SC-21 Science and Technology Manning Affordability Initiative

Systems Engineering Task Analysis

Operational Sequence Diagrams (OSDs)

Version 2.0

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Prepared by:
Melissa Dugger
Chris Parker
John Winters
Basic Commerce and Industries, Inc.
16347 Dahlgren Road
P.O. Box 1748
Dahlgren, VA 22448

John Lackie
Sonalysts, Inc.
P.O. Box 1839
Dahlgren, VA 22448

Prepared for:
Dr. Daniel Wallace
Human Engineering, Code G53
17320 Dahlgren Rd Code G531
Dahlgren, VA 22448-5100

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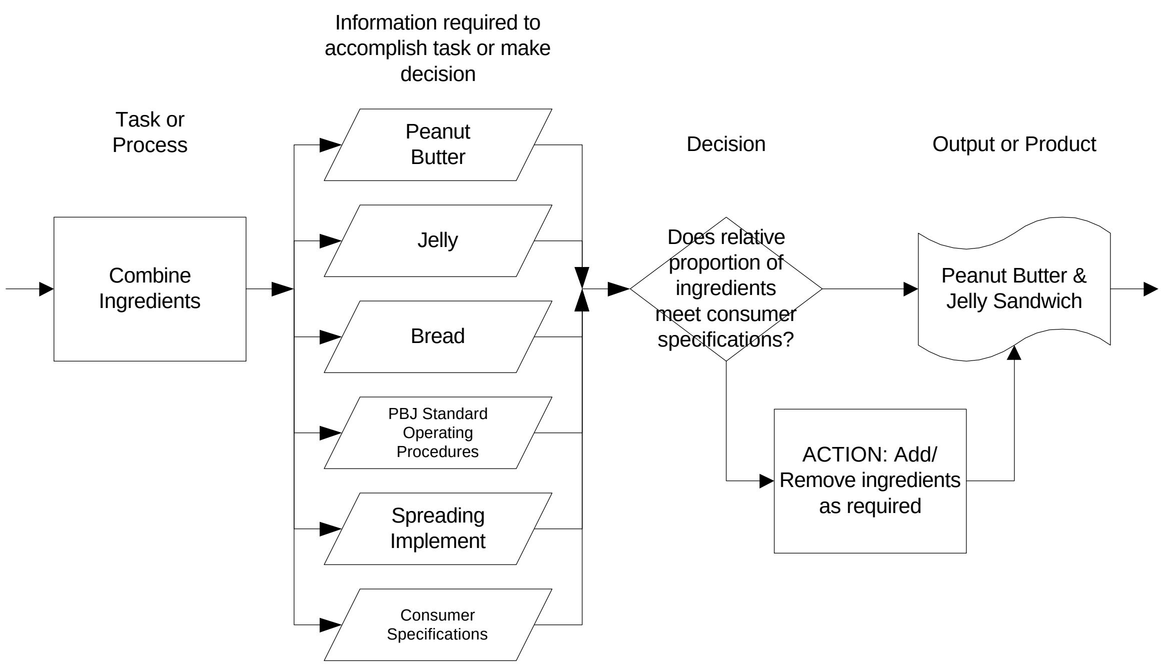
INTRODUCTION

This task analysis of systems engineering is being produced as an intermediate product within the SC-21 Science and Technology Manning Affordability Initiative. The method that has been selected to represent the results of the task analysis is the operational sequence diagram (OSD). The accompanying OSDs, along with the other associated material are intended to serve two purposes. First, as a general task analysis of systems engineering, it is intended to form a basis for a detailed cognitive task analysis (CTA) that will examine critical steps within the systems engineering process and the interaction between systems engineers and human factors practitioners or human engineers. This CTA will provide design guidance for the development of a Human-Centered Design Advisor (HCDA), which is intended to be a decision support tool to assist systems engineers in identifying and addressing human factors issues. Coupled with a similar set of OSDs for human engineering, the system engineering OSDs will enable the identification of significant human engineering inputs to the systems engineering process. Second, it is intended to serve as an inventory of tasks, decisions, and information requirements to aid in the development of the Human-Centered Design Environment (HCDE). The prototype HCDE being developed in this project includes a set of integrated engineering tools, selected to enable a design or development team to include humans within system designs earlier and more accurately. These OSDs will serve as a baseline to evaluate the functionality of the prototype HCDE and its integrated tools, and they will also serve as a blueprint for the definition of test scenarios to evaluate the usability of the HCDE.

Introduction to Use of OSDs for Task Analysis

Different symbols are used in these OSDs to represent different elements of the systems engineering process. These symbols are frequently used in the recurring pattern of a ***task unit***. (See figure below for an example of a task unit from the creation of a peanut butter & jelly sandwich.) Within a task unit, the order of the symbols is not intended to represent any temporal flow or order. The first symbol within a task unit is a rectangle that represents the title or description of the task. The second element is one or more parallelograms, each of which represents a separate piece of information or other item that is required to accomplish the task or make a decision. A diamond, representing a decision to be made follows the information requirements. The final piece of the typical task unit is a wavy rectangle, which signifies a defined output or product of the task or decision.



TASK UNIT

Although not part of the typical task unit, “action” boxes are used to represent an implicitly defined discrete process that may be taken as an independent action. This notionally *could* be decomposed further, but there is nothing to be gained by the exercise. For example, in the case of the peanut butter and jelly sandwich, given that it is already known how to spread the ingredients and have the tools to do so, it is implicit that the action "Add/Remove ingredients as required" can be performed to meet the consumer specifications. This is done to simplify the appearance of the OSDs.

Operational Sequence Diagrams were chosen as the method to represent the results of this task analysis since they allow the depiction of the most critical components of the process – the ***tasks*** themselves, their accompanying ***decisions***, ***information*** required to complete tasks or make decisions, and ***products*** or other outputs. Like all forms of task analysis, OSDs have their limitations. One of their deficiencies is that when applied to a process such as systems engineering, they imply a greater degree of sequence, order, and timing than is intended to be captured. Since the exact sequence of many tasks may vary greatly or even overlap, the representation of the most important tasks and decisions is of greater importance than their order.

Additionally, the tasks and decisions that make up the systems engineering process may not be all represented at an even level of detail, concreteness, or repeatability. For example, a task analysis of the process by which an artist creates a painting may consist of the following tasks:

1. Obtain paint
2. Obtain canvas and brushes
3. Paint picture

Given this representation of the tasks involved in artistic painting, it is doubtful that anyone could fully understand the creative and abstract nature of the painting process or that by following it, an amateur could create an accurate reproduction of a famous work of art.

The goal, however, of these diagrams is to support the design of tools to support the systems engineering process and to provide a framework for further examination of difficult or critical tasks and decisions through further analysis. Returning to the painting example, tools to aid and speed the completion of steps 1 and 2 would free up more time for the painter to concentrate on the most crucial step, painting the picture itself. Similarly, step 3 would be identified as a task in need of further exploration and definition, as could be accomplished through a subsequent cognitive task analysis.

Within this set of OSDs, many of the tasks, decisions, products, and information requirements exhibit a distinct military or Department of Defense flavor or quality. This trend holds particularly true for information requirements and for the OSDs dealing with the generation of requirements. The overall flow of the process as captured in the OSDs, however, is intended to be applicable to the development of non-military systems. For example, the first task unit in OSD SE110 deals with the review of existing scenarios, requirements, and threats, and includes information requirements of Analysis of Alternatives results, Comparison Systems, Force Structure, and Current & Predicted Threats. For an automobile manufacturer, these information requirements would not exist as precisely defined here, but parallel information requirements such as Market Trends, Customer Surveys, Current Product Line, and Current & Predicted Competitor Vehicles would be relevant.

Scope of Systems Engineering OSDs

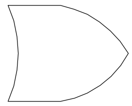
The following two pages show a basic flow diagram of the process described by the set of OSDs. Each small box within this diagram represents a separate OSD, each of which is made up of several task units and other elements and may cover three to six pages. Only the most general flow has been shown in this diagram. Multiple cycles of iteration and interconnection are assumed but not explicitly depicted. As shown in the flow diagram, the start of the process assumes the external creation of a Mission Need Statement (MNS), Concept of Operations (CONOPs), and Operational Requirements Document (ORD). Additionally, it is assumed that an Analysis of Alternatives has been performed. The results of all of these analyses, or at least their most current iterations, are assumed to be available to those working within the systems engineering process. The focus of the OSDs is on system development up until Preliminary Design Review, and phases such as production, test and evaluation, and deployment are not covered.

The tasks and actions within this systems engineering process are not necessarily carried out by a single individual. Instead, any number of individuals may accomplish these tasks serially or in parallel. The flow of work through the tasks should be assumed to follow a "bus stop" metaphor – if there are no passengers to be picked up or dropped off at a particular stop, then there is no need for the bus to stop. In the same way, if a task or decision is not applicable to the system under design or if the action has already been satisfactorily completed, then there is no need to perform the action in question.

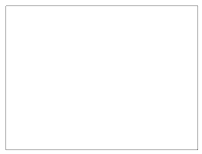
As mentioned earlier, the process as represented contains a variety of references to the development of military systems. This is due in part to the fact that many of the sources used to develop these OSDs were of military origin. A list of the most prominent sources is as follows:

- IEEE 1220-1998, *Standard for Application and Management of the Systems Engineering Process*
- EIA 632, *Processes for Engineering a System*
- EIA/IS 632, *Systems Engineering*, EIA Interim Standard
- DoD Directives 5000.1 and 5000.2-R
- *INCOSE Systems Engineering Handbook* (1998), Release 1.0
- *System Engineering Management* (1998) by Benjamin Blanchard
- *Seminar on Systems Requirements and Architecture Definition for Systems of Systems*, presented at NSWC on June 23, 1998
- *System Requirements Engineering Plan Brief – Application to the DD 21 Surface Combatant*, presented on March 6 1998 by P.J. Stafford

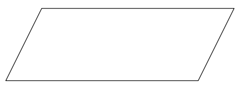
OPERATIONAL SEQUENCE DIAGRAM CONVENTIONS



Action Cue / Trigger

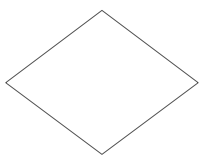


Task/Process

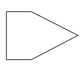


Information Requirement
(produced internal to the process)

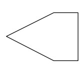
Information Requirement
(produced external to the process)



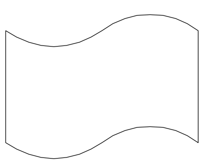
Decision



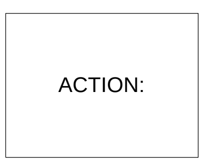
Task Feed ("Goes to")



Task Feed ("Comes from")



Output or Product



Action

DEFINITIONS

A-Spec [SE520] – Specification that states all necessary functional requirements of a system in terms of technical performance and mission requirements, including test provisions to assure that all requirements are achieved. Also referred to as Type-A Specification (DSMC).

Analysis of Alternatives (AOA) [SE110, SE140] – A comparison and evaluation of competing system concepts on the basis of operational suitability, efficiency, effectiveness, and cost (both acquisition and operational). Weighs and trades off the relative value of each parameter under consideration. Intended to aid and document decision-making by illuminating the relative advantages and disadvantages of the alternatives under consideration. Shows the sensitivity of each alternative to possible changes in key assumptions or variables (DOD 5000.1).

Alternative Concept Review (ACR) [SE110, SE140] – Review to select a system concept or concepts to which the system definition activities are to be applied (IEEE 1220, Section 5.1.4.1).

B-Spec [SE520] – Specification that states all necessary design requirements of a configuration/development item in terms of performance. Also referred to as Type-B Specification (DSMC).

Commercial Off-The-Shelf (COTS) [SE130, SE 220, SE310, SE340] – Articles of supply readily available from established commercial distribution sources which the Department of Defense or inventory managers in the Military Services have designated to be obtained directly or indirectly from such sources. Also referred to as Commercial Items.

Comparison Systems [SE110, SE210, SE220, SE310] – This information requirement includes data on pre-existing systems that have been determined to be similar to the system under design in purpose, function, or other relevant characteristics. The information includes “Lessons Learned” from successes or failures of previous systems or programs or other critical events. The comparison systems may be officially selected or agreed to by those working on the current system or they may be identified in a more informal manner.

Concept of Operations (CONOPS) [SE110, SE120, SE130, SE140] – A document that identifies the relationship, dependencies, and desired interfaces envisioned between the new or upgraded system and other existing or planned systems. It describes the operational structure, capabilities, basing, integration, and the interoperability of all the operational and supporting systems.

Configuration Baseline [SE310, SE330, SE520, SE530] – An approved documentation of the processes and components that make up the design of a system.

Configuration Control Board (CCB) [SE510] – The CCB provides a forum for the review and disposition of proposed changes to baselined requirements, documentation, and software. The CCB is a working group consisting of representatives from the various disciplines and organizations of the developing project. The exact number, skills, and level of management of the CCB participants will vary, depending upon the change request to be reviewed.

Constraint [SE110, SE120, SE130, SE140, SE210, SE220, SE310, SE510, SE520, SE530] – A limitation or implied requirement which constrains the design solution or implementation of the systems engineering process, is not changeable by the enterprise, and is generally non-allocable (IEEE 1220).

Cost Breakdown Structure [SE420]

Derived Requirement [SE130, SE220] – A requirement that follows from the further definition, development, or decomposition of other requirements or of system design. All derived requirements must be traceable to one or more source requirements.

Design Reference Mission (DRM) [SE110, SE120, SE140, SE210, SE220, SE320, SE330, SE530] – A mission or missions that the system under design will be required to perform.

Engineering Change Proposal (ECP) [SE510, SE520] – A term which includes both a proposed engineering change and the documentation by which the change is described and suggested (MIL-STD-481A).

Functional Baseline [SE220, SE520] – (1) The initially approved documentation describing a system's or configuration item's functional, performance, interoperability, and interface requirements and the verification required to demonstrate the achievement of those specified requirements (MIL-STD-499B-UNAPPROVED). (2) The initially approved documentation describing a system's or item's functional, interoperability, and interface characteristics and the verification required to demonstrate the achievement of those specified characteristics (MIL-STD-973). (3) Documentation describing a system's/segment's functional characteristics and the verification required to demonstrate the achievement of those specified functional characteristics (DSMC).

Functional Element Allocation Options [SE310] – Potential alternatives for the allocation of a function or subfunction to an element of the system being designed. Allocation can be made to any combination of hardware, software, or human tasks, or the system can be designed such that the allocation varies as a function of time or system state.

Functional Element List [SE310] – An inventory of the functions and subfunctions that are to be allocated to different portions of the system being designed.

Functional Requirement [SE140, SE210, SE220, SE310] – (1) The necessary task, action, or activity that must be accomplished (MIL-STD-499B-UNAPPROVED). (2) A statement which identifies what a product or process must accomplish to produce required behavior and/or results (IEEE P1220).

Guidance [SE120, SE130, SE140, SE320, SE410, SE420, SE530] – Any instruction or direction provided to the performers of the systems engineering process that does not fall into an otherwise defined category or product. Guidance is generally informal in nature.

Human Engineering Specialties [SE130] – Includes task analysis, job design, selection and training issues, human physical and cognitive capabilities, human-machine interface design, function allocation, and other categories of input.

Interface Working Group (IFWG) [SE510] – A working group set up within a project to provide a means for tracking interfaces between system components being designed by different activities within the project. The IFWG participates in assessing the impact of a change in one system component on the other system components with which that changed component is related.

Mission Needs Statement (MNS) [SE130, SE330]– A formal document, expressed in broad operational terms and prepared in accordance with CJCS MOP 77, that documents deficiencies in current capabilities and opportunities to provide new capabilities. (DSMC)

Non-Developmental Item (NDI) [SE130, SE 220, SE310, SE340] – (1) Any previously developed item of supply used exclusively for governmental purposes by a Federal Agency, a State or local government, or a foreign government with which the United States has a mutual defense cooperation agreement; (2) any item described in (1) that requires only minor modification or modifications of the type customarily available in the commercial marketplace in order to meet the requirements of the procuring department or agency; or any item described in (1) or (2) solely because the item is not yet in use (Federal Acquisition Regulation, Part 2.101, Definitions)

Operational Requirements [SE130] – The characteristics, capabilities, and performance the system must possess to meet its operations needs.

Operational Requirements Document (ORD) [SE120, SE130, SE140, SE330, SE410] – A definition of a specific concept of system intended to establish measurable objectives for the system. The ORD follows the MNS, and includes minimum acceptable requirements for the system, critical system characteristics, and describes pertinent quantitative and qualitative performance, operation, and support parameters, characteristics, and requirements.

Performance Requirement [SE140, SE210, SE220, SE320, SE410, SE530] – (1) The extent to which a mission or function must be executed, generally measured in terms of quantity, quality, coverage, timeliness or readiness (MIL-STD-499B-UNAPPROVED). (2) The measurable criteria which identifies a quality attribute of a function, or how well a functional requirement must be accomplished (IEEE P1220).

Preliminary Design Review (PDR) [SE520] – A formal review which confirms that the preliminary design logically follows the SFR findings and meets the requirements. It normally results in approval to begin detail design. (DSMC)

Requirement – A statement which identifies a product or process limitation, capability, or physical characteristic (IEEE P1220). The different categories of requirements used within this document are Source Requirements, Derived Requirements, Operational Requirements, Functional Requirements, and Performance Requirements.

Requirements Baseline [SE130, SE140, SE220, SE310, SE320, SE330, SE340, SE410, SE510, SE520, SE530] – (1) The composite set of requirements at any time in the system life-cycle which represent the agreed-to and approved set of requirements which serve to guide design and management decision processes (IEEE P1220). (2) The composite set of operational, functional and physical requirements which serve to guide development and management decision processes (IEEE P1220).

Requirements Traceability Matrix [SE120, SE130, SE140, SE220, SE510] – A formal mechanism for tracing requirements back to their rationale for becoming a requirement. The origin of derived requirements can be traced through the requirements traceability matrix.

Source Requirement [SE110, SE130, SE140] – An original, non-derived requirement; one of the initial set of requirements.

Specification [SE340, SE520] -

Specification Change Notice (SCN) [SE510] – (1) A document used to propose, transmit, and record changes to a specification (MIL-STD-481A), (MIL-STD-973), (DoD-STD-480A). (2) A document used in configuration management to propose, transmit, and record changes to a specification (IEEE 610.12-1990).

Specification Tree [SE340, SE510, SE520, SE530] -

System Boundaries [SE120] – The boundaries of the system under design. This includes all portions of the product to be produced by the project. With the exception of required, default, or mandated components, the selection and design of all portions of the system are under the control of the systems engineering process.

System Functional Review (SFR) [SE520] – A formal review of the conceptual design of the system to establish its capability to satisfy requirements. Establishes the functional baseline. (DSMC)

System Requirements Review (SRR) [SE520] – A formal, system-level review conducted to ensure that system requirements have been completely and properly identified and that there is a mutual understanding between the government and contractor. (DSMC)

System Specification [SE520]

Work Breakdown Structure [SE420, SE430, SE530] – (1) A product-oriented family tree composed of hardware, software, services, and other work tasks, which results from project engineering effort during the development and production of an item, and which completely defines the project or program (DoD Directive 5010.19), (DoD-STD-480A). (2) The WBS provides a framework for program and technical planning, cost estimating, resource allocations, performance measurements, and status reporting. The WBS and associated WBS dictionary shall define the total system to be developed or produced; display the total system as a product-oriented family tree composed of hardware, software, services, data, and facilities; and relate the elements of work to each other and to the end product (DoD Directive 5000.2-R)

ACRONYM LIST

AOA....................... Analysis of Alternatives
ACR....................... Alternative Concept Review
CBS....................... Cost Breakdown Structure
CCB....................... Configuration Control Board
CONOPS............... Concept of Operations
COTS .... Commercial Off-The-Shelf
DRM .... Design Reference Mission
MNS .... Mission Need Statement
MOEs .... Measures of Effectiveness
NDI .... Non-Developmental Item
ORD .... Operational Requirements Document
PDR....................... Preliminary Design Review
ROE .... Rules of Engagement
SCN....................... Specification Change Notice
SEDS..................... Systems Engineering Detailed Schedule
SEMP .... Systems Engineering Management Plan
SEMS .... Systems Engineering Master Schedule
SFR .... System Functional Review
SRR....................... System Requirements Review
TPM....................... Technical Performance Measure
WBS .... Work Breakdown Structure

