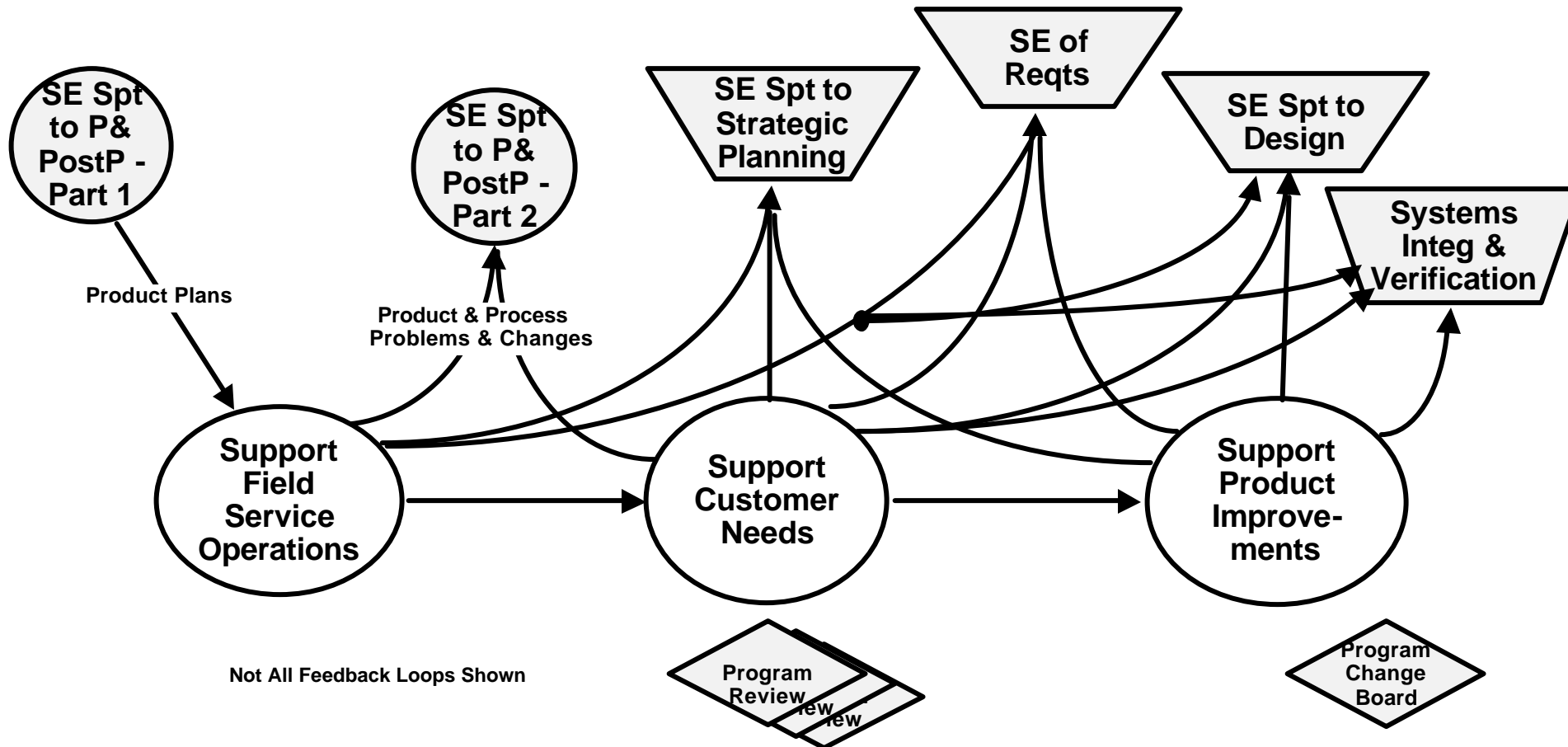
- Implement corrective actions
- Ident test equip fixes
- Ident production equip fixes
- Ident change order needs
- Ident procedure change needs