SE Flow Diagram

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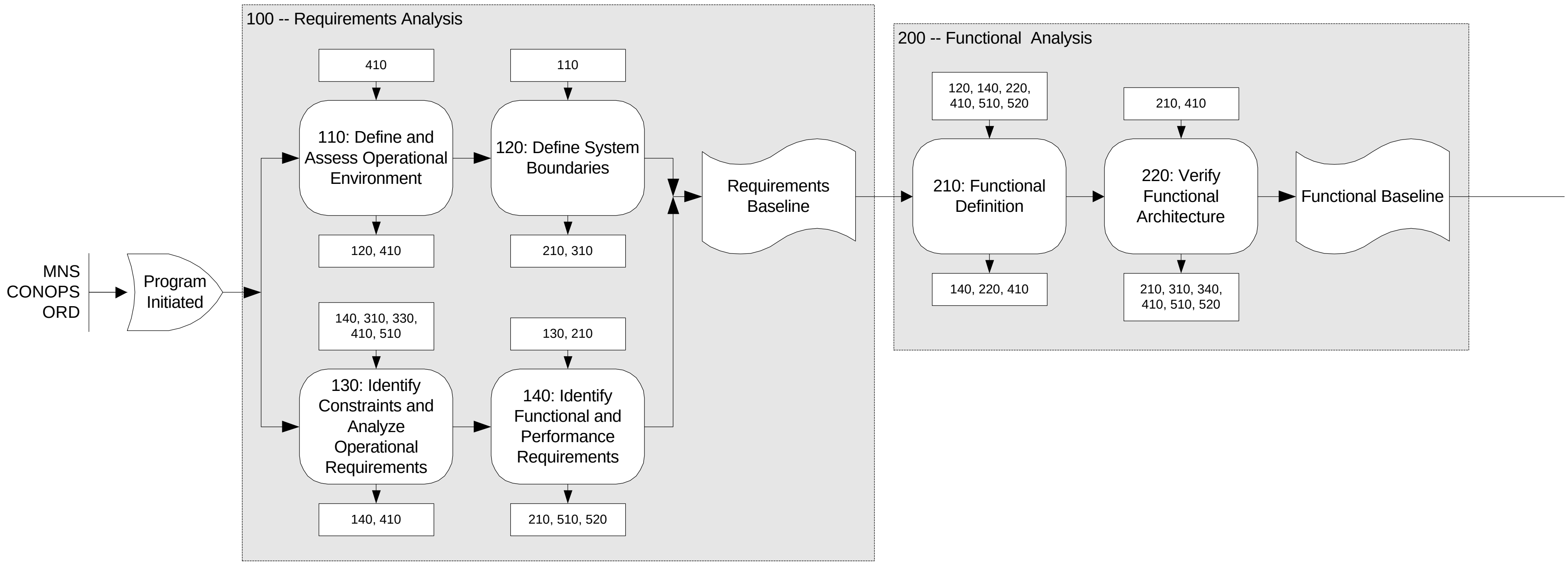
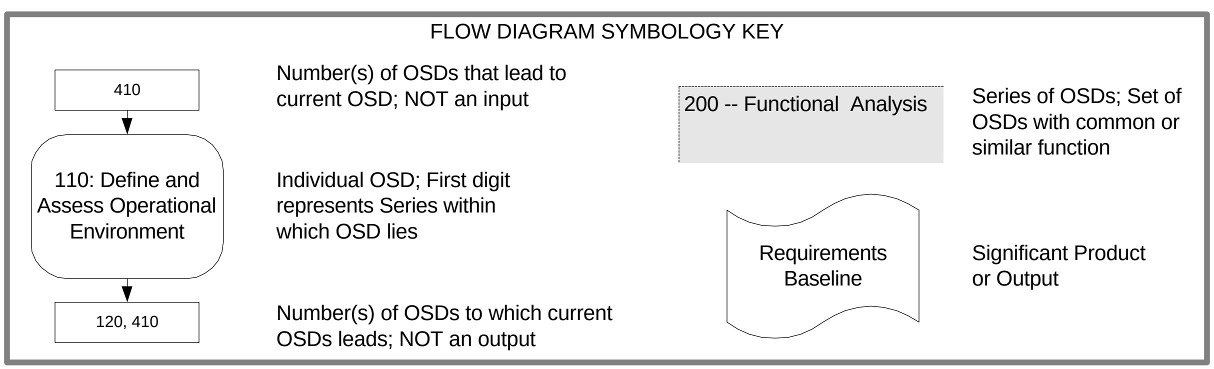
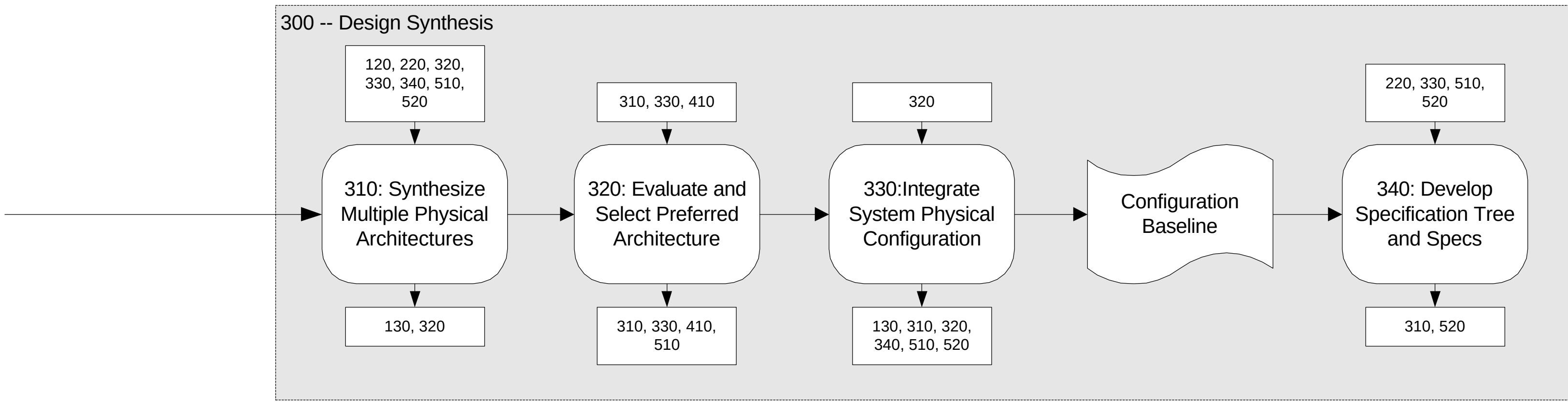
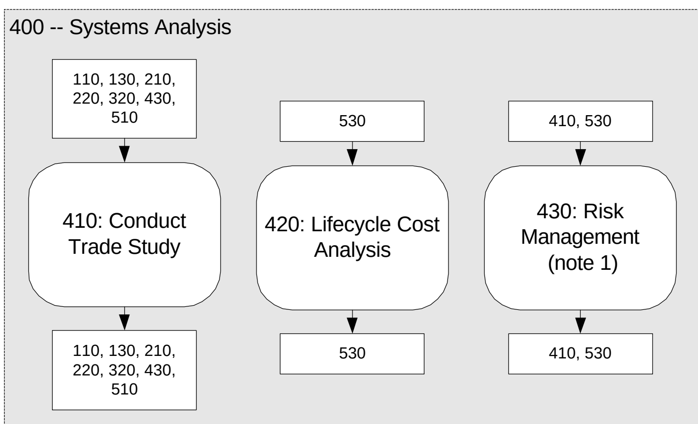
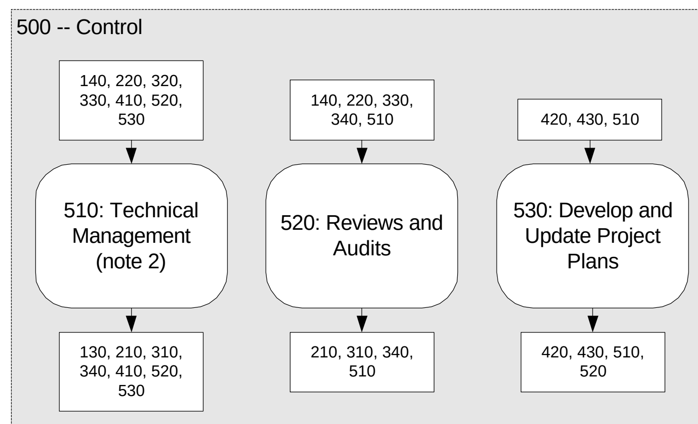










note 1: Risk management in Systems Analysis includes environmental vs. program risk (for definitions see INCOSE handbook p. 4.5-14)

note 2: Technical management includes: configuration management, data management, interface management, and program risk assessment)

100 SERIES – REQUIREMENTS ANALYSIS

Description

The Requirements Analysis series of the OSDs addresses the process through which initial user needs and other source requirements are translated into functional and performance requirements for the system. These processes are performed iteratively with Functional Analysis to define requirements that depend upon further definition or decomposition of the system. This series assumes the availability of a Mission Needs Statement, Concept of Operations, and at least a draft version of an Operational Requirements Document.

OSD Notes

SE110 – Define and Assess Operational Environment

This OSD may also include the development or use of ROC/POE (Required Operational Capability/Predicted Operational Environment)

SE120 – Define System Boundaries

SE130 – Identify Constraints and Analyze Operational Requirements

[TASK] Identify Engineering Specialty Guidelines

This task involves the identification of constraints on the design of the system (in the form of requirements, functions, or components) that are due to factors in different engineering specialty categories. The categories that are listed were taken from the INCOSE Systems Engineering Handbook, Release 1.0, and are meant to serve as an example of the disciplines that may need to be included in this process. It is not meant to be an all-inclusive list of disciplines appropriate for any project.

[TASK] Determine Constraints

This task creates seven sets or categories of constraints: Design, Human, Technology, COTS/NDI, Schedule, Cost, and Risk Constraints. Throughout the rest of the OSDs, they are generally referred to collectively as "Constraints."

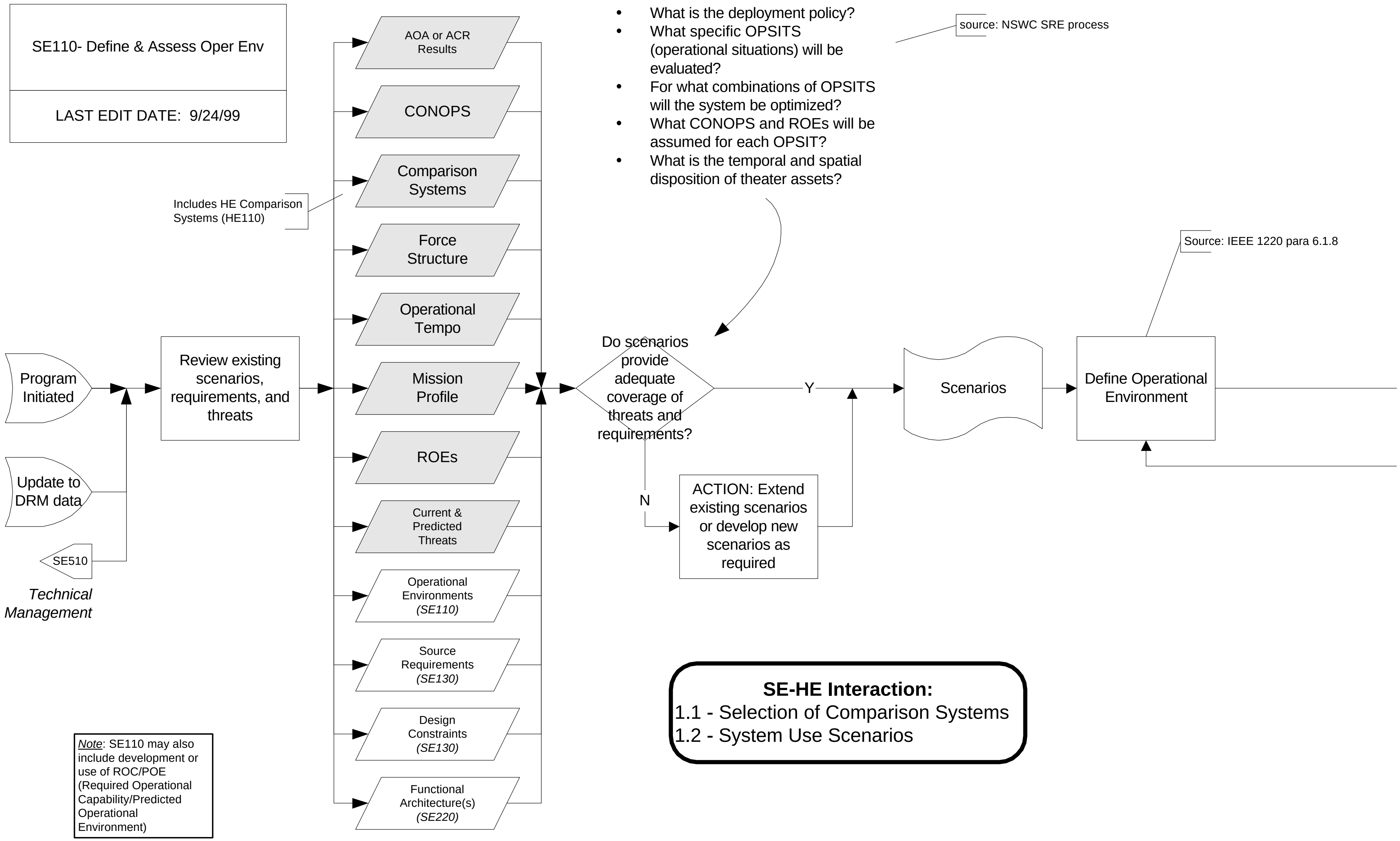
[ACTION] Resolve Constraint or Guideline Conflicts

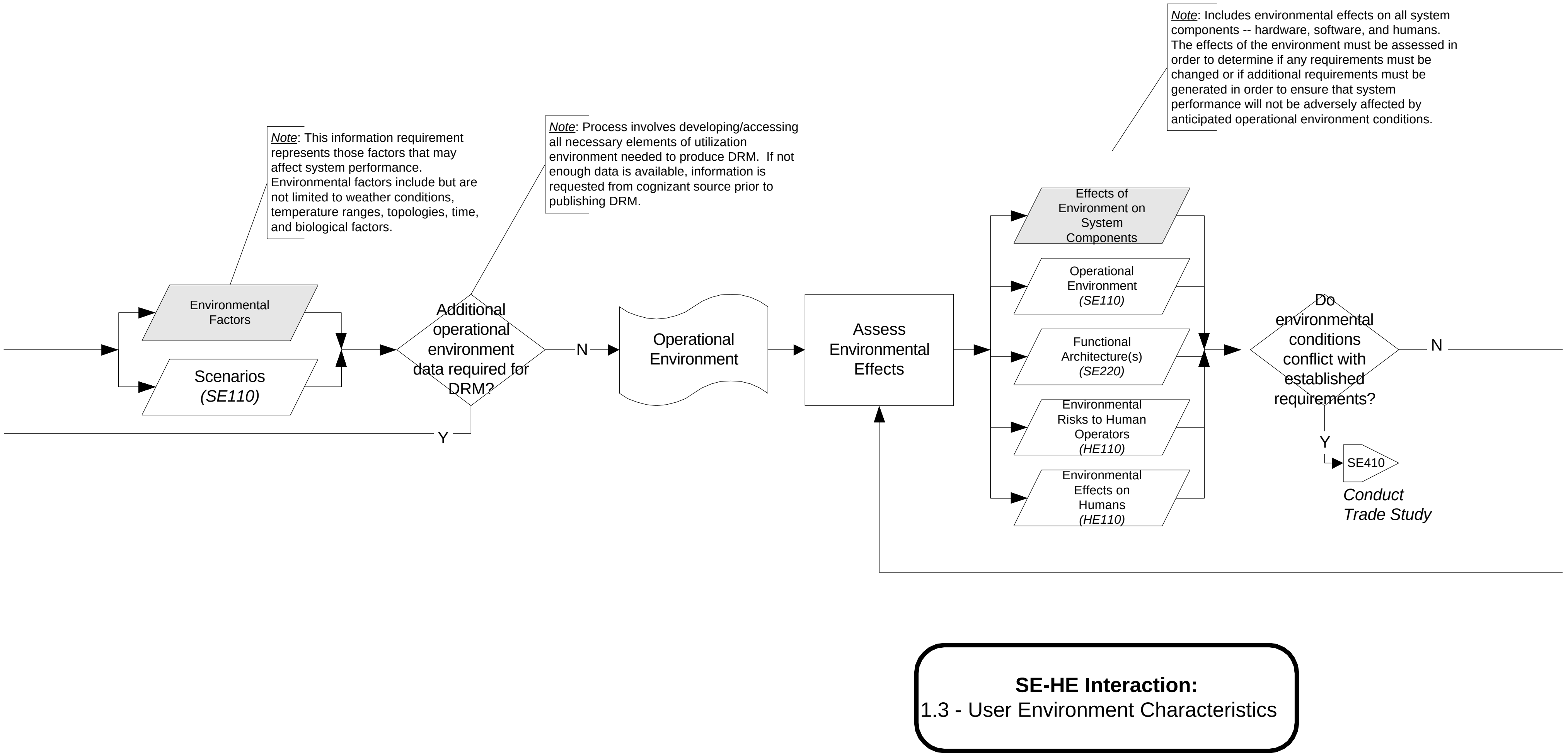
This task involves the following steps:

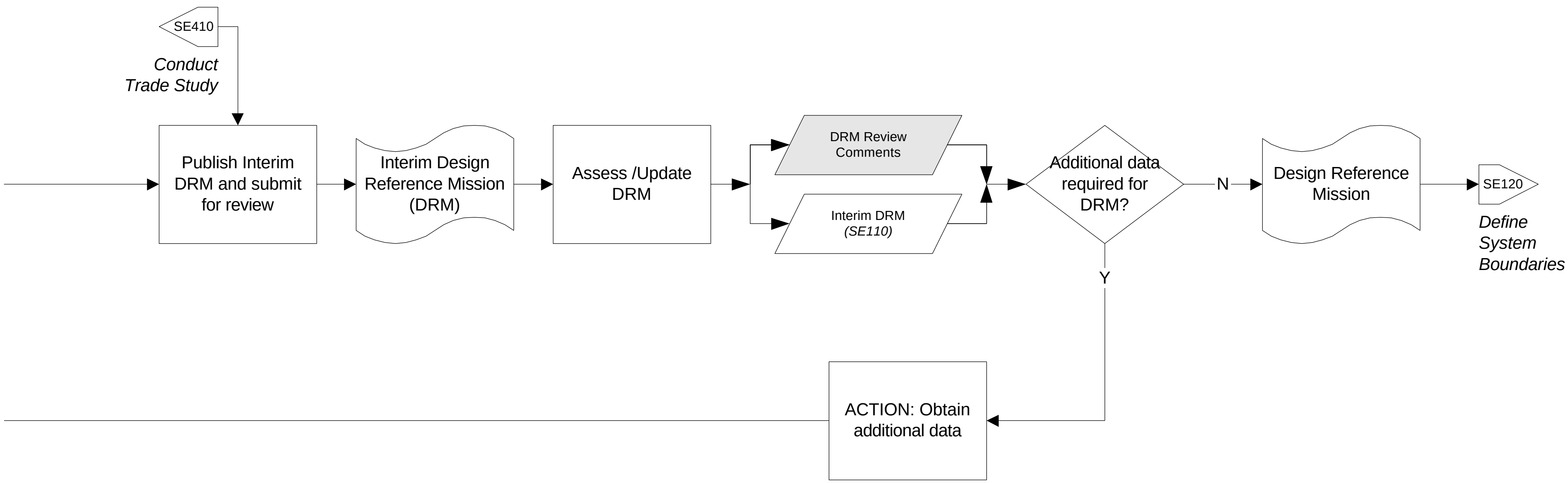
- Explicitly define conflict
- Determine impact of relaxing each conflicting constraint
- Determine resolution method
    - Unilateral decision, with documentation of rationale
    - Pass up to approval authority, customer, program manager, etc.
    - Pass to responsible working group

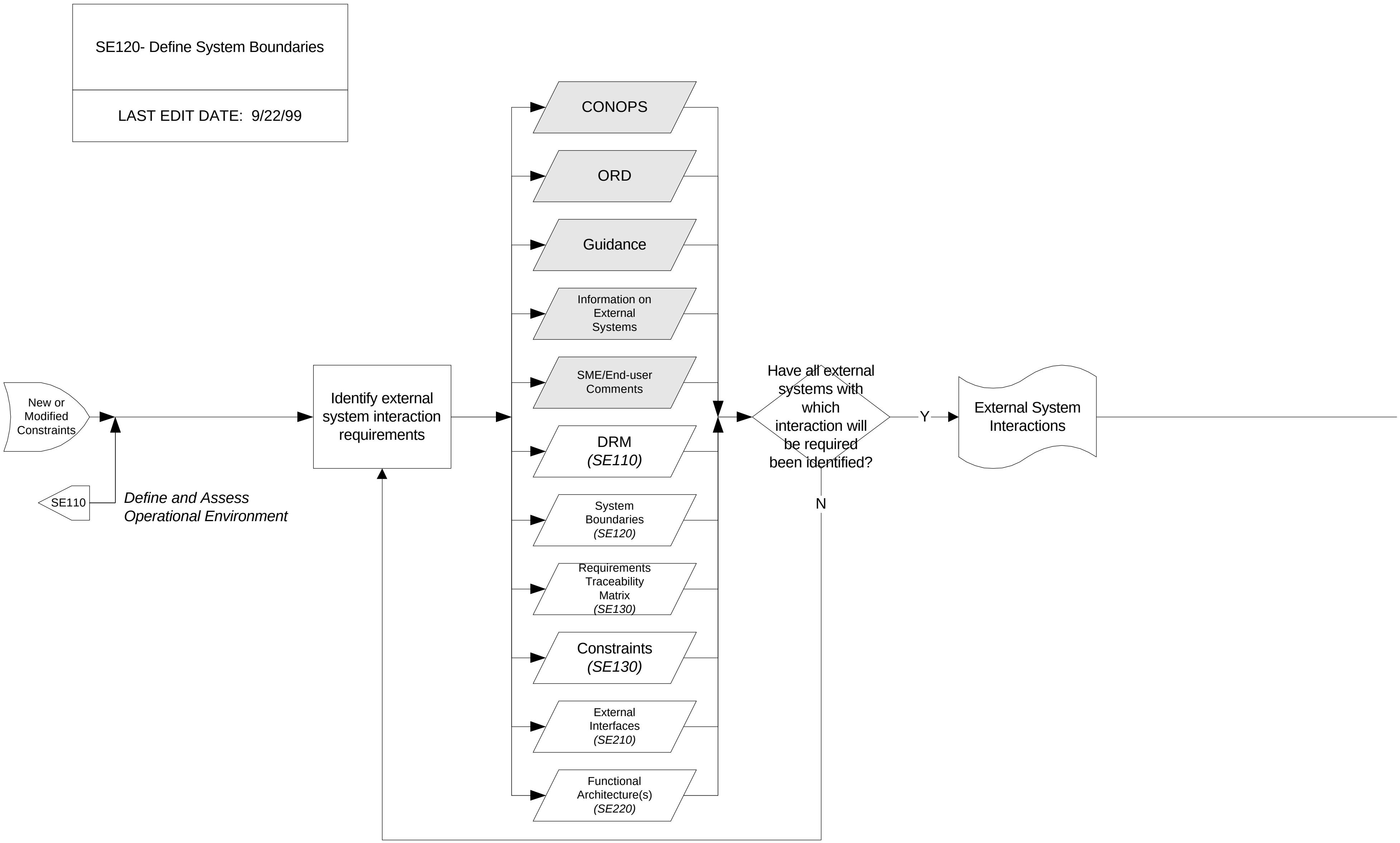
Results of conflict resolution are not specifically identified as a product of the process since the results are produced external to the process. These results can be considered to be included in the “Guidance” information requirement.

SE140 – Identify Functional and Performance Requirements

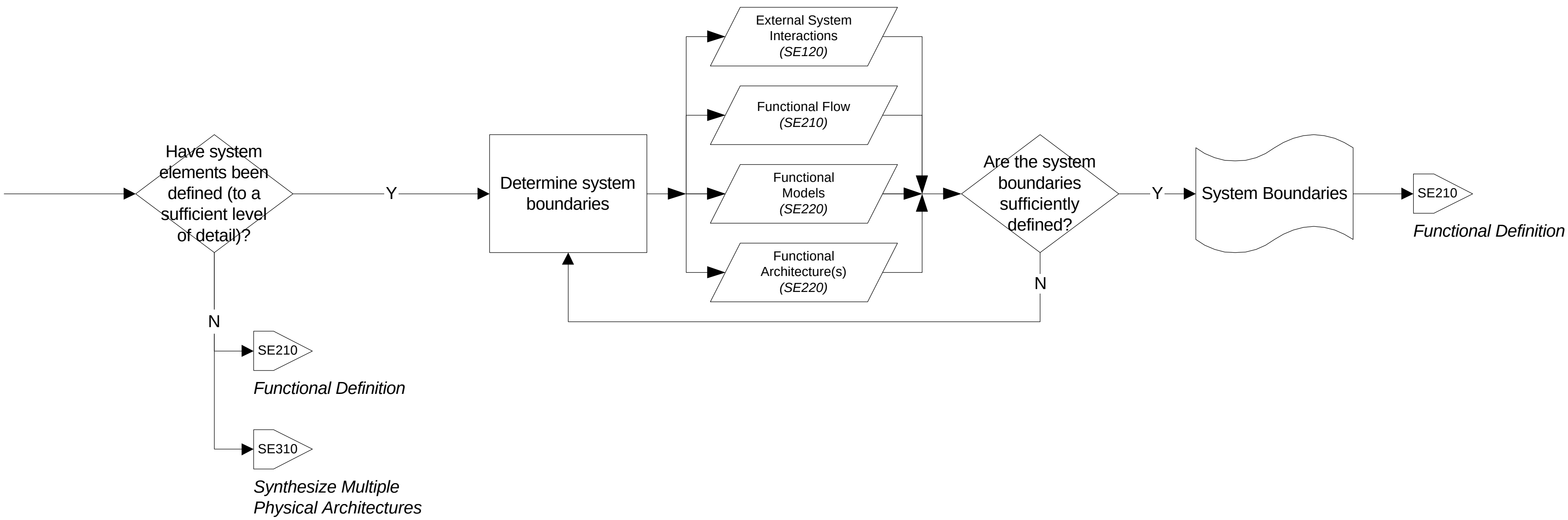

SE110- Define & Assess Oper Env
LAST EDIT DATE: 9/24/99
Program Initiated
Update to DRM data
SE510
Technical Management
Review existing scenarios, requirements, and threats
Includes HE Comparison Systems (HE110)
AOA or ACR Results
CONOPS
Comparison Systems
Force Structure
Operational Tempo
Mission Profile
ROEs
Current & Predicted Threats
Operational Environments (SE110)
Source Requirements (SE130)
Design Constraints (SE130)
Functional Architecture(s) (SE220)
Note: SE110 may also include development or use of ROC/POE (Required Operational Capability/Predicted Operational Environment)
What is the deployment policy?
What specific OPSITS (operational situations) will be evaluated?
For what combinations of OPSITS will the system be optimized?
What CONOPS and ROEs will be assumed for each OPSIT?
What is the temporal and spatial disposition of theater assets?
source: NSWC SRE process
Do scenarios provide adequate coverage of threats and requirements?
Y
N
ACTION: Extend existing scenarios or develop new scenarios as required
Scenarios
Define Operational Environment
Source: IEEE 1220 para 6.1.8
SE-HE Interaction:
1.1 - Selection of Comparison Systems
1.2 - System Use Scenarios