- Implement corrective actions
- Redesign for improved producibility
- Redesign for lower cost
- Conduct value eng
- Generate ECPs & ECOs
- Coord with customer

- Implement corrective actions
- Ident vendor parts needing change
- Ident new vendors
- Re-qual new vendors

Not All Feedback Loops Shown

Support Changes to Product Design, Use & Maintenance



Support Changes to Product Design, Use & Maintenance - Tasks

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- Ident user & operational problems
- Evaluate maintenance concepts
- Ident maint concept & implementation problems
- Identify & fix platform unique interface problems
- Ident field service new reqts
- Support test programs
- Conduct field fixes to:
 - Prime equipment
 - Support equipment
- Define procedural changes needed
- Support operator & maintainer training
- Support field service personnel training
- Ident other platform unique needs

- Ident & manage problems
- Ident new requirements:
 - Threat DB changes
 - Operational SW new needs
 - HW upgrades
 - Changes to assoc HW & SW
- Track on-going orders to ident new reqts, problems & changes
- Support special testing
- Catalog desired changes for next revision
- Analyze user lessons learned

- Ident & support design changes to product
- Ident & support reqts changes to product
- Ident & support re-test of changes
- Ident & support improvements requested by operators
- Ident & support improvements requested by maintainers
- Analyze customer changes for scheduled, emergency & long term change desires
- Analyze production development & use lessons learned
- Analyze new technology utility
- Establish need for & plan pre-planned product improvements



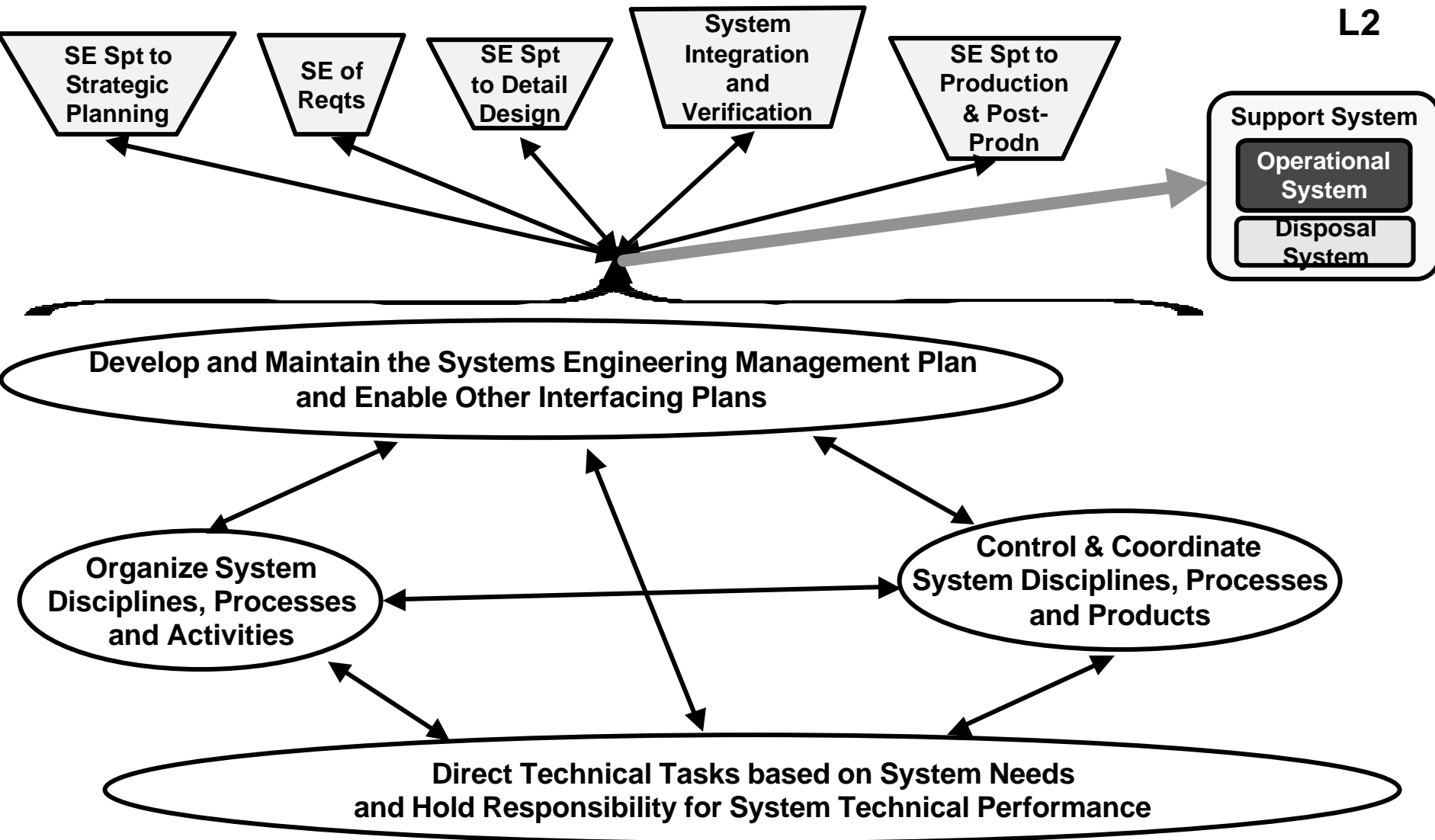
Systems Engineering Management and Control