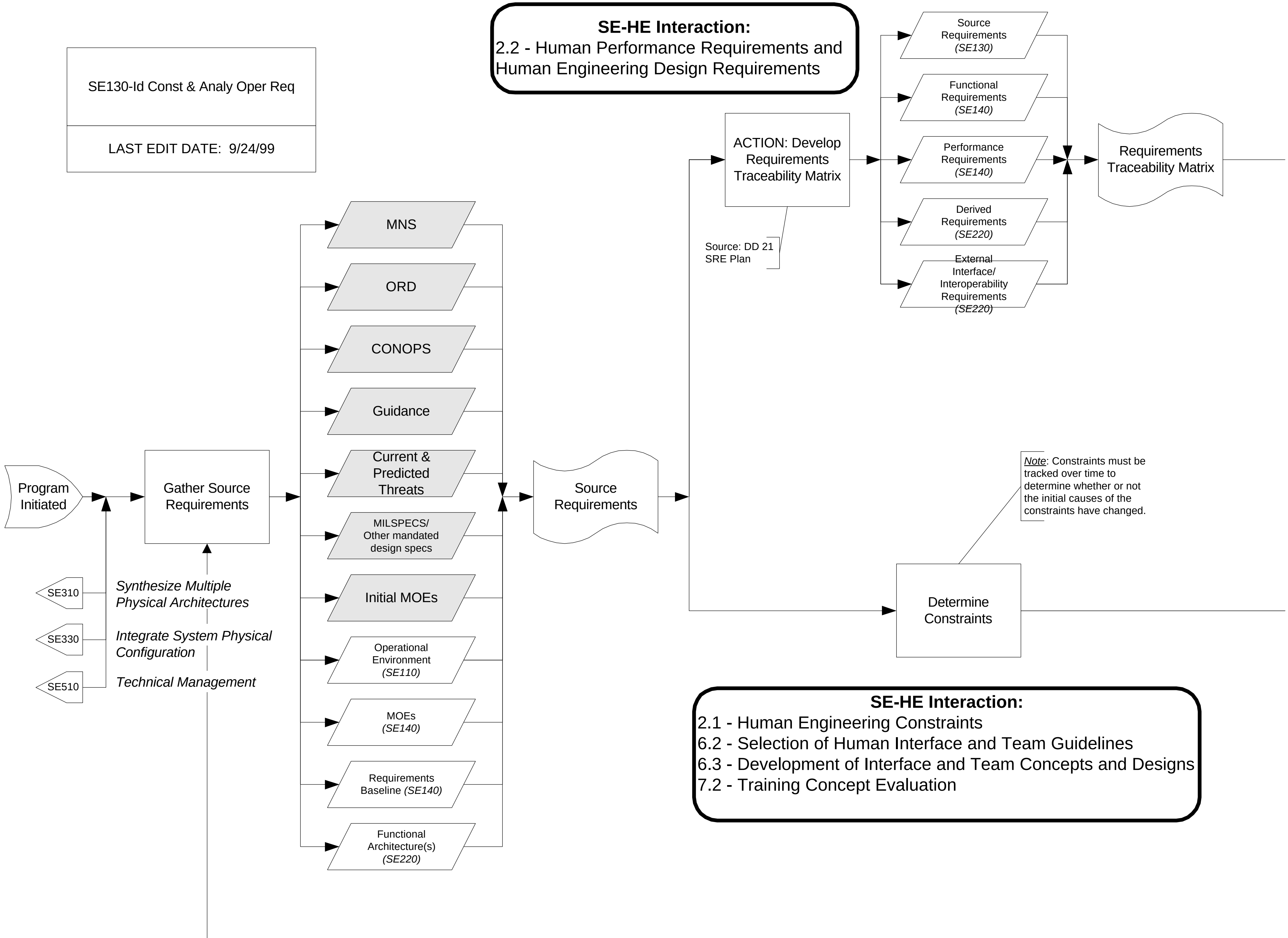

Note: This information requirement represents those factors that may affect system performance. Environmental factors include but are not limited to weather conditions, temperature ranges, topologies, time, and biological factors.
Note: Process involves developing/accessing all necessary elements of utilization environment needed to produce DRM. If not enough data is available, information is requested from cognizant source prior to publishing DRM.
Note: Includes environmental effects on all system components -- hardware, software, and humans. The effects of the environment must be assessed in order to determine if any requirements must be changed or if additional requirements must be generated in order to ensure that system performance will not be adversely affected by anticipated operational environment conditions.
Environmental Factors
Scenarios (SE110)
Additional operational environment data required for DRM?
N
Y
Operational Environment
Assess Environmental Effects
Effects of Environment on System Components
Operational Environment (SE110)
Functional Architecture(s) (SE220)
Environmental Risks to Human Operators (HE110)
Environmental Effects on Humans (HE110)
Do environmental conditions conflict with established requirements?
N
Y
SE410
Conduct Trade Study
SE-HE Interaction:
1.3 - User Environment Characteristics

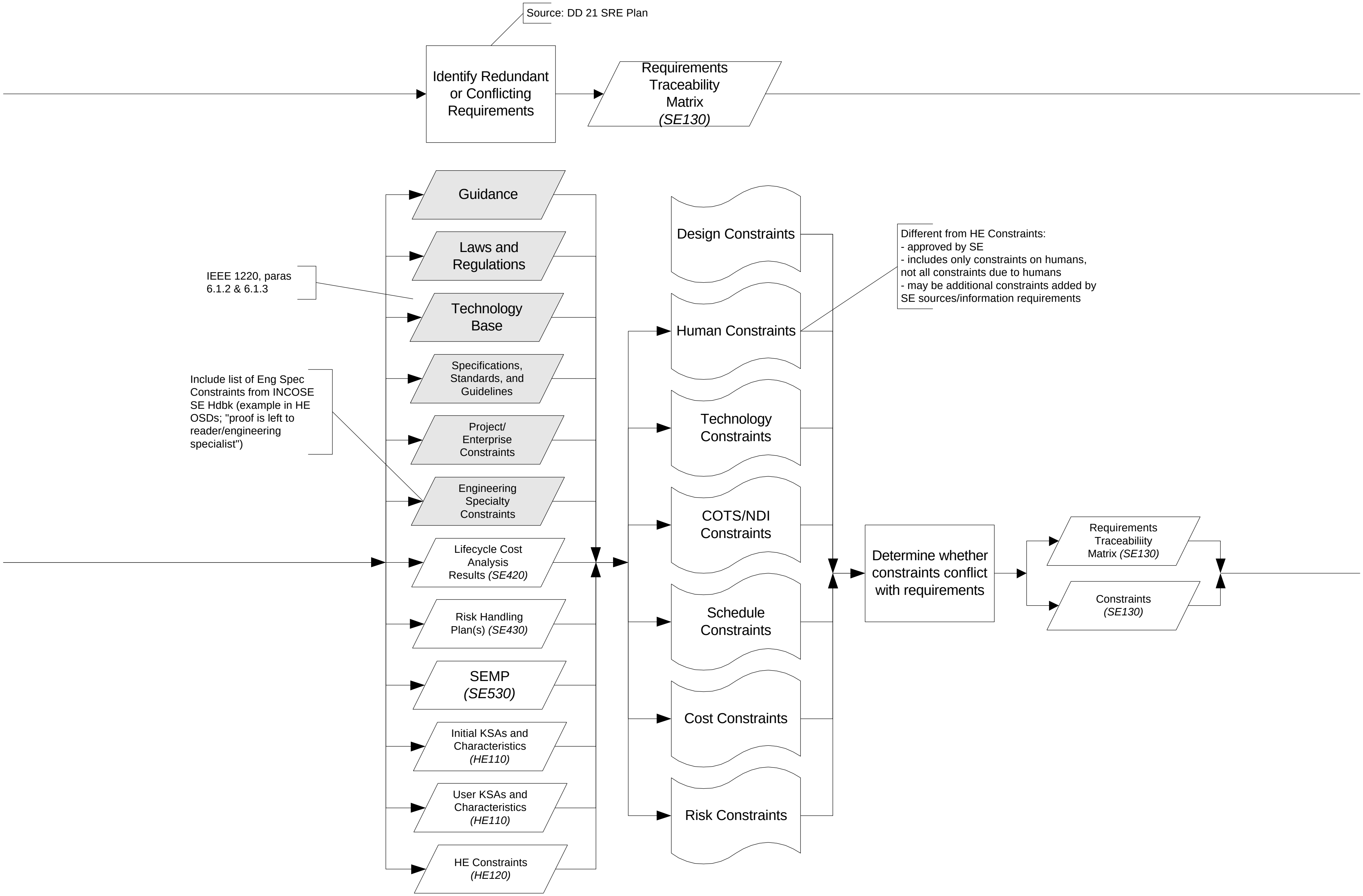

SE410
Conduct Trade Study
Publish Interim DRM and submit for review
Interim Design Reference Mission (DRM)
Assess /Update DRM
DRM Review Comments
Interim DRM (SE110)
Additional data required for DRM?
N
Y
Design Reference Mission
SE120
Define System Boundaries
ACTION: Obtain additional data

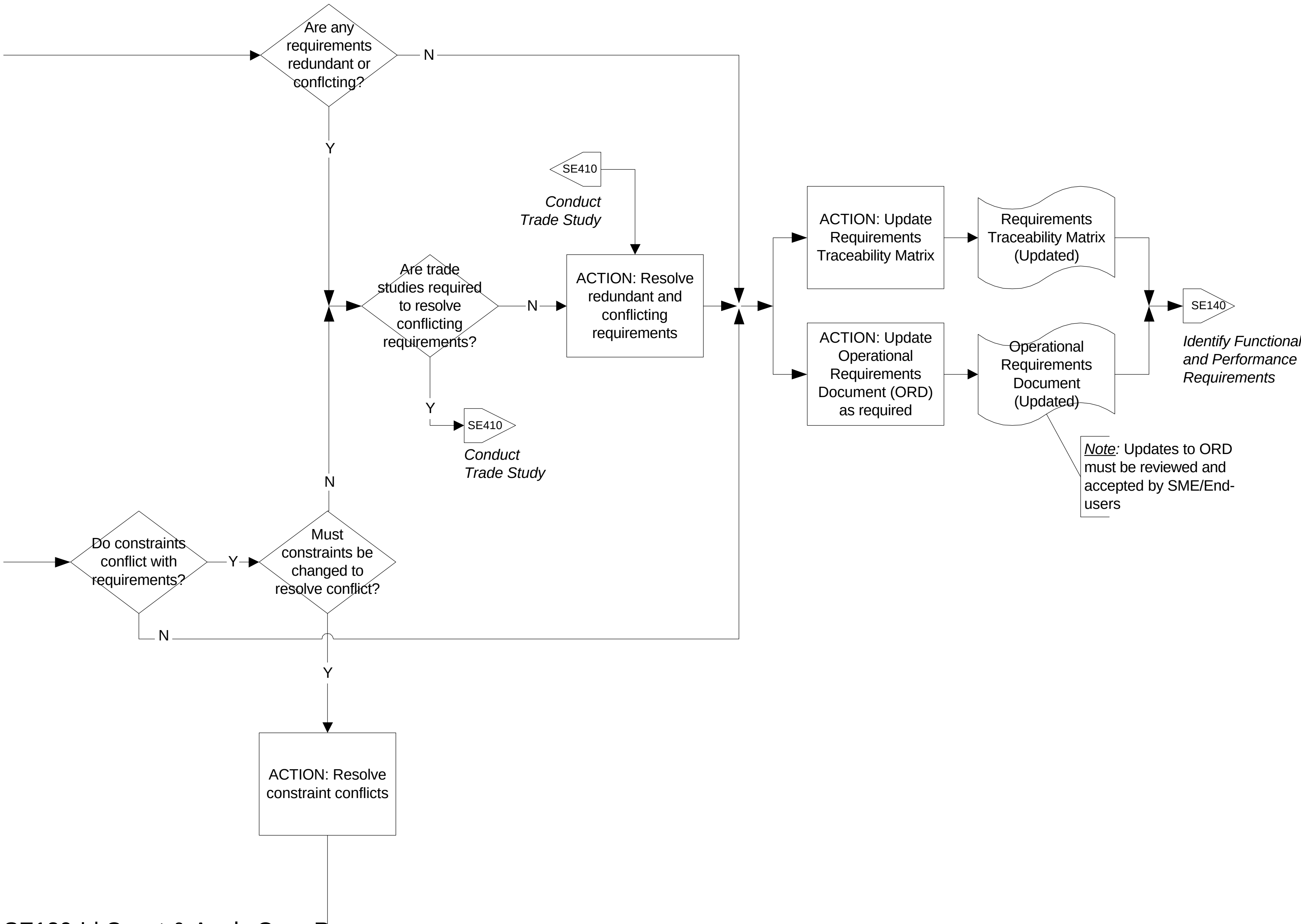

SE120- Define System Boundaries
LAST EDIT DATE: 9/22/99
New or Modified Constraints
SE110
Define and Assess Operational Environment
Identify external system interaction requirements
CONOPS
ORD
Guidance
Information on External Systems
SME/End-user Comments
DRM (SE110)
System Boundaries (SE120)
Requirements Traceability Matrix (SE130)
Constraints (SE130)
External Interfaces (SE210)
Functional Architecture(s) (SE220)
Have all external systems with which interaction will be required been identified?
Y
N
External System Interactions

<u>Interface specification</u>: The description of essential functional, performance, and physical requirements and constraints at a common boundary between two or more system elements. This includes interfaces between humans and hardware or software as well as interfaces between humans themselves. *(source: IEEE 1220)*




SE130-Id Const & Analy Oper Req
LAST EDIT DATE: 9/24/99
SE-HE Interaction:
2.2 - Human Performance Requirements and Human Engineering Design Requirements
Program Initiated
Gather Source Requirements
SE310
SE330
SE510
Synthesize Multiple Physical Architectures
Integrate System Physical Configuration
Technical Management
MNS
ORD
CONOPS
Guidance
Current & Predicted Threats
MILSPECS/ Other mandated design specs
Initial MOEs
Operational Environment (SE110)
MOEs (SE140)
Requirements Baseline (SE140)
Functional Architecture(s) (SE220)
Source Requirements
ACTION: Develop Requirements Traceability Matrix
Source: DD 21 SRE Plan
Source Requirements (SE130)
Functional Requirements (SE140)
Performance Requirements (SE140)
Derived Requirements (SE220)
External Interface/ Interoperability Requirements (SE220)
Requirements Traceability Matrix
Note: Constraints must be tracked over time to determine whether or not the initial causes of the constraints have changed.
Determine Constraints
SE-HE Interaction:
2.1 - Human Engineering Constraints
6.2 - Selection of Human Interface and Team Guidelines
6.3 - Development of Interface and Team Concepts and Designs
7.2 - Training Concept Evaluation


Source: DD 21 SRE Plan
Identify Redundant or Conflicting Requirements
Requirements Traceability Matrix (SE130)
Guidance
Laws and Regulations
IEEE 1220, paras 6.1.2 & 6.1.3
Technology Base
Specifications, Standards, and Guidelines
Include list of Eng Spec Constraints from INCOSE SE Hdbk (example in HE OSDs; "proof is left to reader/engineering specialist")
Project/ Enterprise Constraints
Engineering Specialty Constraints
Lifecycle Cost Analysis Results (SE420)
Risk Handling Plan(s) (SE430)
SEMP (SE530)
Initial KSAs and Characteristics (HE110)
User KSAs and Characteristics (HE110)
HE Constraints (HE120)
Design Constraints
Human Constraints
Different from HE Constraints:
- approved by SE
- includes only constraints on humans, not all constraints due to humans
- may be additional constraints added by SE sources/information requirements
Technology Constraints
COTS/NDI Constraints
Schedule Constraints
Cost Constraints
Risk Constraints
Determine whether constraints conflict with requirements
Requirements Traceabiliity Matrix (SE130)
Constraints (SE130)


Are any requirements redundant or conflcting?
N
Y
SE410
Conduct Trade Study
Are trade studies required to resolve conflicting requirements?
N
Y
SE410
Conduct Trade Study
ACTION: Resolve redundant and conflicting requirements
ACTION: Update Requirements Traceability Matrix
Requirements Traceability Matrix (Updated)
ACTION: Update Operational Requirements Document (ORD) as required
Operational Requirements Document (Updated)
SE140
Identify Functional and Performance Requirements
Note: Updates to ORD must be reviewed and accepted by SME/End-users
Do constraints conflict with requirements?
Y
N
Must constraints be changed to resolve conflict?
N
Y
ACTION: Resolve constraint conflicts

SE140 Id Funct & Perf Req's

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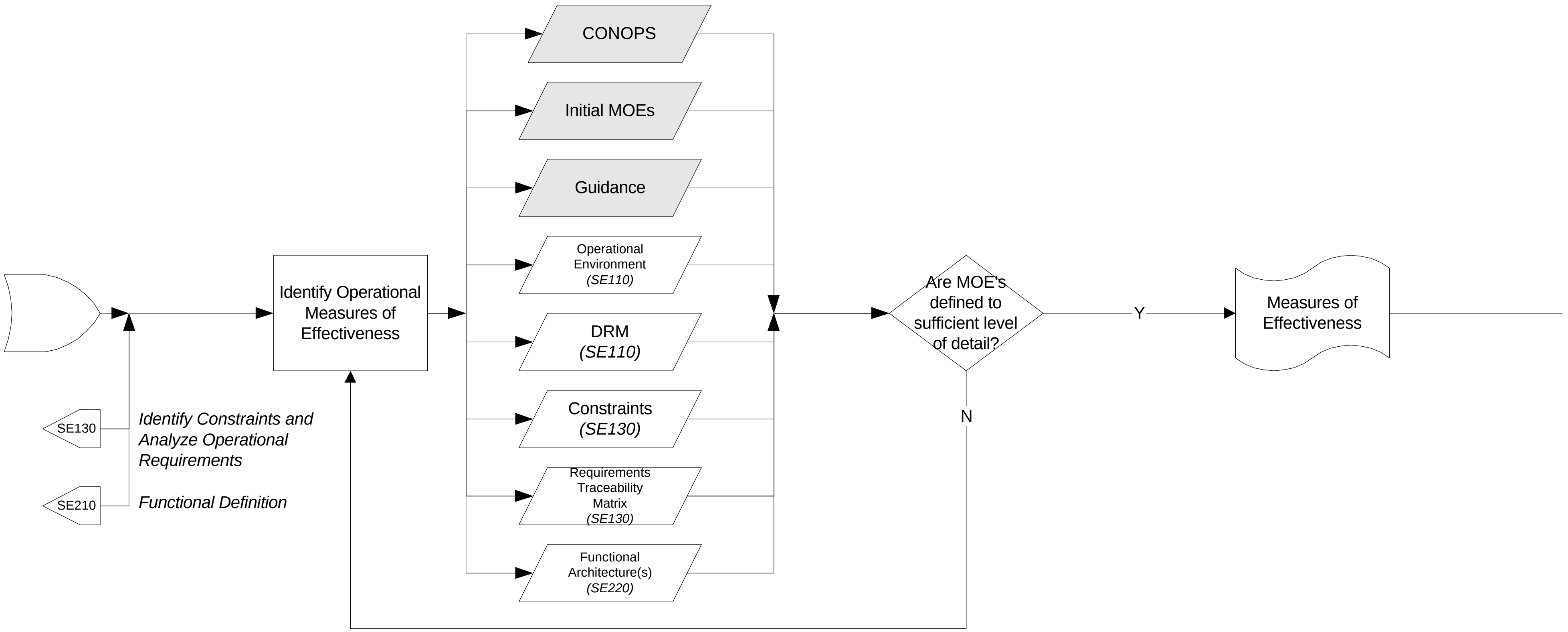
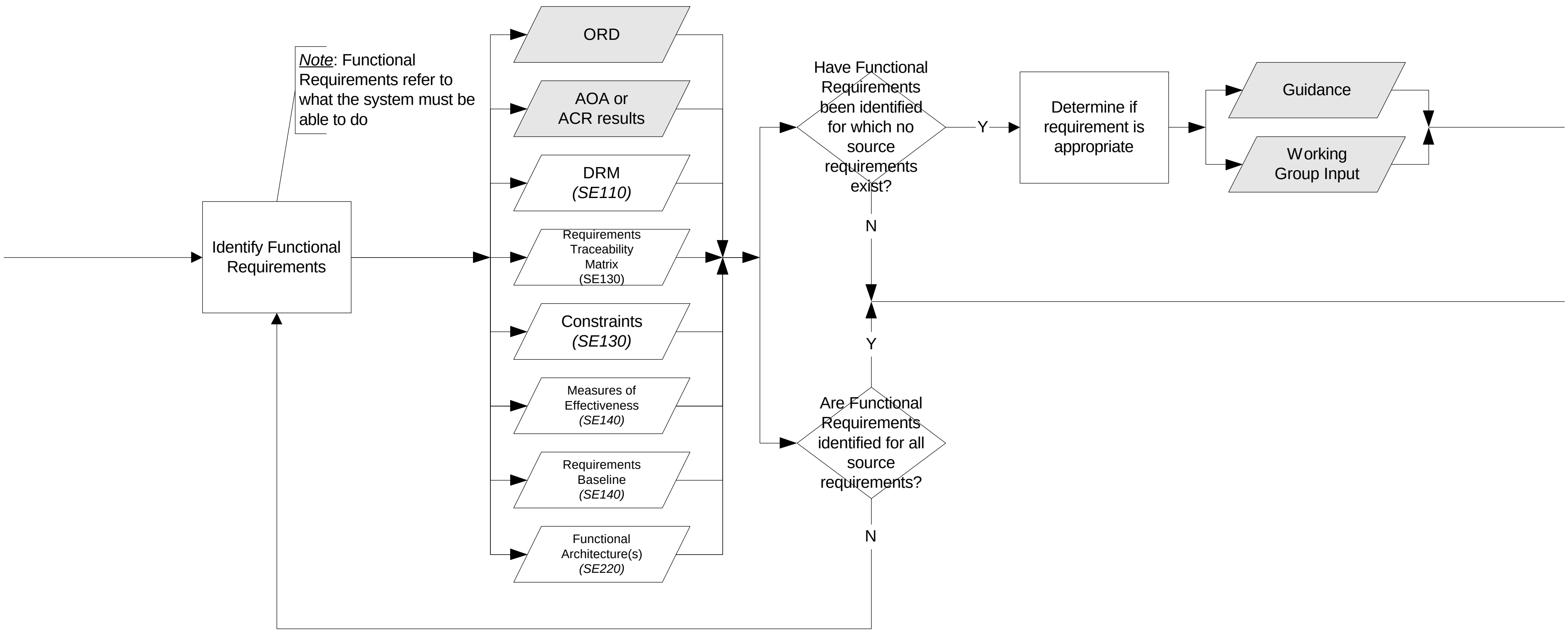
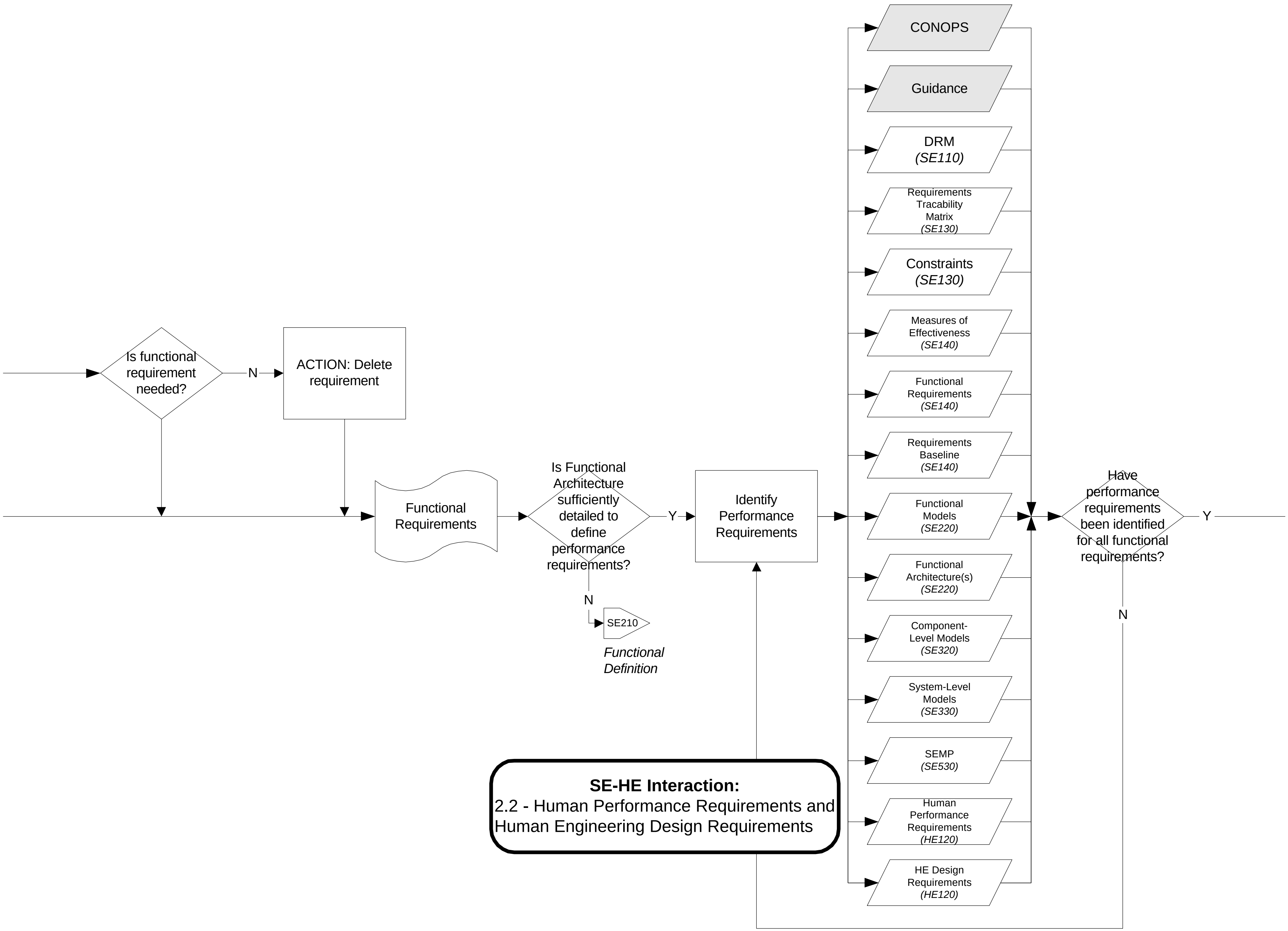
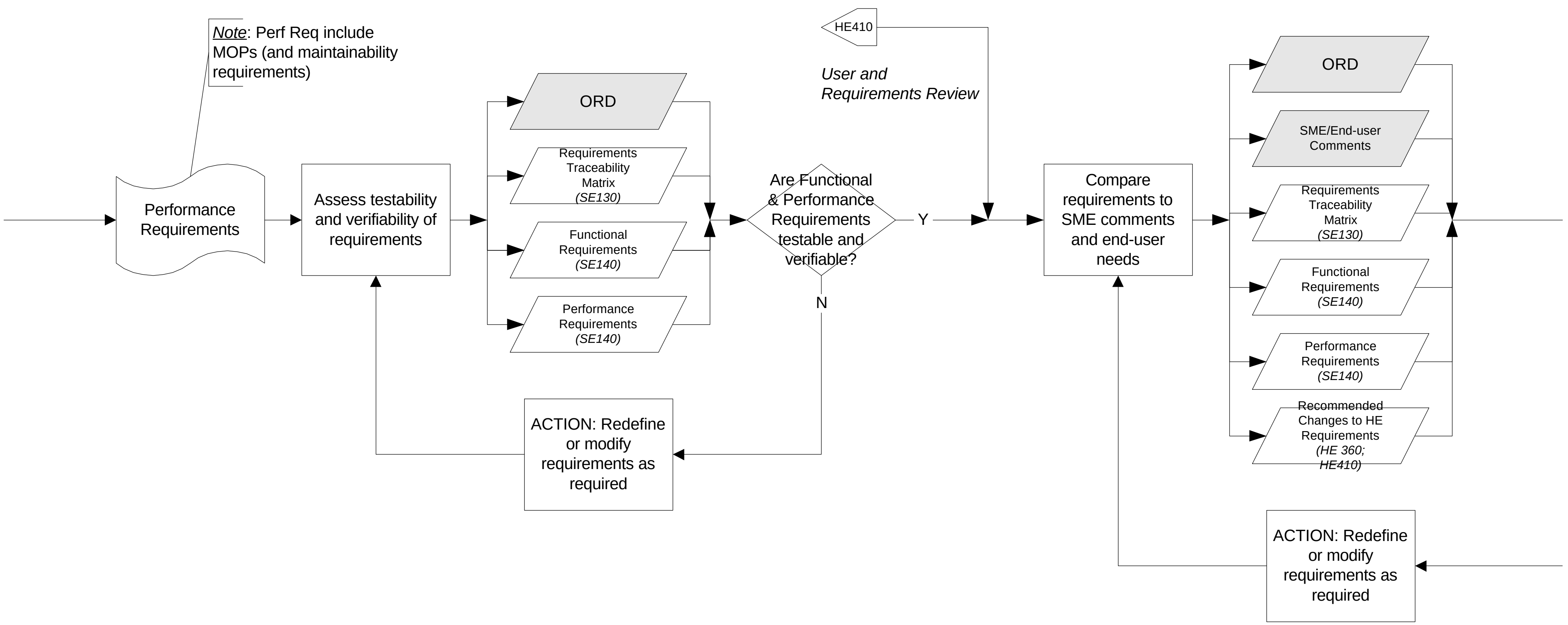


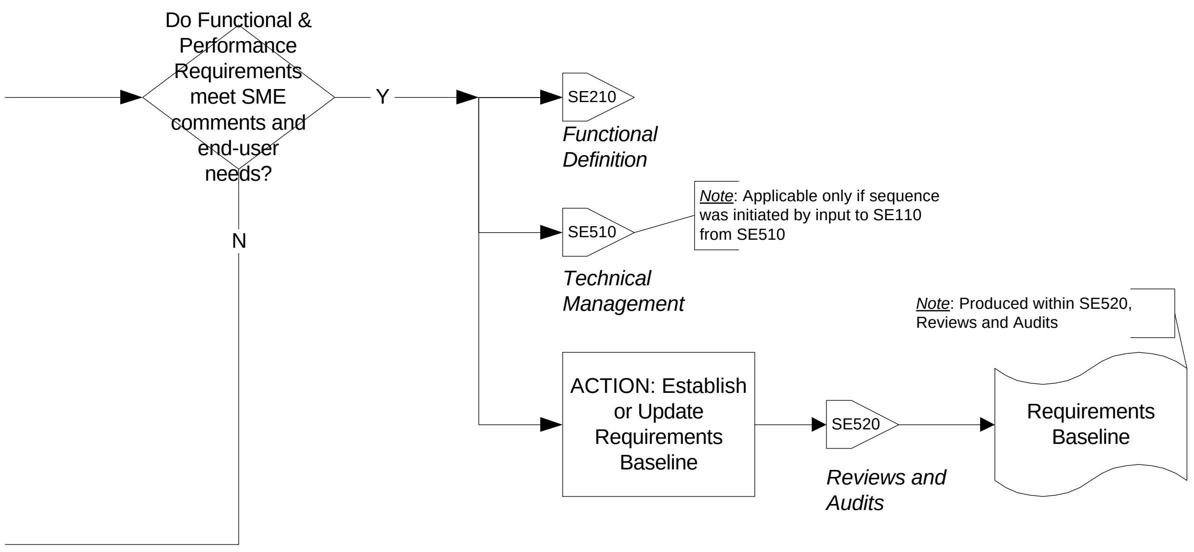


Note: Functional Requirements refer to what the system must be able to do
Identify Functional Requirements
ORD
AOA or ACR results
DRM (SE110)
Requirements Traceability Matrix (SE130)
Constraints (SE130)
Measures of Effectiveness (SE140)
Requirements Baseline (SE140)
Functional Architecture(s) (SE220)
Have Functional Requirements been identified for which no source requirements exist?
Y
N
Determine if requirement is appropriate
Guidance
Working Group Input
Y
Are Functional Requirements identified for all source requirements?
N



CONOPS
Guidance
DRM (SE110)
Requirements Tracability Matrix (SE130)
Constraints (SE130)
Measures of Effectiveness (SE140)
Functional Requirements (SE140)
Requirements Baseline (SE140)
Functional Models (SE220)
Functional Architecture(s) (SE220)
Component-Level Models (SE320)
System-Level Models (SE330)
SEMP (SE530)
Human Performance Requirements (HE120)
HE Design Requirements (HE120)
Is functional requirement needed?
N
ACTION: Delete requirement
Functional Requirements
Is Functional Architecture sufficiently detailed to define performance requirements?
Y
N
SE210
Functional Definition
Identify Performance Requirements
Have performance requirements been identified for all functional requirements?
Y
N
SE-HE Interaction:
2.2 - Human Performance Requirements and Human Engineering Design Requirements


Note: Perf Req include MOPs (and maintainability requirements)
Performance Requirements
Assess testability and verifiability of requirements
ORD
Requirements Traceability Matrix (SE130)
Functional Requirements (SE140)
Performance Requirements (SE140)
Are Functional & Performance Requirements testable and verifiable?
Y
N
ACTION: Redefine or modify requirements as required
HE410
User and Requirements Review
Compare requirements to SME comments and end-user needs
ORD
SME/End-user Comments
Requirements Traceability Matrix (SE130)
Functional Requirements (SE140)
Performance Requirements (SE140)
Recommended Changes to HE Requirements (HE 360; HE410)
ACTION: Redefine or modify requirements as required


Do Functional & Performance Requirements meet SME comments and end-user needs?
Y
N
SE210
Functional Definition
SE510
Note: Applicable only if sequence was initiated by input to SE110 from SE510
Technical Management
Note: Produced within SE520, Reviews and Audits
ACTION: Establish or Update Requirements Baseline
SE520
Reviews and Audits
Requirements Baseline

200 SERIES – FUNCTIONAL ANALYSIS

Description

The Functional Analysis series of the OSDs concerns the definition of top-level system functions, their subsequent decomposition into subfunctions, and the identification of the relevant characteristics of those functions. A functional architecture, which includes functional relationships, inputs and outputs, and associated requirements, is created and verified. Functional Analysis is performed iteratively with requirements Analysis to allow for the decomposition of requirements, and it is performed iteratively with Design Synthesis to permit the allocation of functions and to create a system physical architecture that satisfies the system's requirements.

OSD Notes

SE210 – Functional Definition

[TRIGGER] New Function Identified

This trigger includes the discovery of the need for new functions through the processes of SE220 or other means. It does *not* specifically refer to functions that are novel, innovative, or of an unprecedented nature.

[TASK] Identify Function Interactions

At this point functions are not allocated to hardware, software, or humans, so function interactions include interfaces between humans and other system components and interfaces among humans.

[PRODUCT] Draft Functional Architecture

A draft version of the functional architecture is the product of this OSDs. The following OSD, SE220, addresses the process by which this draft functional architecture is compared to requirements and verified.

SE220 – Verify Functional Architecture

[TASK] Verify Functional Flow with Design Constraints (including COTS constraints)

The information requirements associated with this task include COTS/NDI Constraints and the general category of Constraints. When Constraints is listed as an information requirement, it can be assumed to include all categories of constraints specifically named in SE130, including COTS/NDI Constraints. The COTS/NDI Constraints information requirement is in effect double-listed in this task, but this has been done to emphasize the relevance of these constraints.

[PRODUCT] Function/Constraint Conflict Resolutions

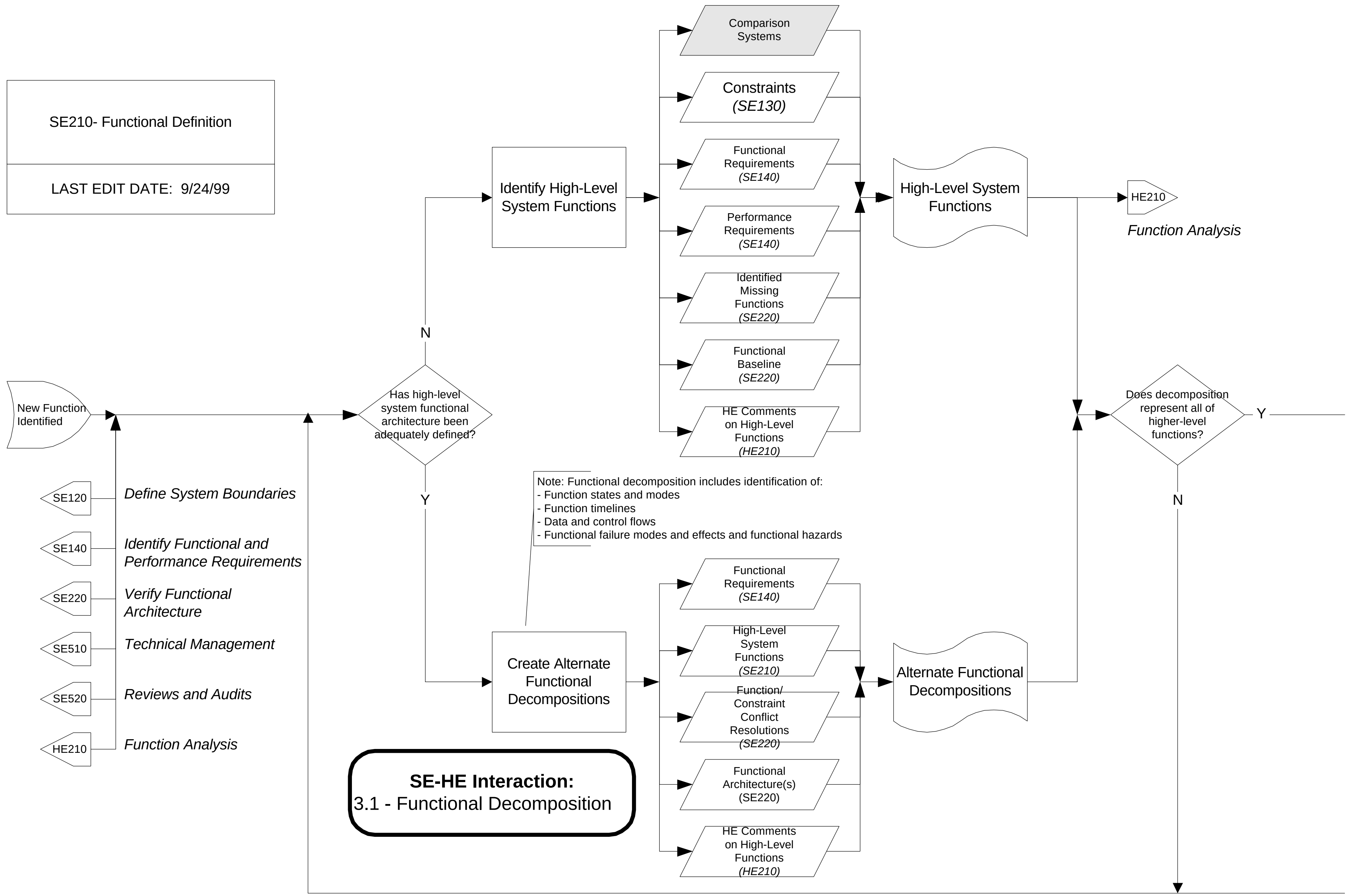
This product is used upon return to SE210 to change the functional decomposition and architecture to conform to constraints.

[PRODUCT] Identified Missing Functions

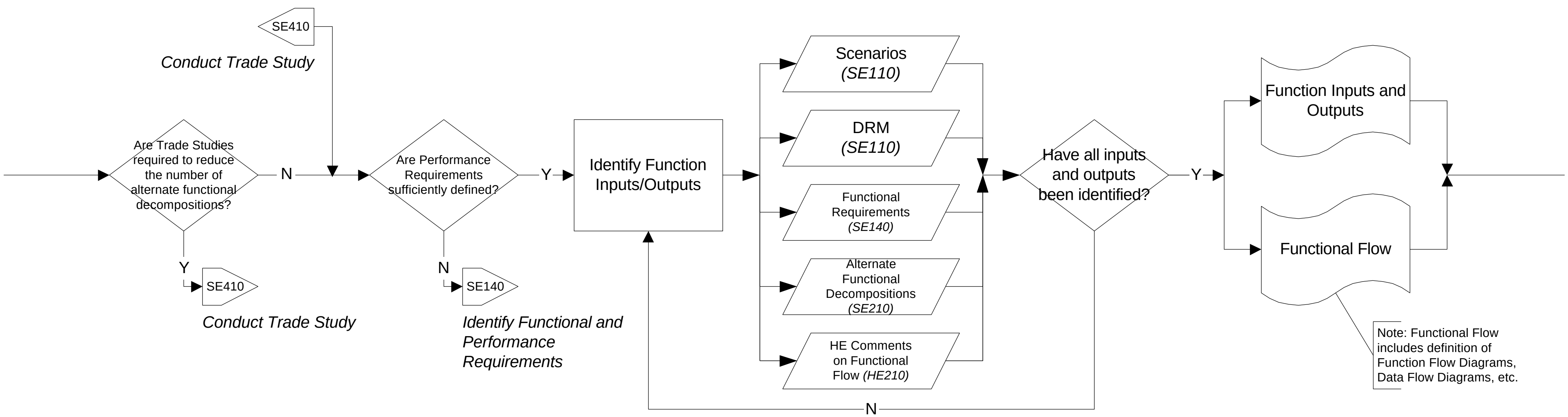
This product is used upon return to SE210 to add missing functions to the functional architecture.

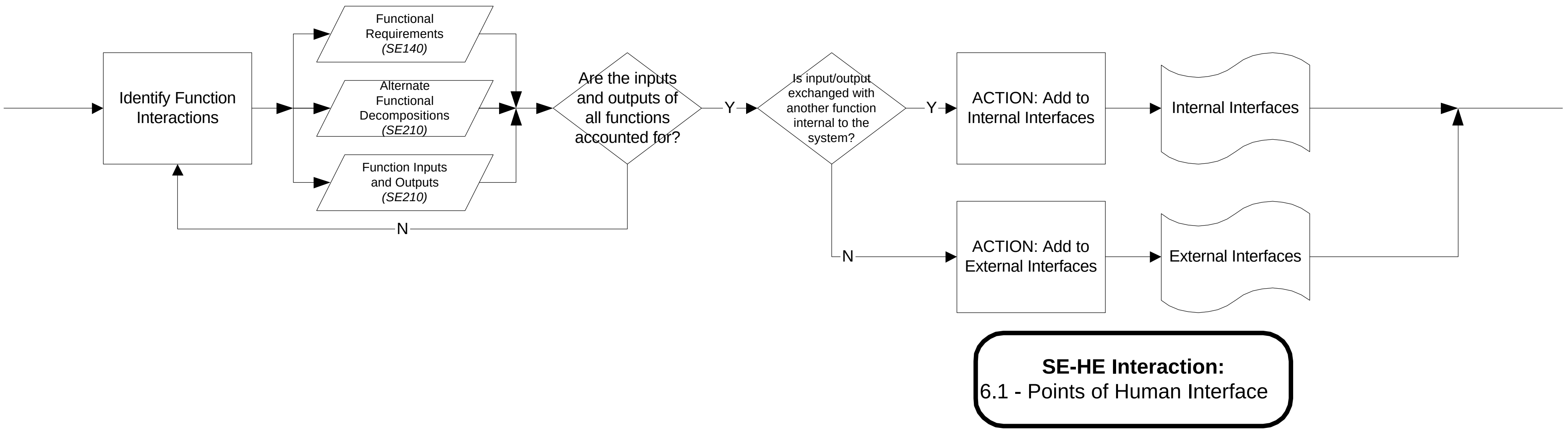
[TASK] Create Functional Models

Functional Models include models both of the system under design and the external systems with which it interacts.

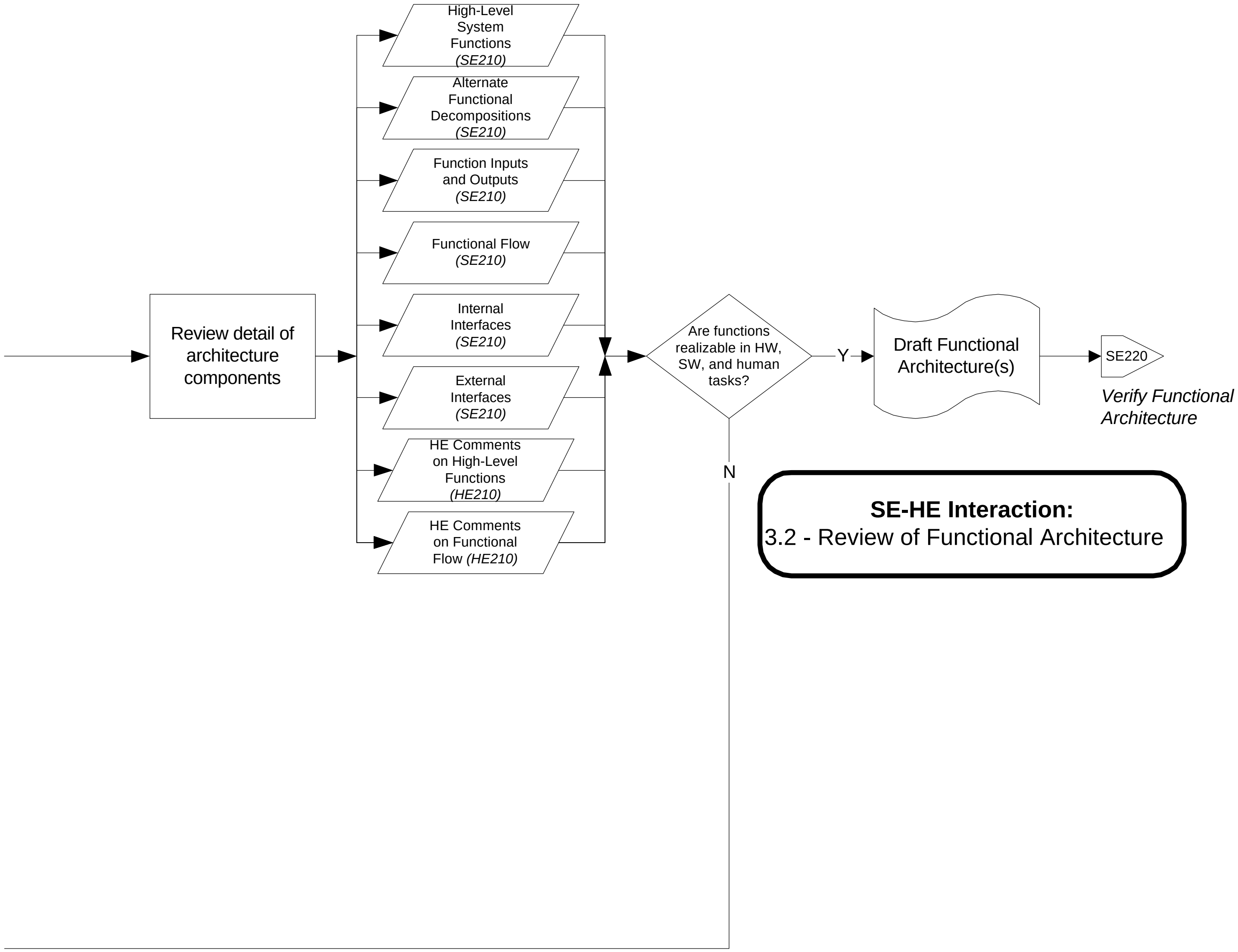


<u>FUNCTIONAL BEHAVIORS.</u> The performing activity analyzes each system function to determine the responses (output) of the system to stimuli (inputs). Analyses are conducted to understand the functional behavior of the system under various conditions and to assess the integrity of the functional architecture. Analyses should involve the simulation or stimulation of functional models utilizing operational scenarios which expose the models to a variety of stressful and non-stressful situations which reflect anticipated operational usage and environments. *(IEEE IS1220)*


SE410
Conduct Trade Study
Are Trade Studies required to reduce the number of alternate functional decompositions?
N
Y
SE410
Conduct Trade Study
Are Performance Requirements sufficiently defined?
Y
N
SE140
Identify Functional and Performance Requirements
Identify Function Inputs/Outputs
Scenarios (SE110)
DRM (SE110)
Functional Requirements (SE140)
Alternate Functional Decompositions (SE210)
HE Comments on Functional Flow (HE210)
N
Have all inputs and outputs been identified?
Y
Function Inputs and Outputs
Functional Flow
Note: Functional Flow includes definition of Function Flow Diagrams, Data Flow Diagrams, etc.