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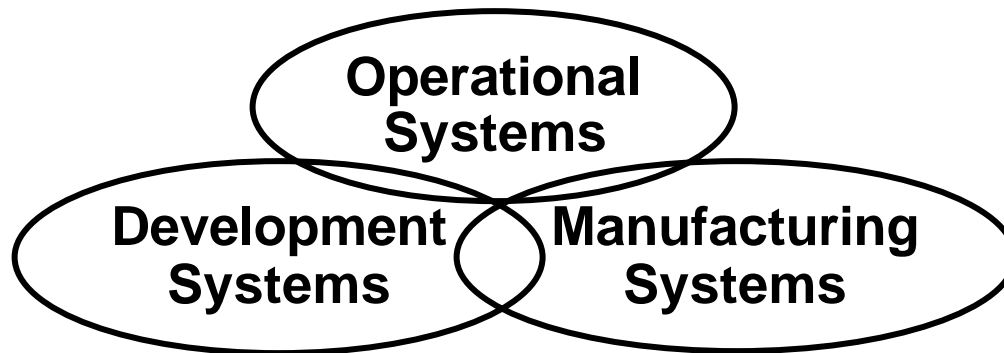
The Systems Approach to Acquisition and Development

The System Elements That Must Interface Successfully

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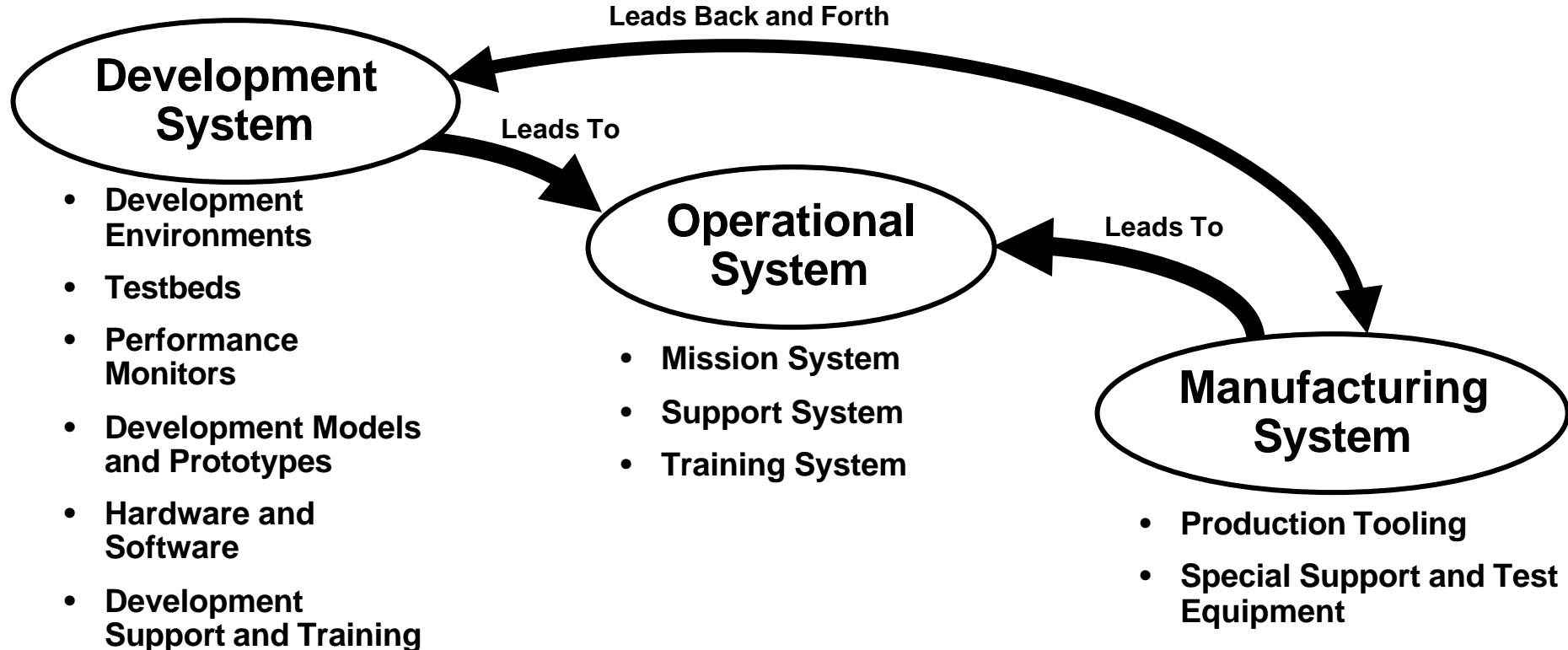
Operational Systems, Development Systems and Manufacturing Systems must be well integrated for an effective product

All The System Elements Must be Addressed by SE

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Development, Operational and Manufacturing Systems

- all must interface correctly for a cost effective, affordable and effectively performing operational and supportable system
- which satisfies both customers and users



The Operational System Elements That Must Interface Successfully

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A System is Broad!

**Operational
Systems**

- **Mission Systems**
- **Support Systems**
- **Training Systems**

**Missions Systems are usually recognized as important,
but Operational Systems also need Support and Training Systems**

What is an Operational System?

- An operational system is one that provides the operational capability to:
 - Meet stated user needs
 - Sustain the capability to meet user needs
- An operational system is comprised of a:
 - Mission system
 - Support system
 - Training system

An Operational System is What the User Wants



What is a Manufacturing System?

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- The system that provides a capability to produce the elements of the operational system
 - Mission, support and training systems
- It includes the hardware, software and manufacturing processes for the fabrication, assembly and verification of the elements of the operational system
 - Work instruction, tooling, machinery, manufacturing layouts, test equipment
- It results in production of the target operational system

What is a Development System?