Identify Function Interactions
Functional Requirements (SE140)
Alternate Functional Decompositions (SE210)
Function Inputs and Outputs (SE210)
Are the inputs and outputs of all functions accounted for?
Y
N
Is input/output exchanged with another function internal to the system?
Y
N
ACTION: Add to Internal Interfaces
ACTION: Add to External Interfaces
Internal Interfaces
External Interfaces
SE-HE Interaction:
6.1 - Points of Human Interface



Review detail of architecture components
High-Level System Functions (SE210)
Alternate Functional Decompositions (SE210)
Function Inputs and Outputs (SE210)
Functional Flow (SE210)
Internal Interfaces (SE210)
External Interfaces (SE210)
HE Comments on High-Level Functions (HE210)
HE Comments on Functional Flow (HE210)
Are functions realizable in HW, SW, and human tasks?
Y
N
Draft Functional Architecture(s)
SE220
Verify Functional Architecture
SE-HE Interaction:
3.2 - Review of Functional Architecture

SE220- Verify Functional Arch

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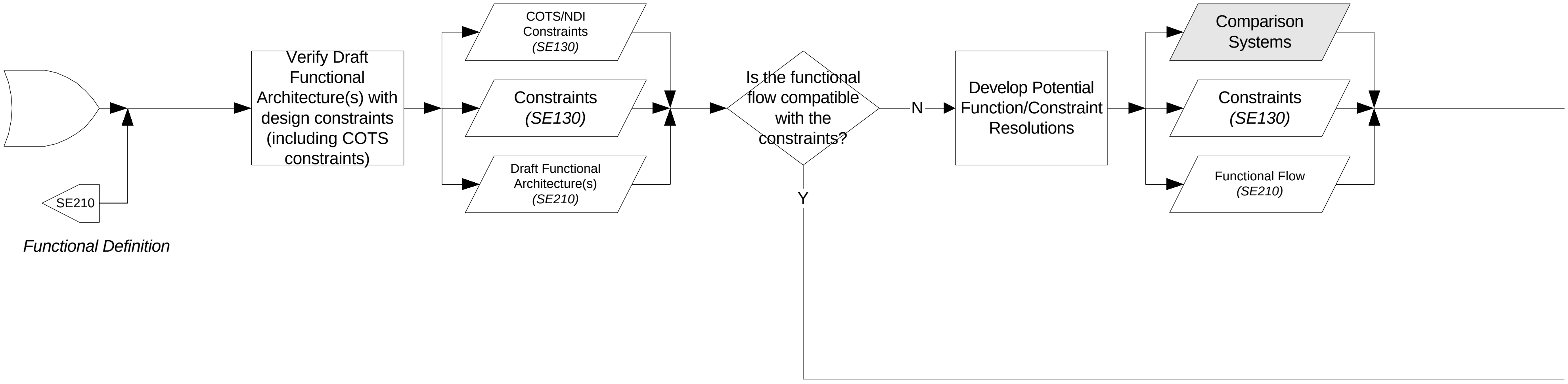
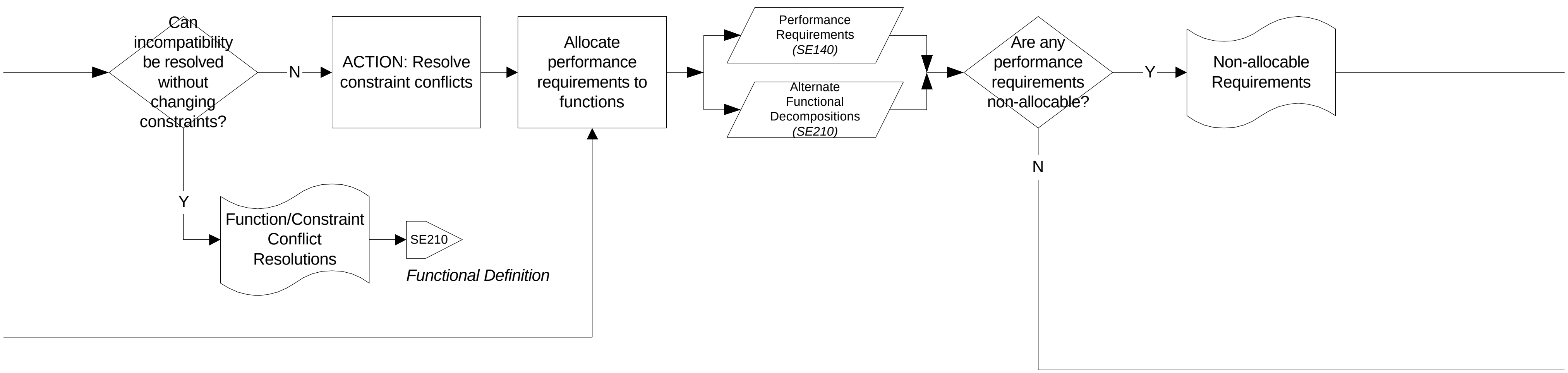
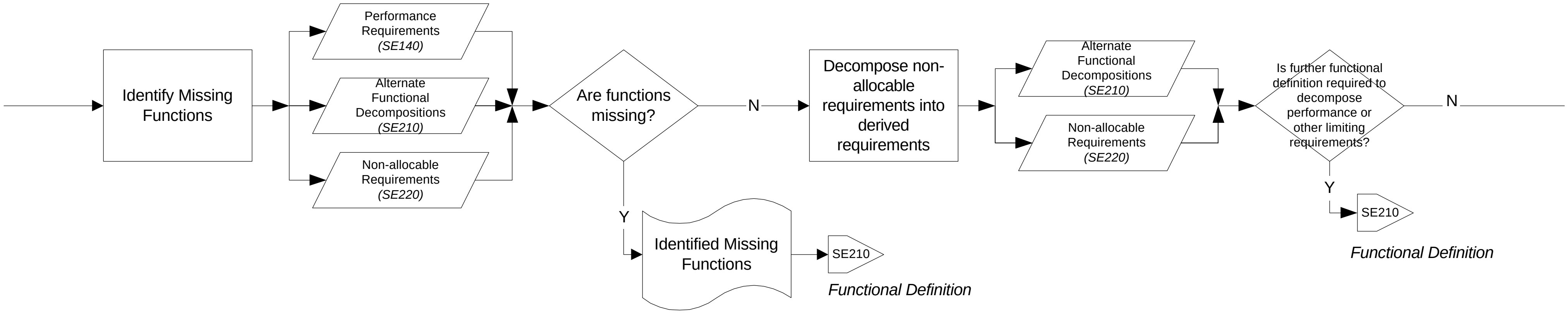
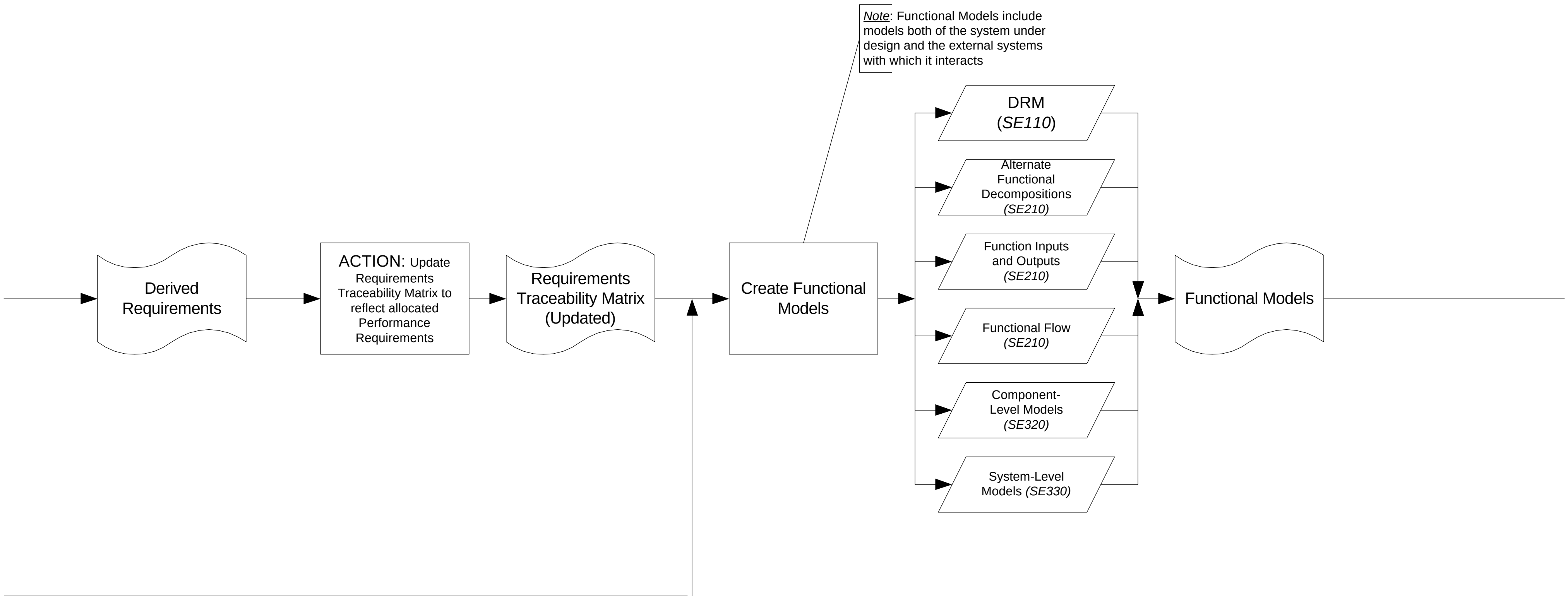
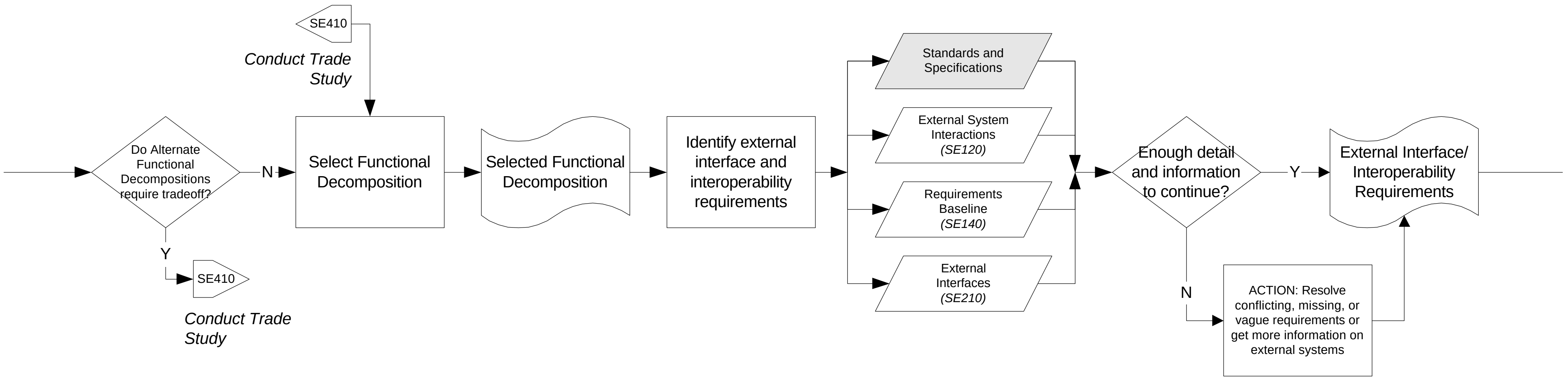



Can incompatibility be resolved without changing constraints?
N
ACTION: Resolve constraint conflicts
Allocate performance requirements to functions
Performance Requirements (SE140)
Alternate Functional Decompositions (SE210)
Are any performance requirements non-allocable?
Y
Non-allocable Requirements
N
Y
Function/Constraint Conflict Resolutions
SE210
Functional Definition

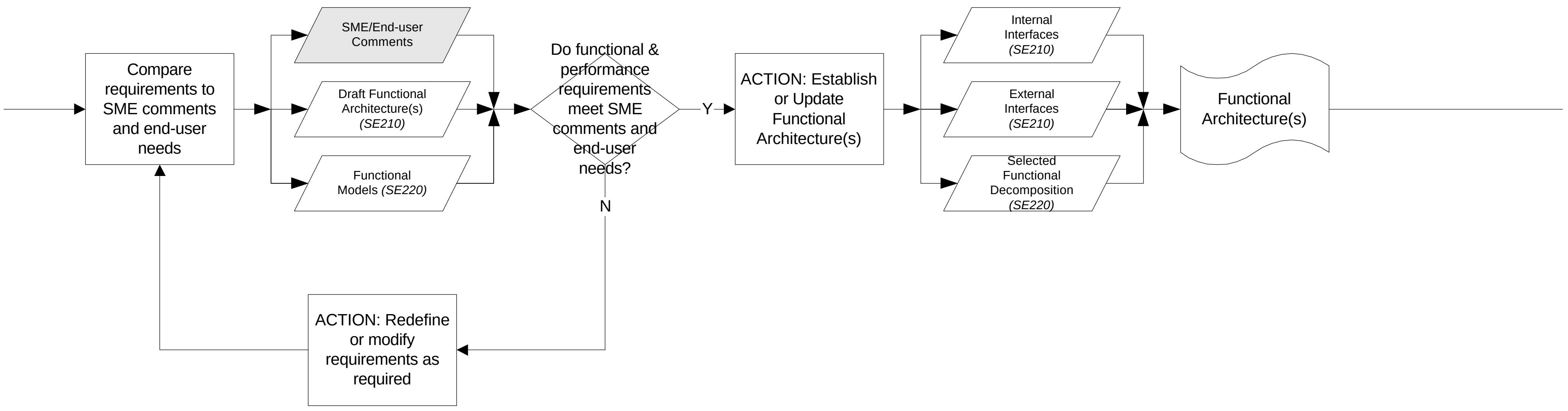


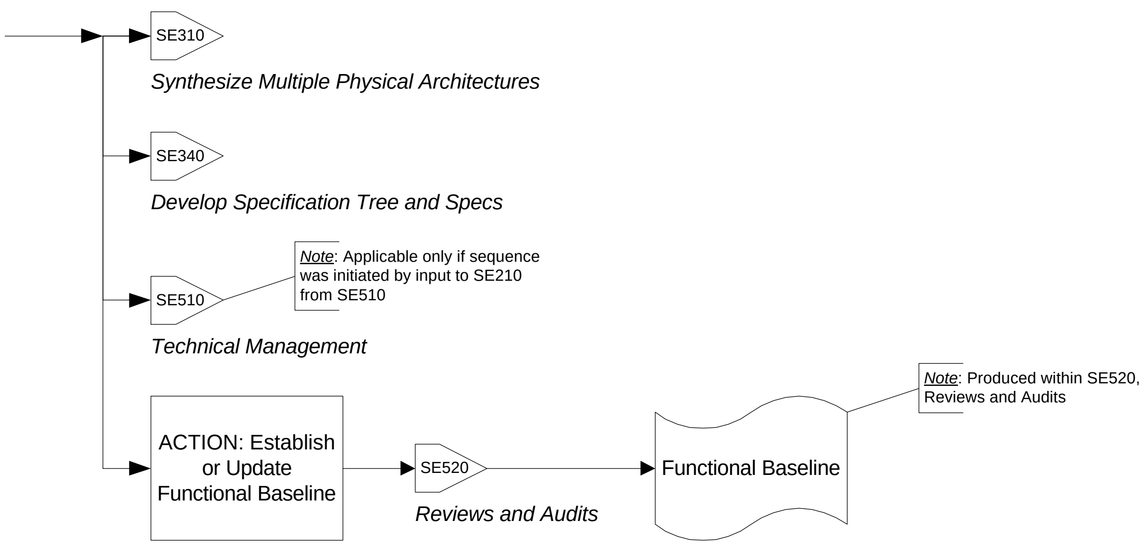
Identify Missing Functions
Performance Requirements (SE140)
Alternate Functional Decompositions (SE210)
Non-allocable Requirements (SE220)
Are functions missing?
N
Y
Identified Missing Functions
SE210
Functional Definition
Decompose non-allocable requirements into derived requirements
Alternate Functional Decompositions (SE210)
Non-allocable Requirements (SE220)
Is further functional definition required to decompose performance or other limiting requirements?
N
Y
SE210
Functional Definition


Note: Functional Models include models both of the system under design and the external systems with which it interacts
Derived Requirements
ACTION: Update Requirements Traceability Matrix to reflect allocated Performance Requirements
Requirements Traceability Matrix (Updated)
Create Functional Models
DRM (SE110)
Alternate Functional Decompositions (SE210)
Function Inputs and Outputs (SE210)
Functional Flow (SE210)
Component-Level Models (SE320)
System-Level Models (SE330)
Functional Models



Do Alternate Functional Decompositions require tradeoff?
N
Y
SE410
Conduct Trade Study
SE410
Conduct Trade Study
Select Functional Decomposition
Selected Functional Decomposition
Identify external interface and interoperability requirements
Standards and Specifications
External System Interactions (SE120)
Requirements Baseline (SE140)
External Interfaces (SE210)
Enough detail and information to continue?
Y
N
External Interface/ Interoperability Requirements
ACTION: Resolve conflicting, missing, or vague requirements or get more information on external systems


Compare requirements to SME comments and end-user needs
SME/End-user Comments
Draft Functional Architecture(s) (SE210)
Functional Models (SE220)
Do functional & performance requirements meet SME comments and end-user needs?
Y
N
ACTION: Establish or Update Functional Architecture(s)
Internal Interfaces (SE210)
External Interfaces (SE210)
Selected Functional Decomposition (SE220)
Functional Architecture(s)
ACTION: Redefine or modify requirements as required


SE310
Synthesize Multiple Physical Architectures
SE340
Develop Specification Tree and Specs
SE510
Note: Applicable only if sequence was initiated by input to SE210 from SE510
Technical Management
ACTION: Establish or Update Functional Baseline
SE520
Reviews and Audits
Functional Baseline
Note: Produced within SE520, Reviews and Audits

300 SERIES – DESIGN SYNTHESIS

Description

The Design Synthesis series of the OSDs concerns the definition of a physical architecture that will meet the functional and performance requirements defined in the Requirements Analysis process. Candidate solutions are identified through the allocation of functions to hardware, software, and humans within the system. Solutions are designed at the component and subsystem levels and then integrated at the system level and compared with the system's requirements for interaction with its environment and external systems.

OSD Notes

SE310 – Synthesize Multiple Physical Architectures

[ACTION] Identify Currently Unavailable Technological or Human Capabilities That Must Be Developed

This action represents the identification of areas where new technological capabilities should be developed or at least explored to be used in system design. This also includes the identification of new training or selection requirements to make additional human capabilities available.

SE320 – Evaluate and Select Preferred Architecture

[TASK] Create Component-Level Models

The term "models" is intended to include executable simulations of system or component performance, static systems designs such as diagrams or schematics, and prototypes or other physical simulations. This type of modeling is intended to include human performance and task models.

[ACTION] Adjust Design

This action represents a small change in the design in an attempt to achieve the desired improvements. Significant design changes are accomplished by a return to SE310.

SE330 – Integrate System Physical Configuration

[TASK] Create System-Level Models

System-level models include models of the system under design, models that integrate system component models, models of external systems with which the components in question interact, and prototypes and other simulations of the system.

SE340 – Develop Specification Tree and Specs

This OSD is derived primarily from the INCOSE Systems Engineering Handbook, Release 1.0, Section 4.4.6.