- A system that provides the capability to define requirements; design, verify and produce a capability to meet the requirements; and validate that the resulting capability meets the user needs for
 - Operational systems
 - Manufacturing systems
- It includes the hardware, software and development processes for the definition and implementation of plans, requirements definition, design and integration of the elements of the operational system; and verification of the elements of the complete system
 - Development techniques, laboratories, computer aided development machines, test equipment
- It results in development of the:
 - Target operational system
 - Manufacturing system for the target operational system



All System Elements Must be Acquired

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- The Acquisition System is the system that provides the capability to plan, fund, develop, manufacture and validate new or modified operational capability for users
 - Mission, support and training systems
 - Usually defines the product life cycle
- The Acquisition System is controlled by the laws and regulations governing the conduct of business of each agency
 - DoD, NASA, industry or commercial
- The Acquisition System includes
 - Processes, rules, case law, operating instructions, policies and procedures
 - Development agencies, installation agencies, operational agencies, support agencies, training agencies, auditors, inspectors

What is the System Acquisition and Development Hierarchy?

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- There are multiple levels in acquisition and development of systems:
 - Acquisition is concerned with the program funding, planning and management of bringing new systems on board
 - Development is concerned with system funding, planning and technical management of bringing new systems on board
 - Functional engineering processes have basic capabilities which their practioners must understand to perform their tasks

Acquisition System

Development Systems
Systems Engineering
activites

Functional Systems
Systems Engineering
Process Engines

Partitioning Criteria:

- Acquisition process and products governed by externally applied laws and regulations
- Development Systems driven by engineering needs and controlled by tailoring and guidelines for specific missions, customers and systems
- Process engines consist of basic capabilities, primitive processes, elemental disciplines, teachable skills and measureable performance areas for SE function



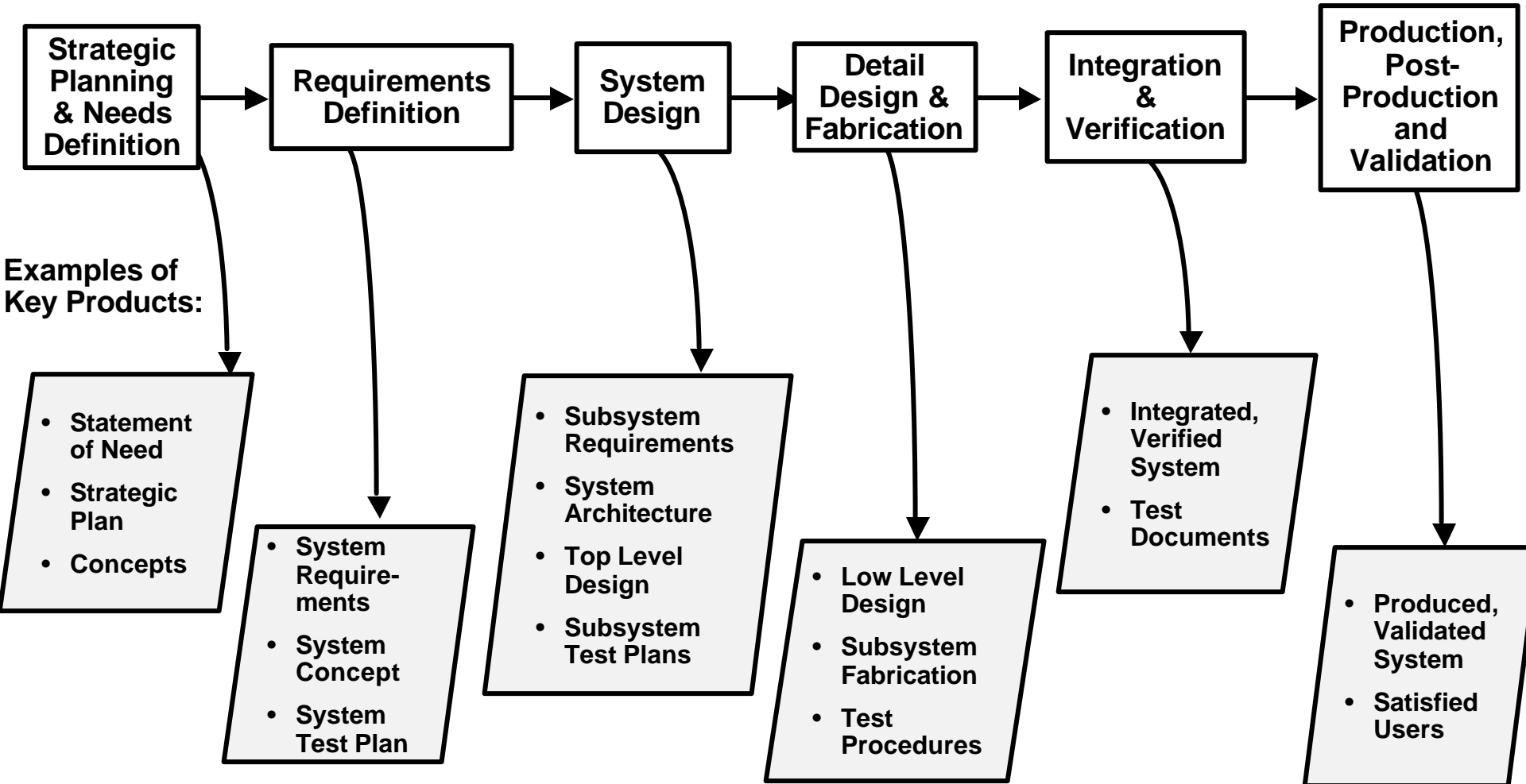
Development System Elements and Flow (Level 0-DS)