SE310- Synth Multiple Phys Arch

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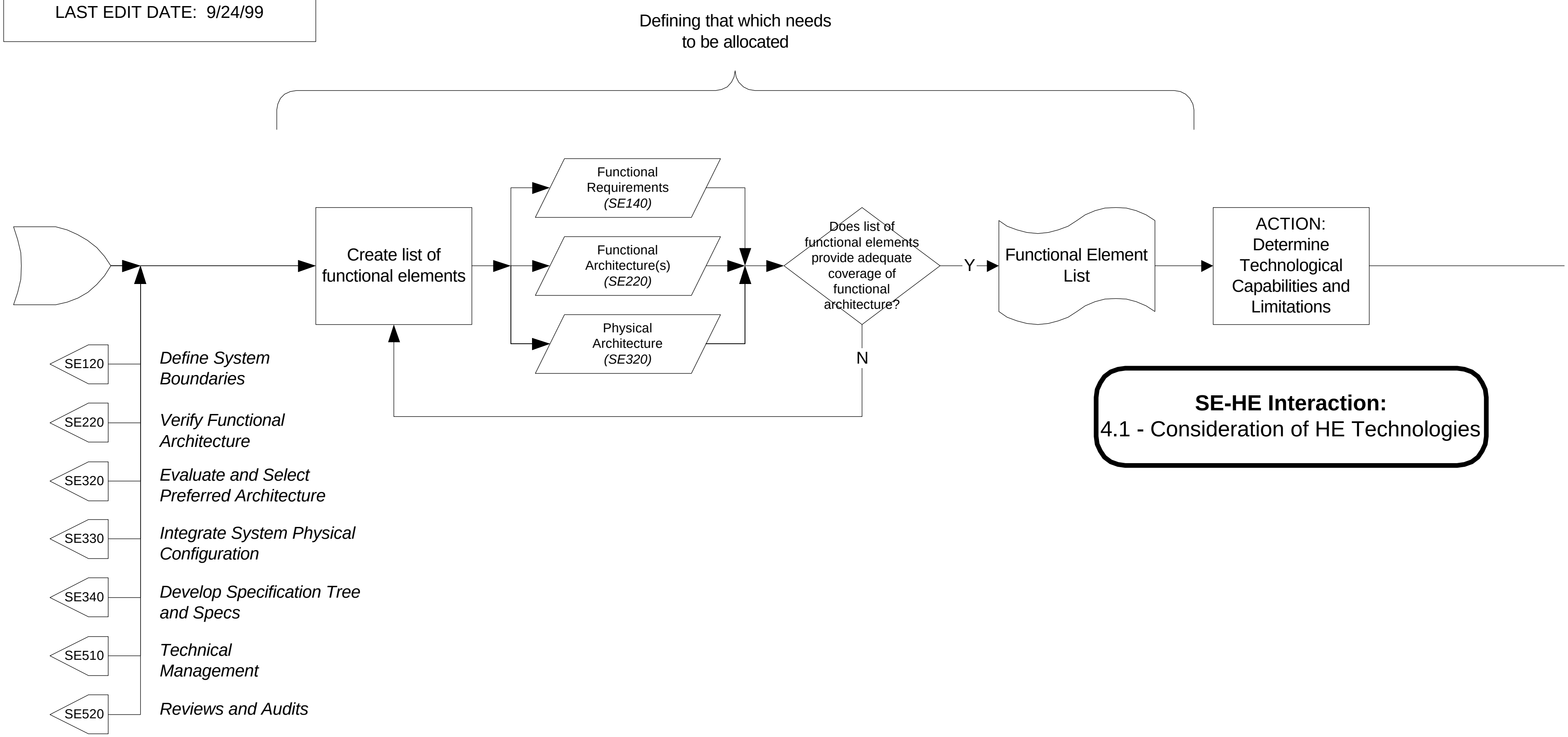
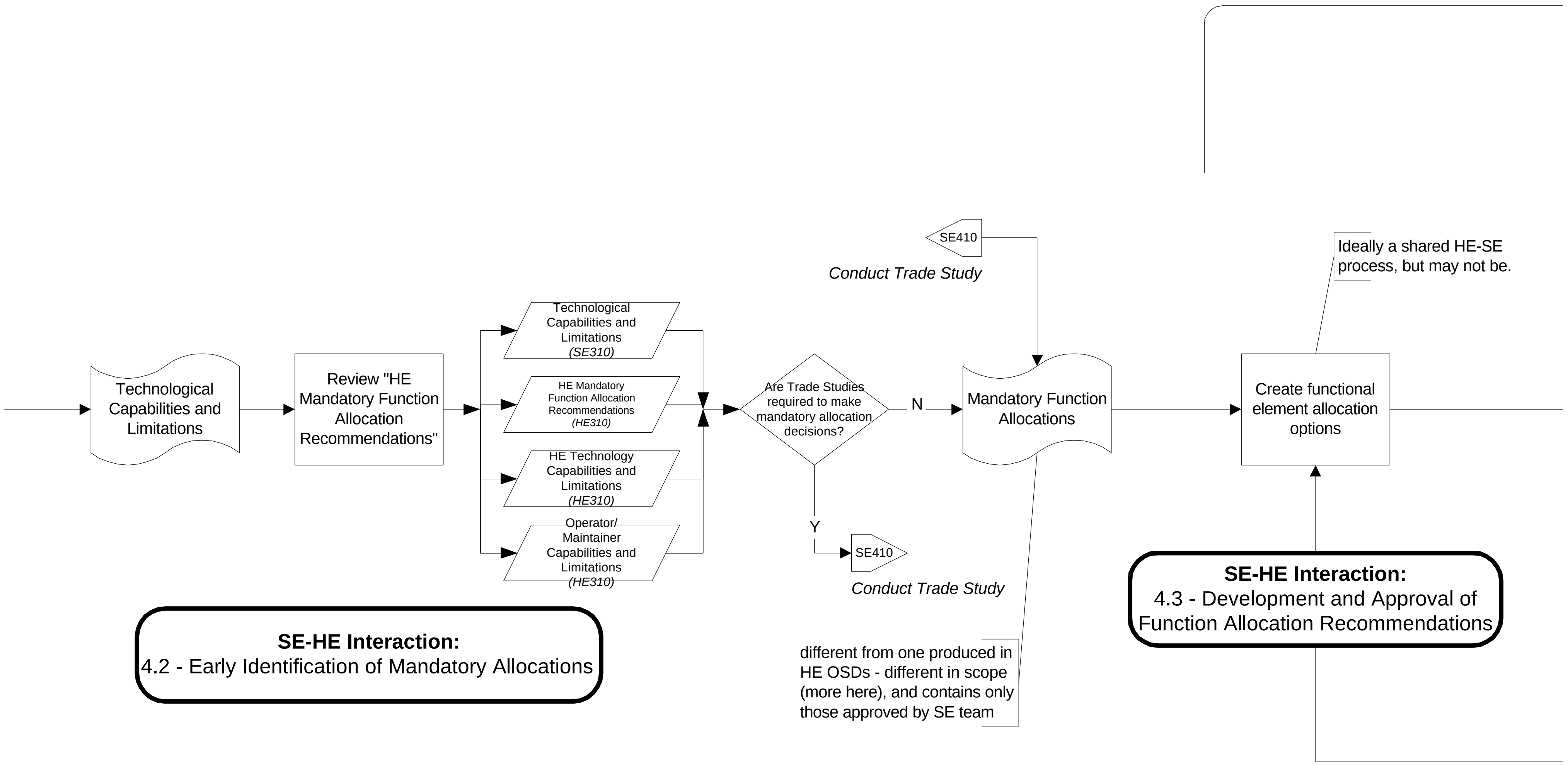
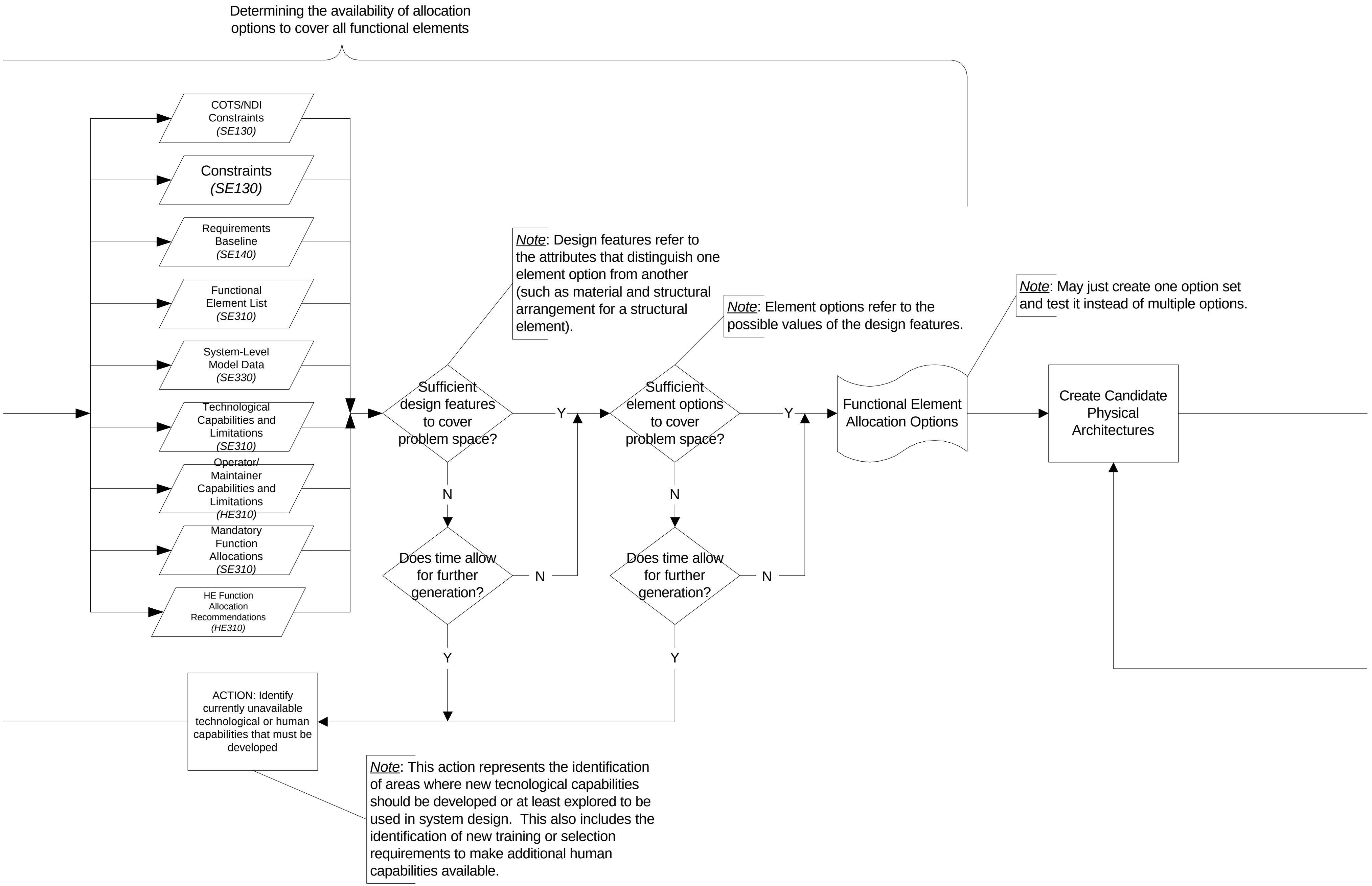
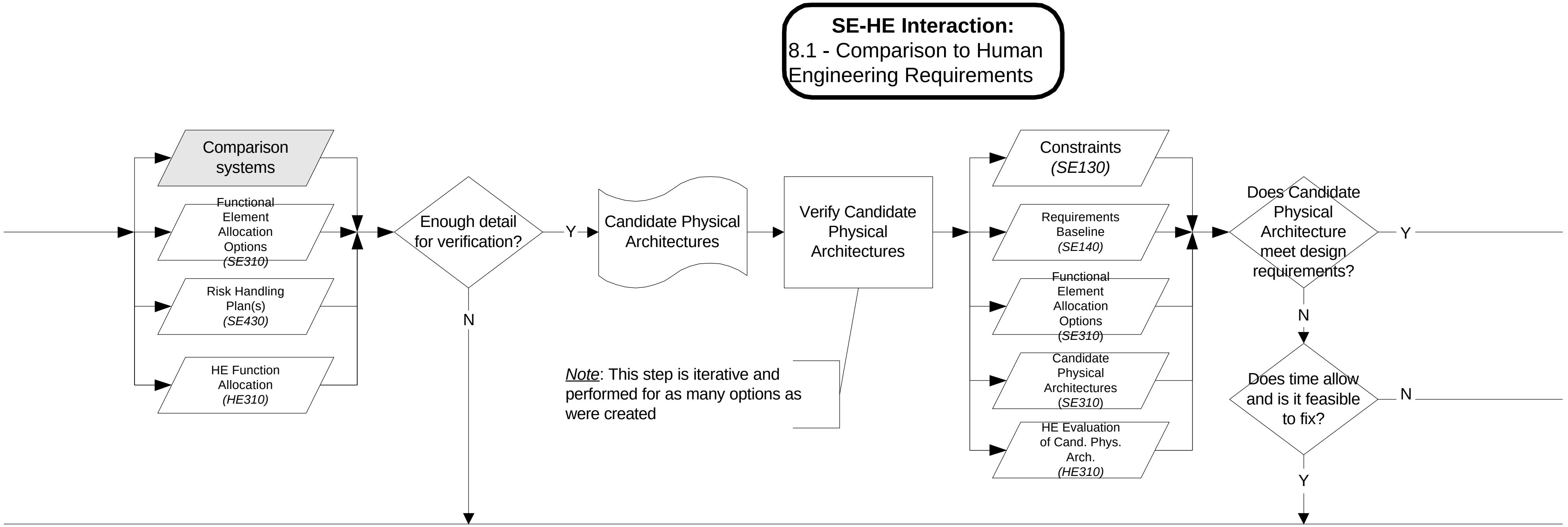


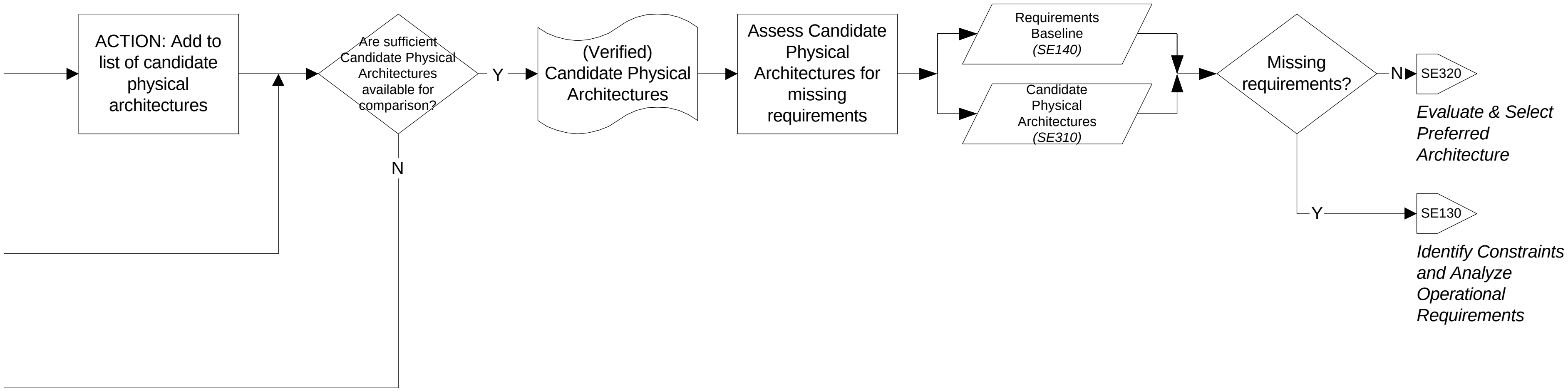
Note: Adapted from INCOSE Systems Engineering Handbook, Rev. 1.0, Section 4.4


Technological Capabilities and Limitations
Review "HE Mandatory Function Allocation Recommendations"
Technological Capabilities and Limitations (SE310)
HE Mandatory Function Allocation Recommendations (HE310)
HE Technology Capabilities and Limitations (HE310)
Operator/ Maintainer Capabilities and Limitations (HE310)
Are Trade Studies required to make mandatory allocation decisions?
N
Y
SE410
Conduct Trade Study
SE410
Conduct Trade Study
Mandatory Function Allocations
different from one produced in HE OSDs - different in scope (more here), and contains only those approved by SE team
Create functional element allocation options
Ideally a shared HE-SE process, but may not be.
SE-HE Interaction:
4.2 - Early Identification of Mandatory Allocations
SE-HE Interaction:
4.3 - Development and Approval of Function Allocation Recommendations



Determining the availability of allocation options to cover all functional elements
COTS/NDI Constraints (SE130)
Constraints (SE130)
Requirements Baseline (SE140)
Functional Element List (SE310)
System-Level Model Data (SE330)
Technological Capabilities and Limitations (SE310)
Operator/ Maintainer Capabilities and Limitations (HE310)
Mandatory Function Allocations (SE310)
HE Function Allocation Recommendations (HE310)
Note: Design features refer to the attributes that distinguish one element option from another (such as material and structural arrangement for a structural element).
Sufficient design features to cover problem space?
Y
N
Does time allow for further generation?
N
Y
Note: Element options refer to the possible values of the design features.
Sufficient element options to cover problem space?
Y
N
Does time allow for further generation?
N
Y
Note: May just create one option set and test it instead of multiple options.
Functional Element Allocation Options
Create Candidate Physical Architectures
ACTION: Identify currently unavailable technological or human capabilities that must be developed
Note: This action represents the identification of areas where new tecnological capabilities should be developed or at least explored to be used in system design. This also includes the identification of new training or selection requirements to make additional human capabilities available.


SE-HE Interaction:
8.1 - Comparison to Human Engineering Requirements
Comparison systems
Functional Element Allocation Options (SE310)
Risk Handling Plan(s) (SE430)
HE Function Allocation (HE310)
Enough detail for verification?
Y
N
Candidate Physical Architectures
Verify Candidate Physical Architectures
Note: This step is iterative and performed for as many options as were created
Constraints (SE130)
Requirements Baseline (SE140)
Functional Element Allocation Options (SE310)
Candidate Physical Architectures (SE310)
HE Evaluation of Cand. Phys. Arch. (HE310)
Does Candidate Physical Architecture meet design requirements?
Y
N
Does time allow and is it feasible to fix?
N
Y



ACTION: Add to list of candidate physical architectures
Are sufficient Candidate Physical Architectures available for comparison?
Y
N
(Verified) Candidate Physical Architectures
Assess Candidate Physical Architectures for missing requirements
Requirements Baseline (SE140)
Candidate Physical Architectures (SE310)
Missing requirements?
N
SE320
Evaluate & Select Preferred Architecture
Y
SE130
Identify Constraints and Analyze Operational Requirements

SE320- Eval & Select Pref Arch

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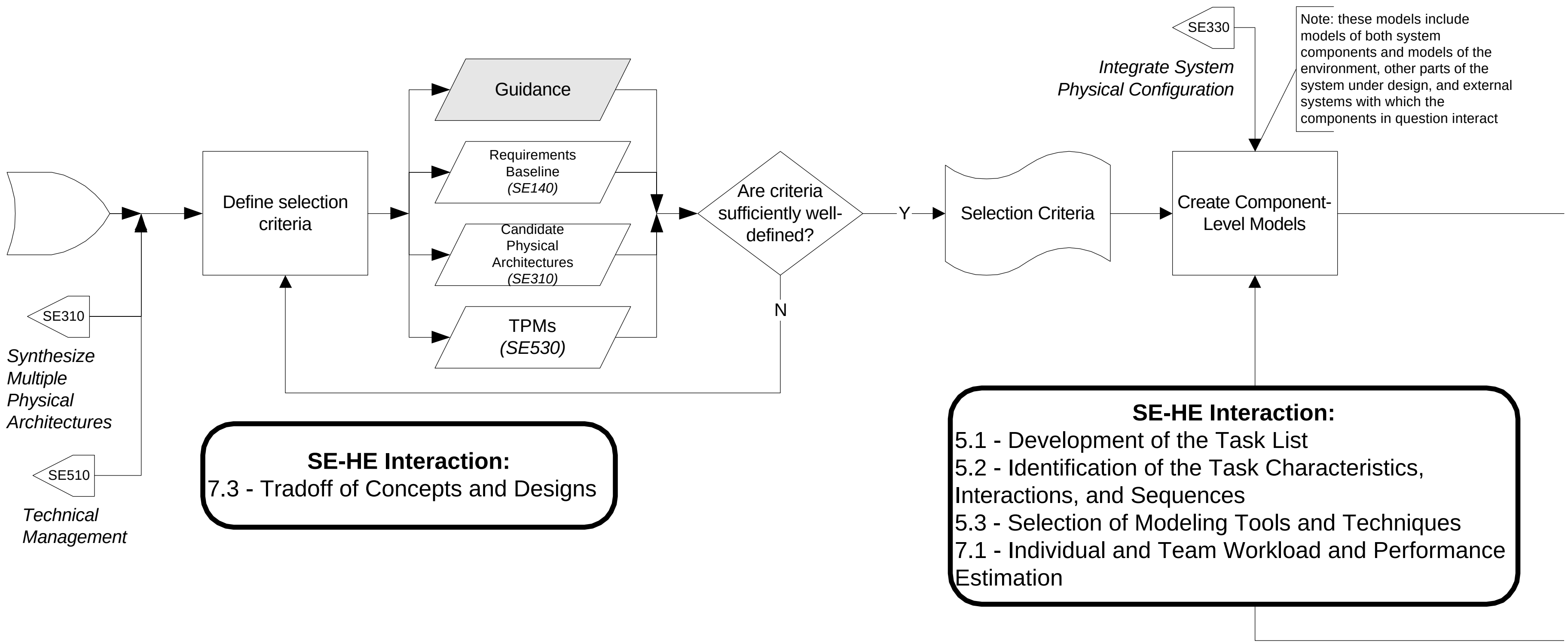
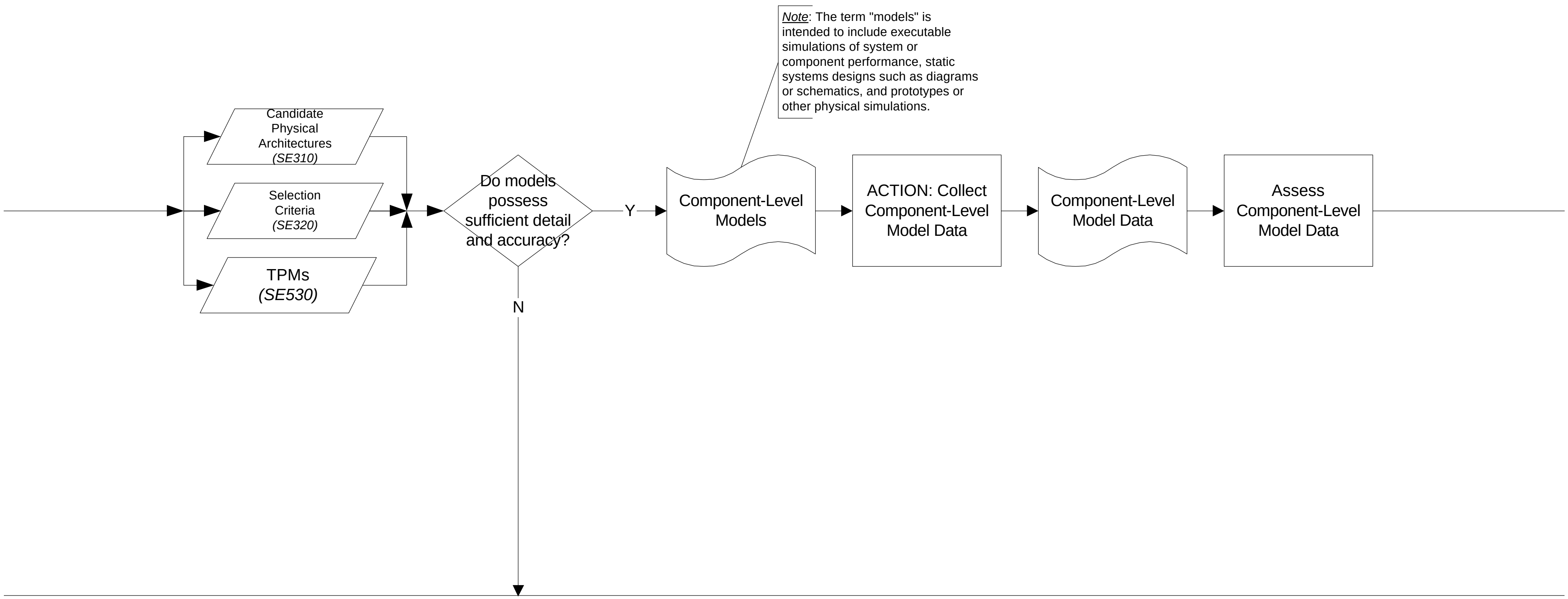
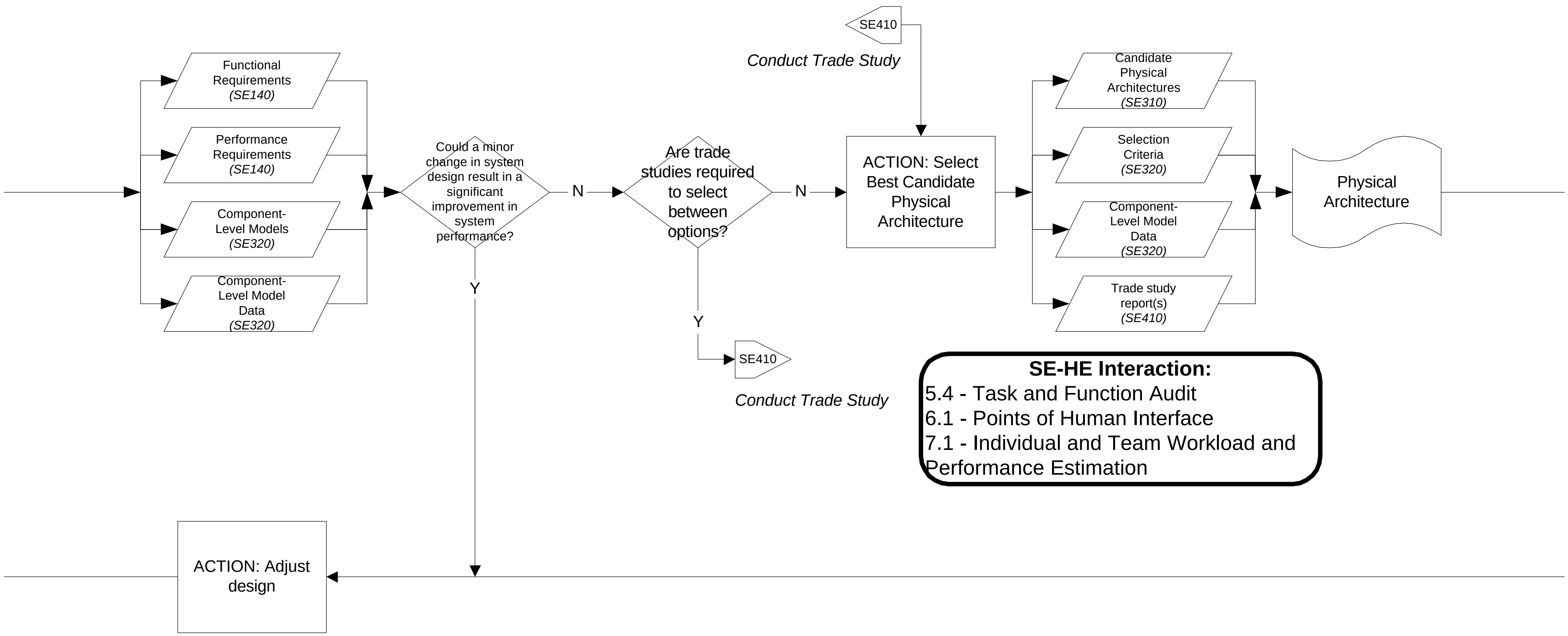
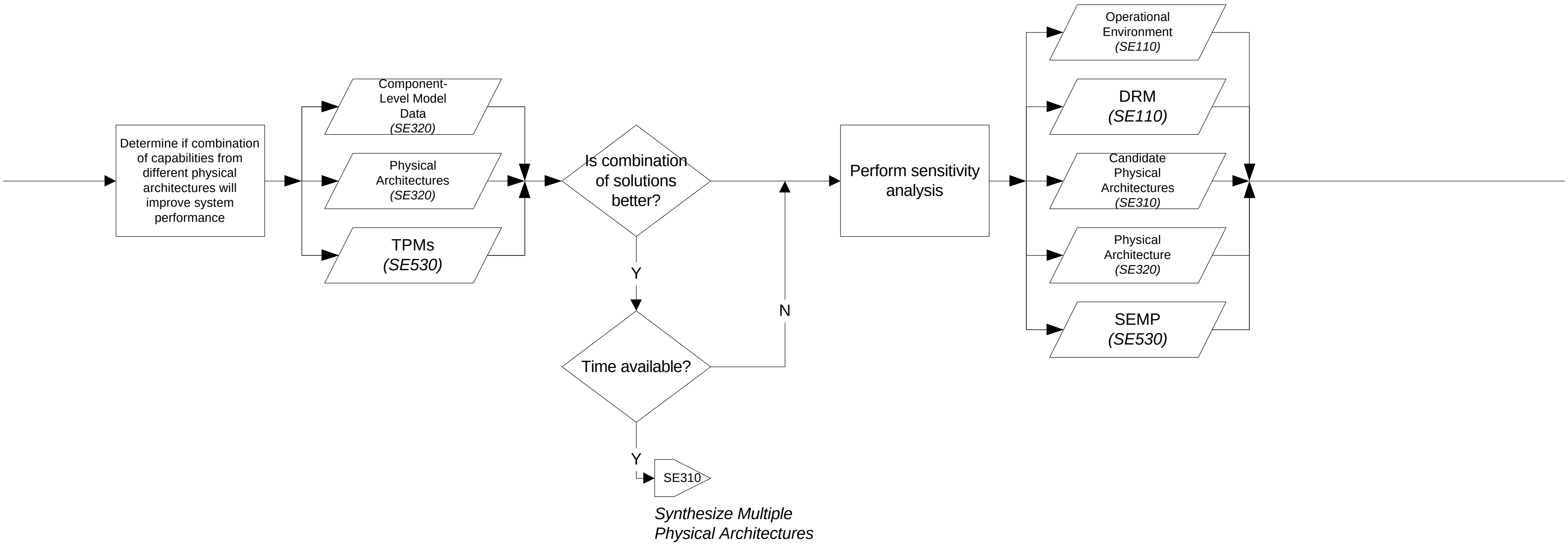
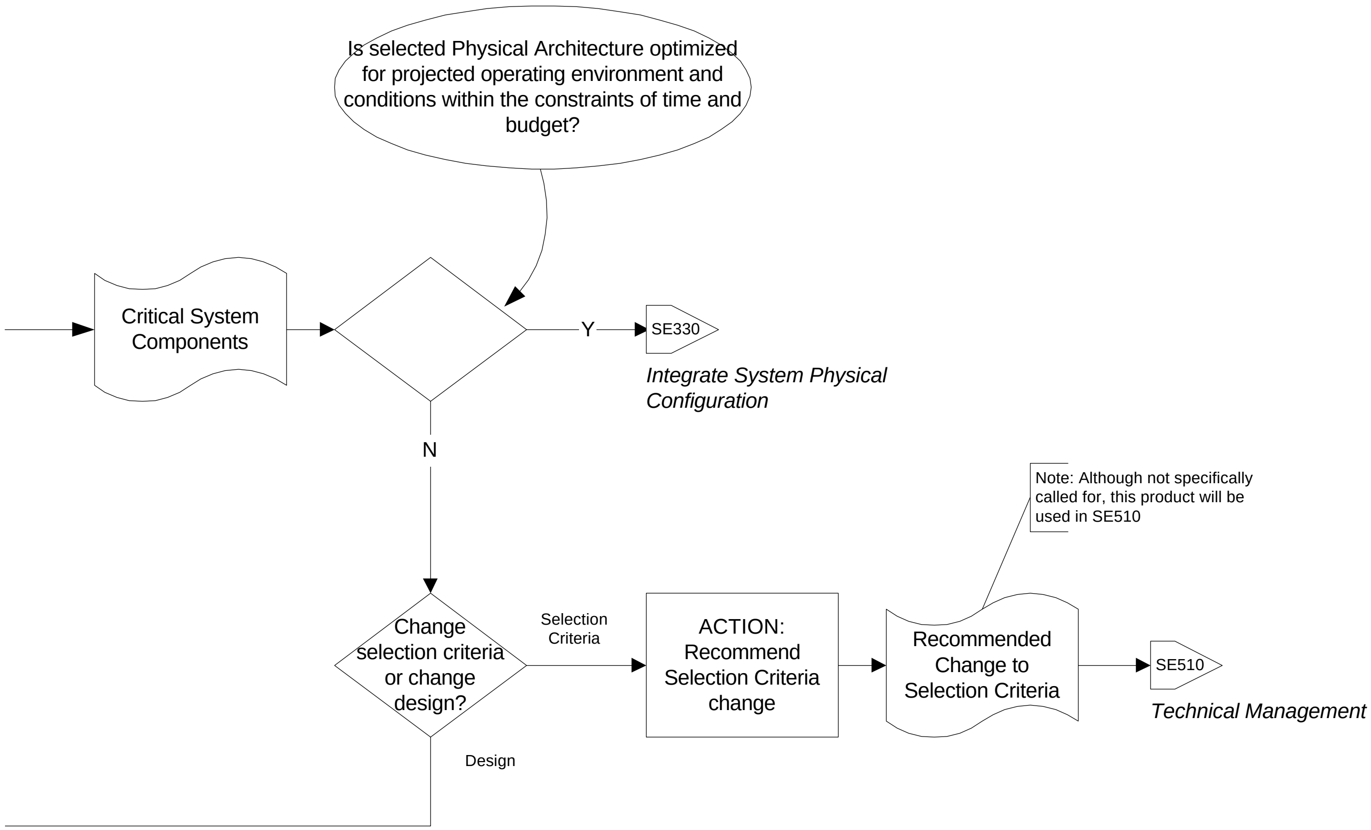


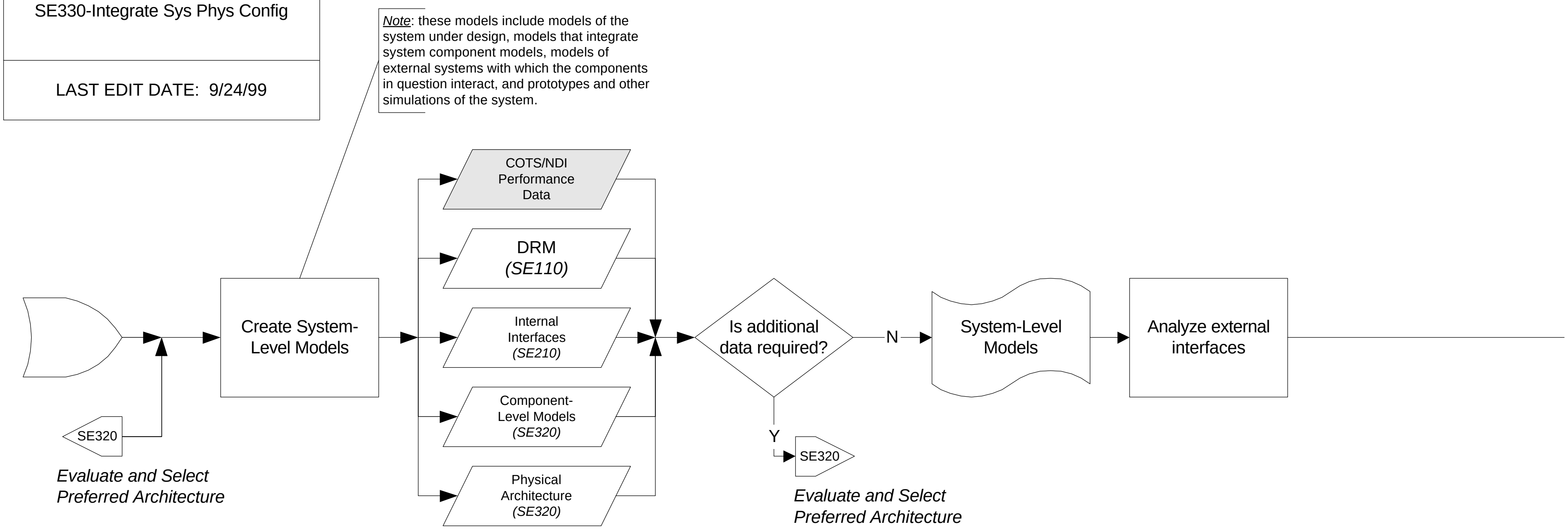

Note: The term "models" is intended to include executable simulations of system or component performance, static systems designs such as diagrams or schematics, and prototypes or other physical simulations.
Candidate Physical Architectures (SE310)
Selection Criteria (SE320)
TPMs (SE530)
Do models possess sufficient detail and accuracy?
Y
N
Component-Level Models
ACTION: Collect Component-Level Model Data
Component-Level Model Data
Assess Component-Level Model Data


Functional Requirements (SE140)
Performance Requirements (SE140)
Component-Level Models (SE320)
Component-Level Model Data (SE320)
Could a minor change in system design result in a significant improvement in system performance?
N
Y
Are trade studies required to select between options?
N
Y
SE410
Conduct Trade Study
SE410
Conduct Trade Study
ACTION: Select Best Candidate Physical Architecture
Candidate Physical Architectures (SE310)
Selection Criteria (SE320)
Component-Level Model Data (SE320)
Trade study report(s) (SE410)
Physical Architecture
SE-HE Interaction:
5.4 - Task and Function Audit
6.1 - Points of Human Interface
7.1 - Individual and Team Workload and Performance Estimation
ACTION: Adjust design

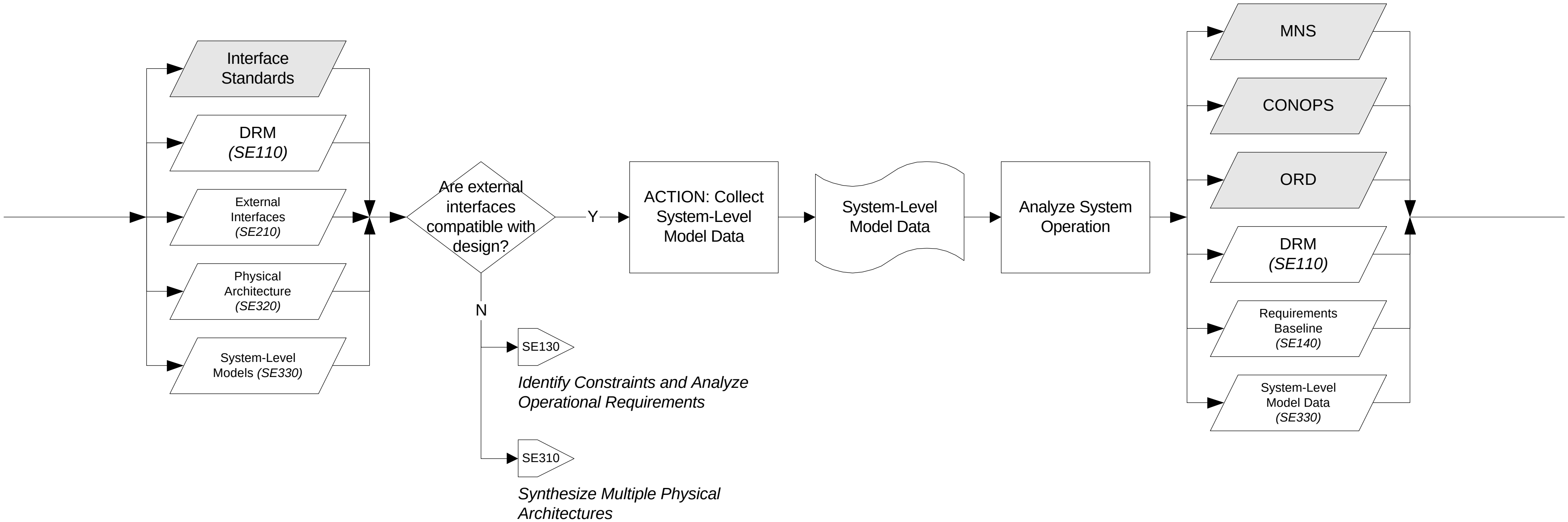

Determine if combination of capabilities from different physical architectures will improve system performance
Component-Level Model Data (SE320)
Physical Architectures (SE320)
TPMs (SE530)
Is combination of solutions better?
Y
Time available?
N
Y
SE310
Synthesize Multiple Physical Architectures
Perform sensitivity analysis
Operational Environment (SE110)
DRM (SE110)
Candidate Physical Architectures (SE310)
Physical Architecture (SE320)
SEMP (SE530)

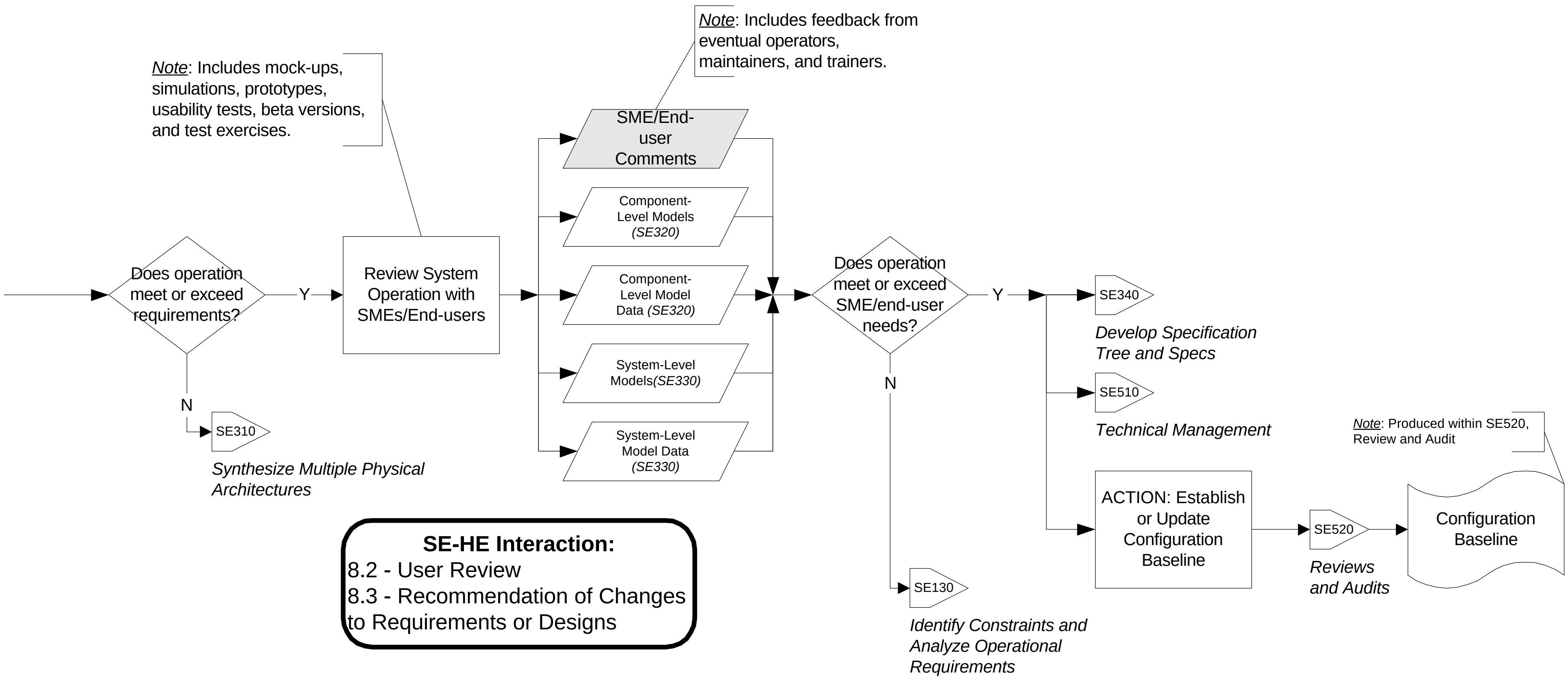

Is selected Physical Architecture optimized for projected operating environment and conditions within the constraints of time and budget?
Critical System Components
Y
SE330
Integrate System Physical Configuration
N
Note: Although not specifically called for, this product will be used in SE510
Change selection criteria or change design?
Selection Criteria
ACTION: Recommend Selection Criteria change
Recommended Change to Selection Criteria
SE510
Technical Management
Design

SE330-Integrate Sys Phys Config
LAST EDIT DATE: 9/24/99



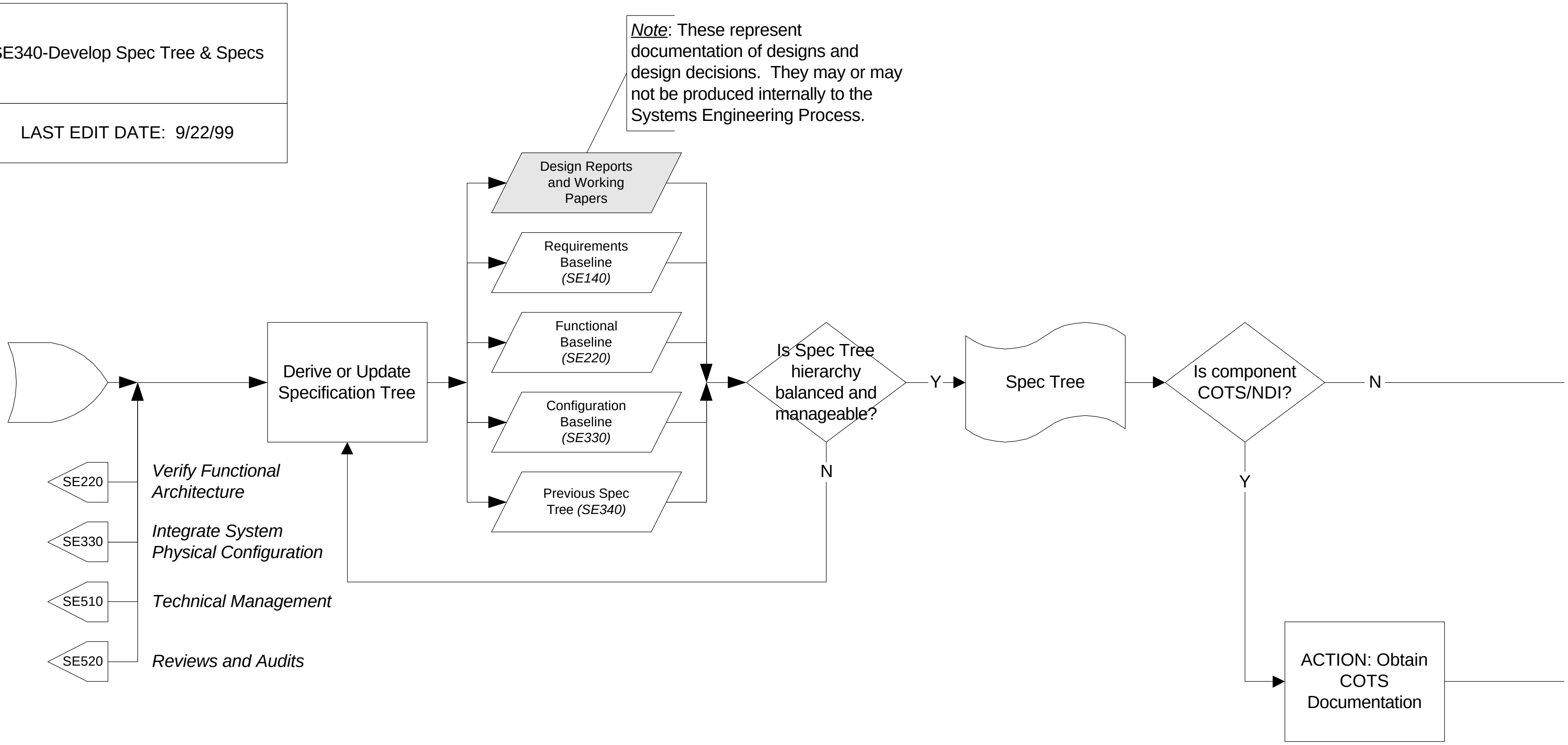
SE-HE Interaction:
5.3 - Selection of Modeling Tools and Techniques


Interface Standards
DRM (SE110)
External Interfaces (SE210)
Physical Architecture (SE320)
System-Level Models (SE330)
Are external interfaces compatible with design?
Y
N
SE130
Identify Constraints and Analyze Operational Requirements
SE310
Synthesize Multiple Physical Architectures
ACTION: Collect System-Level Model Data
System-Level Model Data
Analyze System Operation
MNS
CONOPS
ORD
DRM (SE110)
Requirements Baseline (SE140)
System-Level Model Data (SE330)


Note: Includes mock-ups, simulations, prototypes, usability tests, beta versions, and test exercises.
Note: Includes feedback from eventual operators, maintainers, and trainers.
Does operation meet or exceed requirements?
Y
N
SE310
Synthesize Multiple Physical Architectures
Review System Operation with SMEs/End-users
SME/End-user Comments
Component-Level Models (SE320)
Component-Level Model Data (SE320)
System-Level Models(SE330)
System-Level Model Data (SE330)
Does operation meet or exceed SME/end-user needs?
Y
N
SE130
Identify Constraints and Analyze Operational Requirements
SE340
Develop Specification Tree and Specs
SE510
Technical Management
ACTION: Establish or Update Configuration Baseline
SE520
Reviews and Audits
Note: Produced within SE520, Review and Audit
Configuration Baseline
SE-HE Interaction:
8.2 - User Review
8.3 - Recommendation of Changes to Requirements or Designs

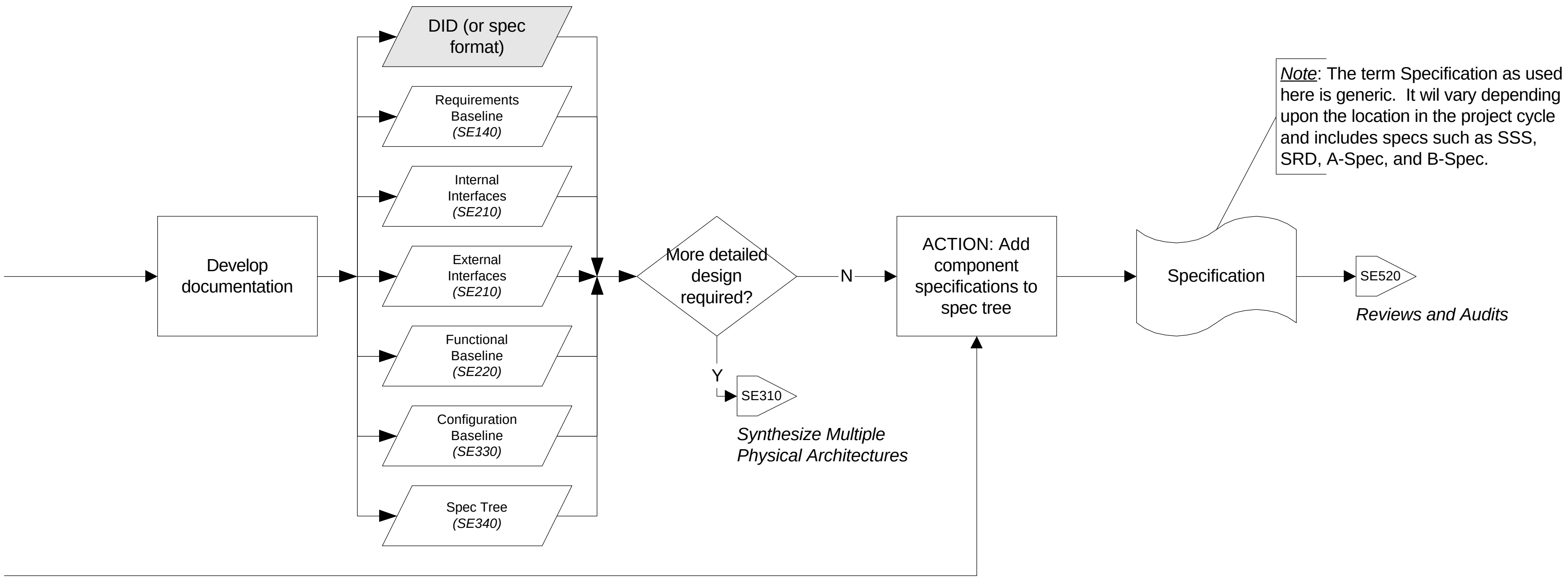
SE340-Develop Spec Tree & Specs

LAST EDIT DATE: 9/22/99



Derived primarily from INCOSE Systems Engineering Handbook, Release 1.0, Section 4.4.6

- Derive specification tree
- Document details for each spec (create for new items, obtain for off-the-shelf items)
- "Craft" requirements for each spec
- Produce drawings and schematics (design documentation)
- Review (?)