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Activities:





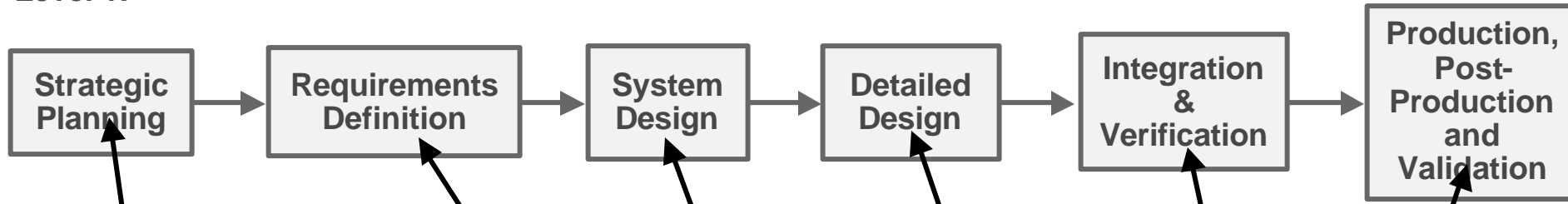
Level 1 Development Process Is Tailored to Missions and Systems

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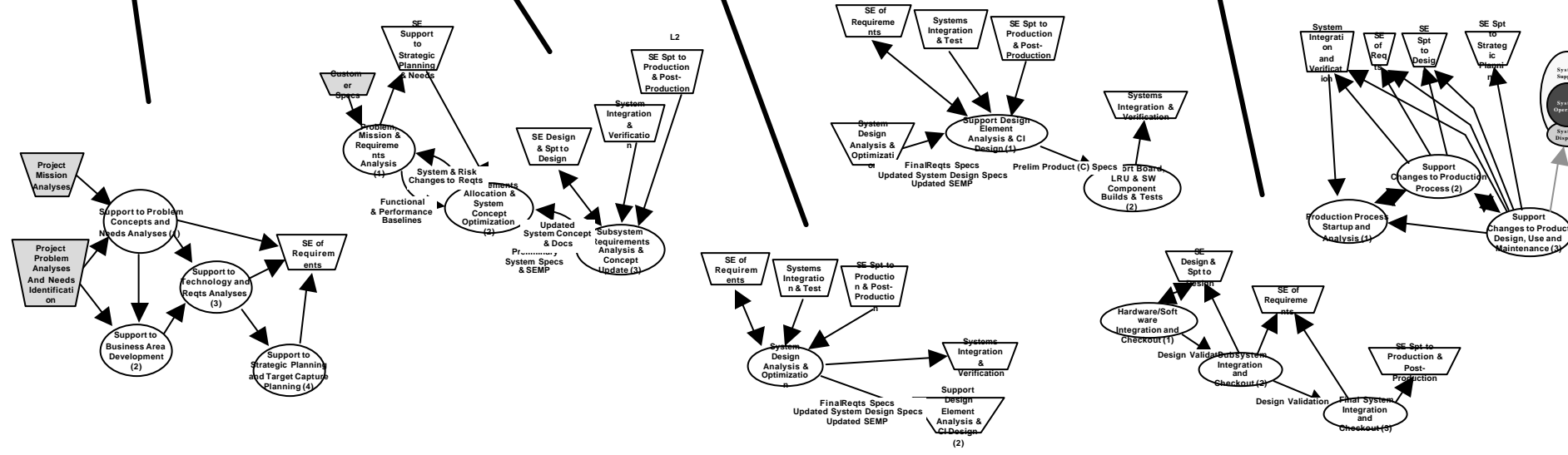
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Level 1:



Level 2 Tailored Activities:



Level 1 Tailored Activities can be tailored to/from: NAWC-WD, NASA, USAF and others (e.g., Lockheed, AT&T, Harris, etc.)

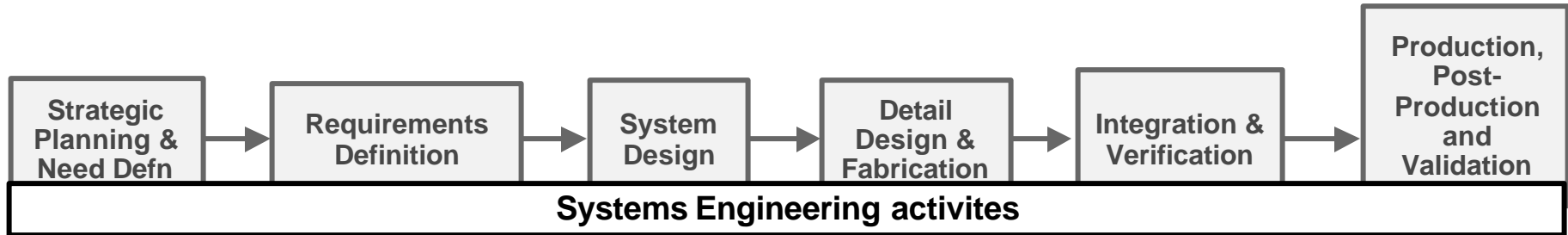


Where Does Systems Engineering Fit In to Development?

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- Systems Engineering activities
 - Are a horizontal slice, integrating all the Development System activities
 - Identify needs, design the system architecture, support detail design, support system evaluation and selloff, enable full production, assess operation, establish support capabilities and provide for disposal capabilities
 - Provide the tailoring of the Development System to specific mission and agency needs for the system to be developed
- Systems engineering activities implement the processes using the disciplines and elemental capabilities of the Systems Engineering Process Engine applicable to the agency



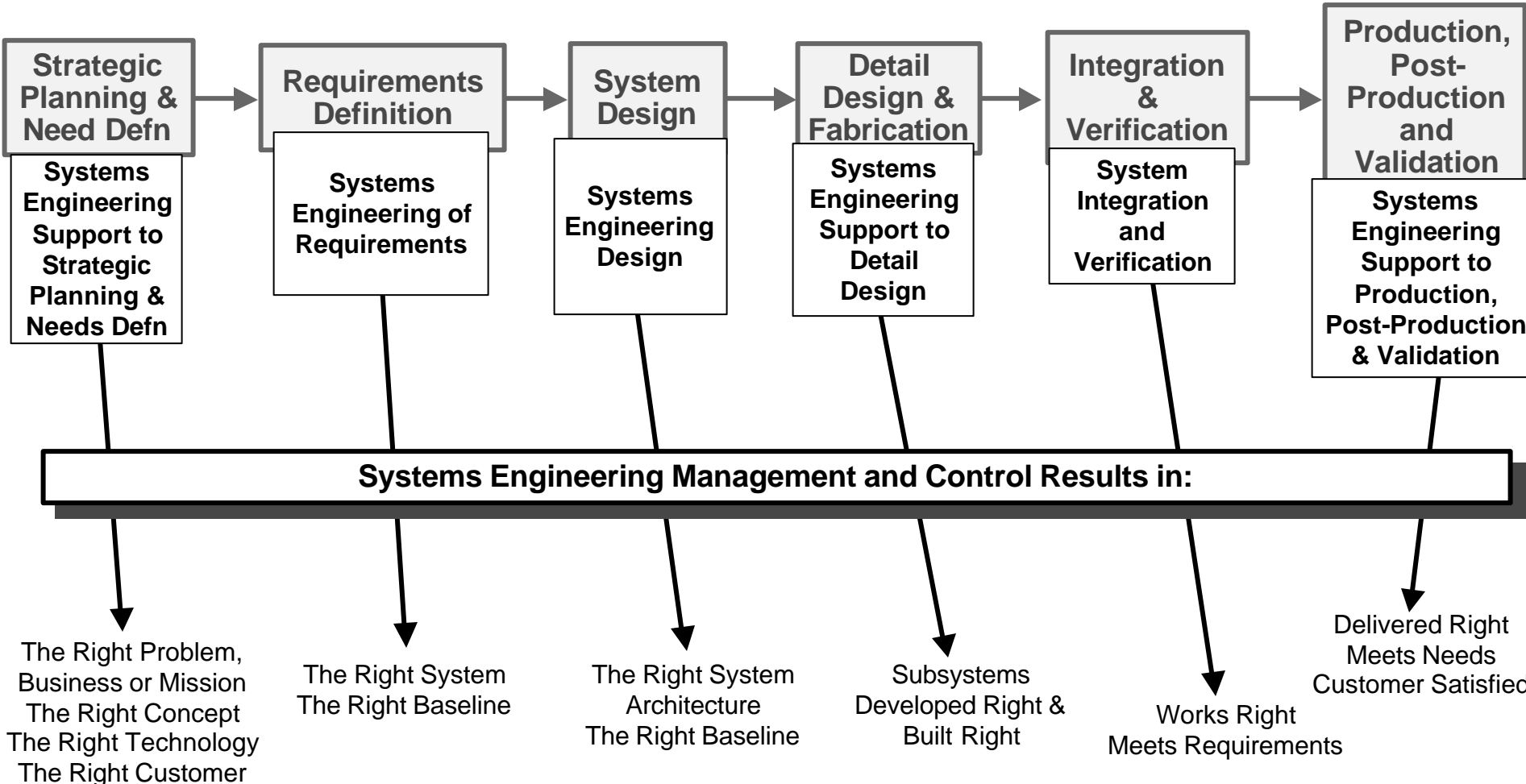
Development Systems Rely On Systems Engineering for Focus

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What SE does in Development Systems:



Note: A Customer is anyone who needs or uses the products or services of Systems Engineering; either internal or external; either Government, industry or commercial.



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Systems Addenda



New Definitions Offered for Systems

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- **Sysware:**

Hardware, firmware, software and ilityware used throughout the life cycle of a system as part of the system or as support, design, production, disposal of the system.

- **Sysware engineer:**

The combined expertise and successful experiences of hardware, software and ilityware engineers combined into a system life cycle expert. (See systems engineer, old term)

- **Sysware engineering:**

The teaming of sysware engineers to the common goal of an integrated sysware life cycle process