Develop documentation
DID (or spec format)
Requirements Baseline (SE140)
Internal Interfaces (SE210)
External Interfaces (SE210)
Functional Baseline (SE220)
Configuration Baseline (SE330)
Spec Tree (SE340)
More detailed design required?
N
Y
SE310
Synthesize Multiple Physical Architectures
ACTION: Add component specifications to spec tree
Specification
SE520
Reviews and Audits
Note: The term Specification as used here is generic. It wil vary depending upon the location in the project cycle and includes specs such as SSS, SRD, A-Spec, and B-Spec.

400 SERIES – SYSTEM ANALYSIS

Description

The Systems Analysis series of the OSDs contains three separate main tasks. First, trade studies are conducted, with modeling and simulation if required, to compare alternative requirements, functional decompositions, design options, and other variables. Second, Life-Cycle Cost Analysis addresses the estimation of the cost of the system being designed. The cost of all different life-cycle areas may be addressed, and results will be used as inputs in other decisions throughout the systems engineering process. Third, Risk Management assesses the risks of various design options or decisions, and its output is used to make design decisions.

OSD Notes

SE410 – Conduct Trade Study

This OSD is derived primarily from the INCOSE Systems Engineering Handbook, Release 1.0, Section 4.5.1.

[Information Requirement] Trade Study Alternatives

This information requirement represents options that are being compared through the trade study. The options may be alternative design scenarios (from SE110), competing requirements (from SE130), functional models or decompositions (from SE210 and SE220), design options (from SE320), or any other item requiring comparison (from SE510).

SE420 – Life-Cycle Cost Analysis

This OSD is derived primarily from the INCOSE Systems Engineering Handbook, Release 1.0, Section 4.5.4 and from Appendix B, "Life-Cycle Cost-Analysis Process," of Systems Engineering Management (Blanchard, 1998)

[TASK] Select Cost Estimation Categories

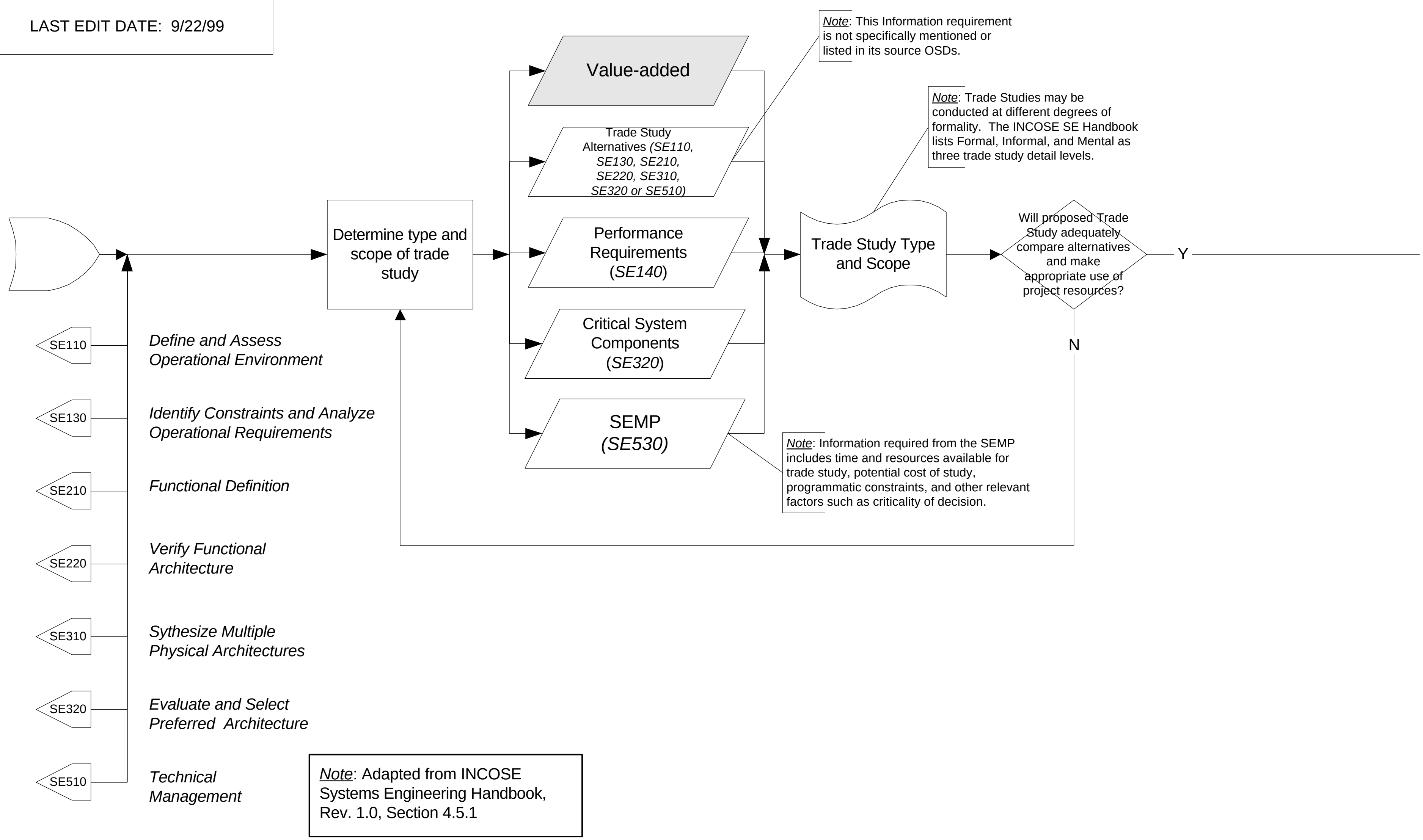
Cost Estimation Categories may vary from project to project. An example of selected categories is Research and Development Cost, Production and Deployment Cost, and Operations and Support Cost (INCOSE, 1998). Another example would be to break the cost into the following categories (Blanchard, 1998):

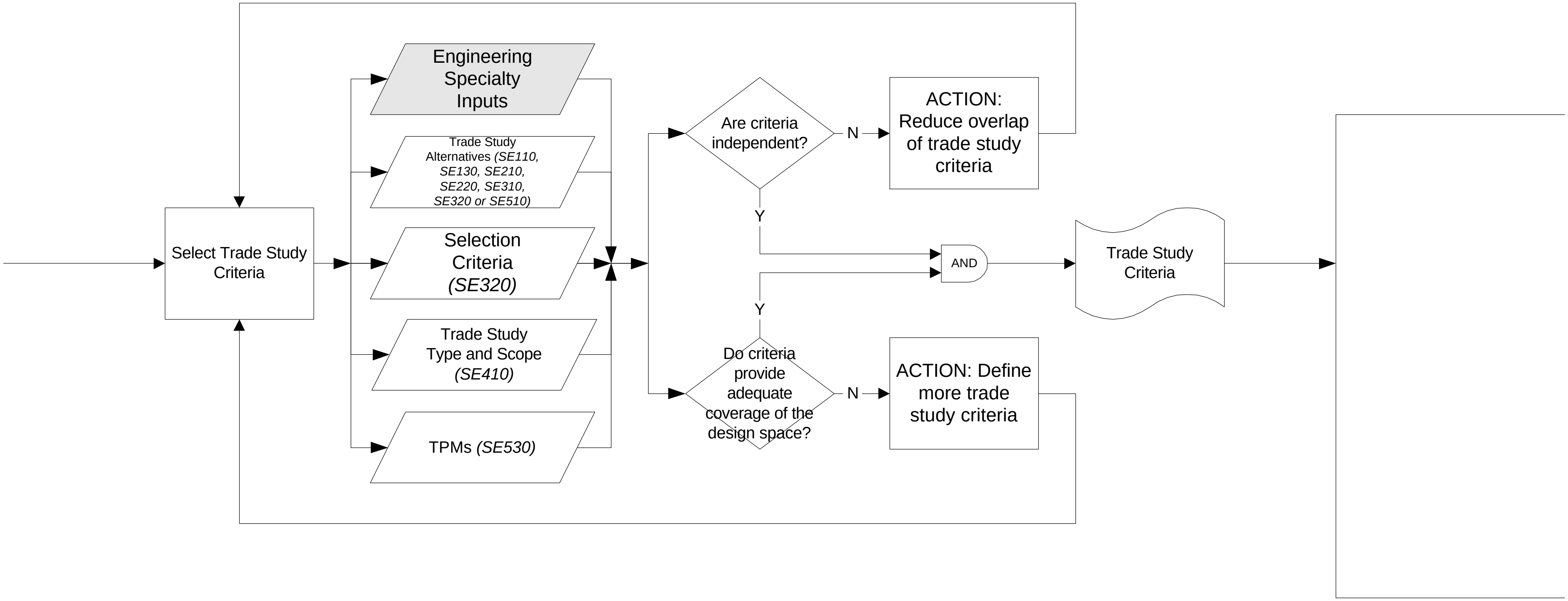
- Acquisition cost
- Operations cost
- Maintenance cost
- Software cost
- Technical Data cost
- Training cost
- Production Distribution cost
- Test and Support Equipment cost
- Supply Support cost
- Retirement and Disposal cost

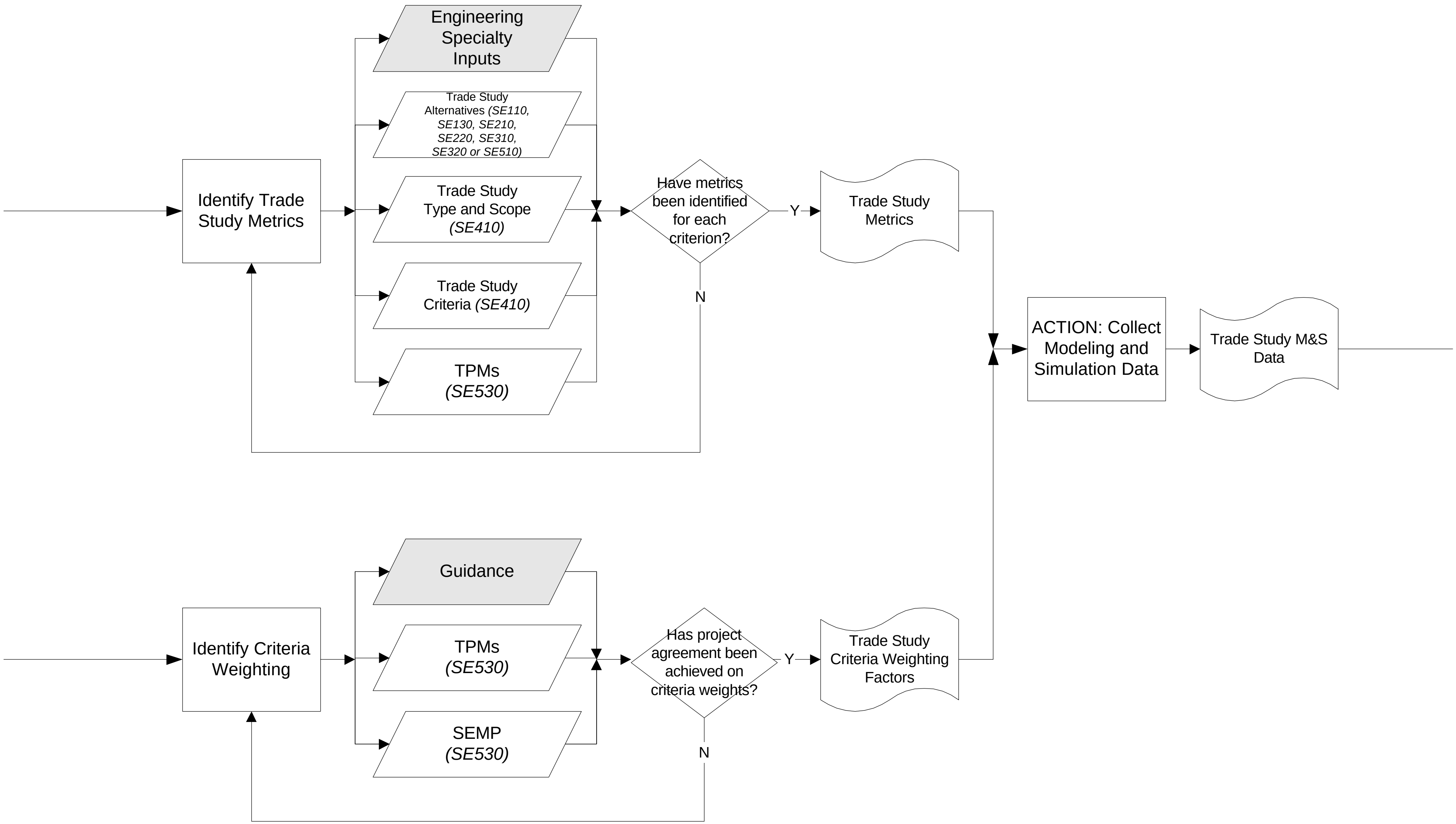
SE430 – Risk Management

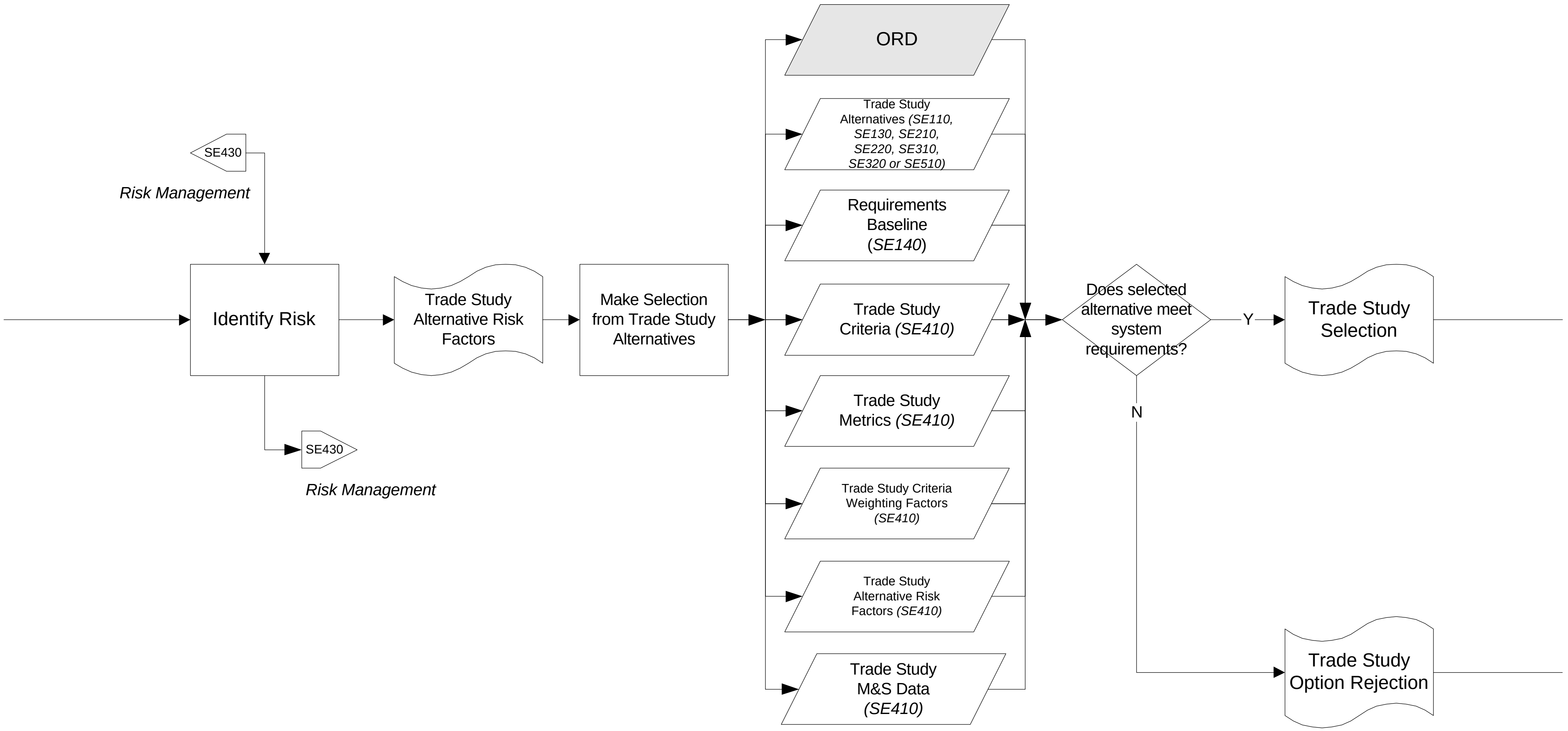
SE410- Conduct Trade Study

LAST EDIT DATE: 9/22/99

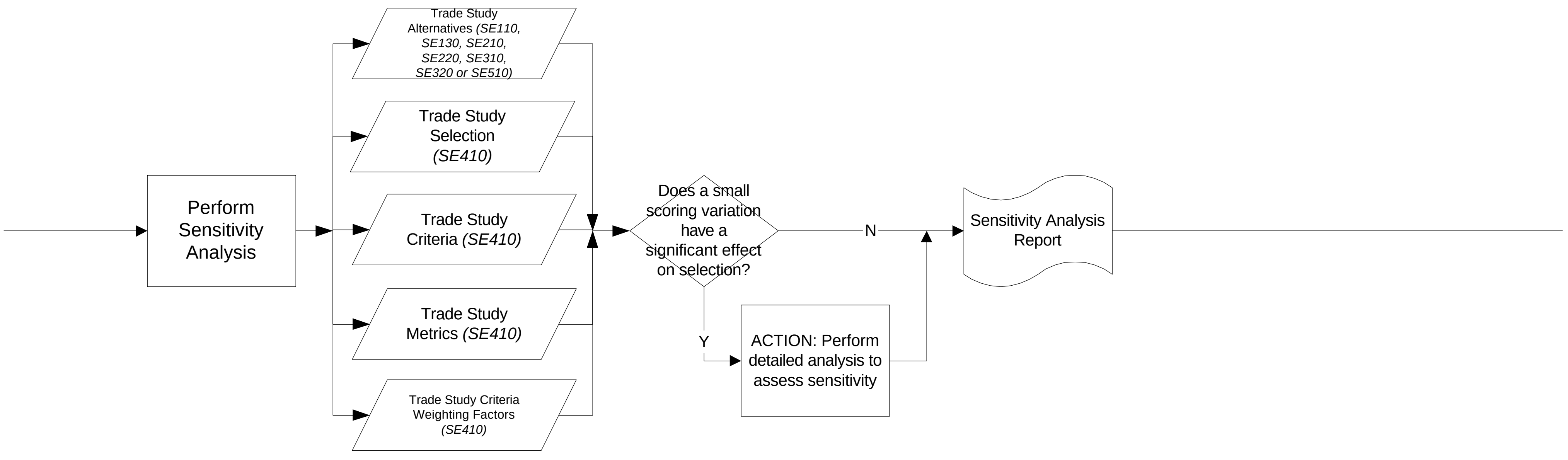


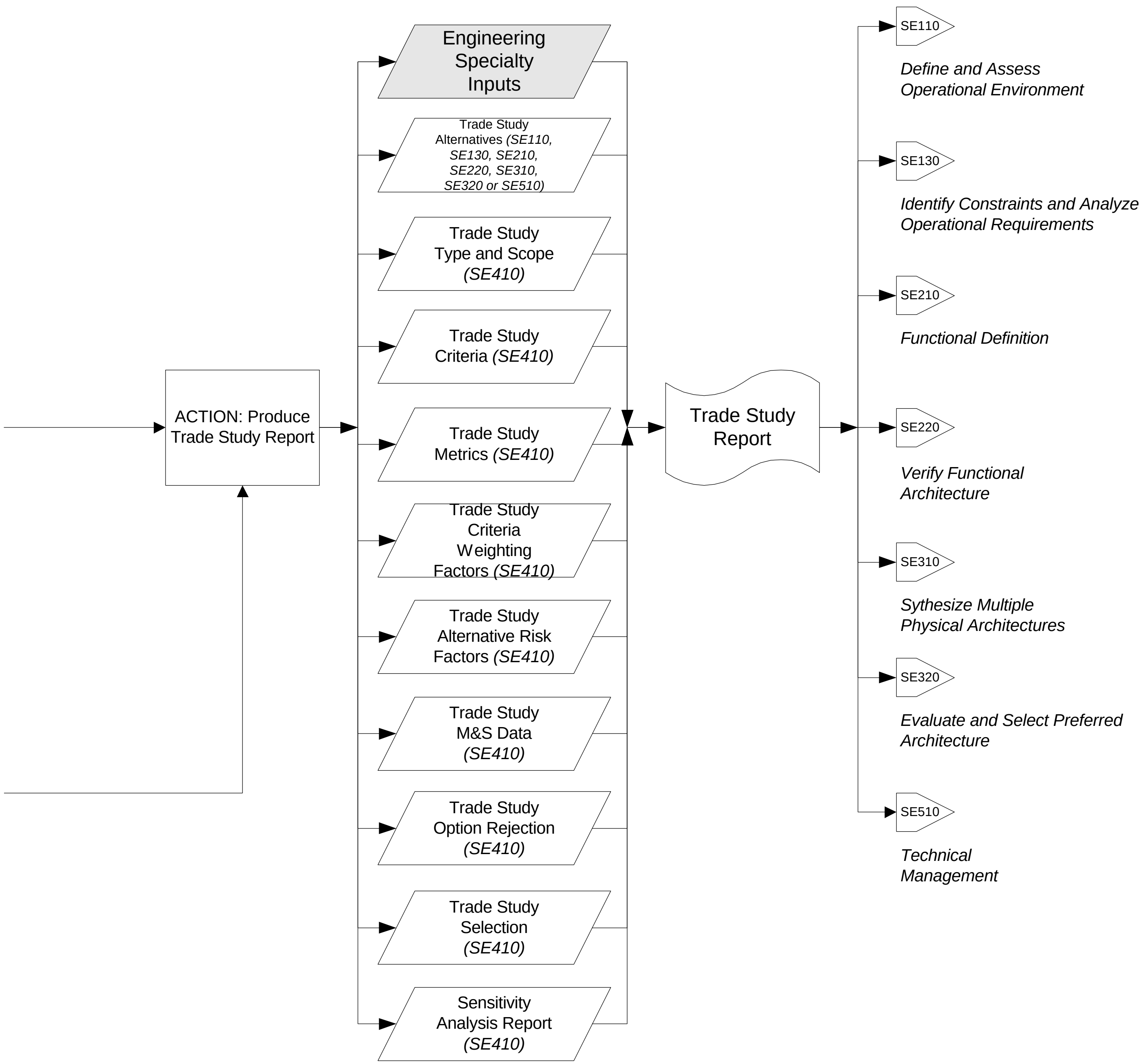

Select Trade Study Criteria
Engineering Specialty Inputs
Trade Study Alternatives (SE110, SE130, SE210, SE220, SE310, SE320 or SE510)
Selection Criteria (SE320)
Trade Study Type and Scope (SE410)
TPMs (SE530)
Are criteria independent?
N
ACTION: Reduce overlap of trade study criteria
Y
AND
Trade Study Criteria
Y
Do criteria provide adequate coverage of the design space?
N
ACTION: Define more trade study criteria


Identify Trade Study Metrics
Engineering Specialty Inputs
Trade Study Alternatives *(SE110, SE130, SE210, SE220, SE310, SE320 or SE510)*
Trade Study Type and Scope *(SE410)*
Trade Study Criteria *(SE410)*
TPMs *(SE530)*
Have metrics been identified for each criterion?
Y
N
Trade Study Metrics
ACTION: Collect Modeling and Simulation Data
Trade Study M&S Data
Identify Criteria Weighting
Guidance
TPMs *(SE530)*
SEMP *(SE530)*
Has project agreement been achieved on criteria weights?
Y
N
Trade Study Criteria Weighting Factors



SE430
Risk Management
Identify Risk
SE430
Risk Management
Trade Study Alternative Risk Factors
Make Selection from Trade Study Alternatives
ORD
Trade Study Alternatives (SE110, SE130, SE210, SE220, SE310, SE320 or SE510)
Requirements Baseline (SE140)
Trade Study Criteria (SE410)
Trade Study Metrics (SE410)
Trade Study Criteria Weighting Factors (SE410)
Trade Study Alternative Risk Factors (SE410)
Trade Study M&S Data (SE410)
Does selected alternative meet system requirements?
Y
N
Trade Study Selection
Trade Study Option Rejection

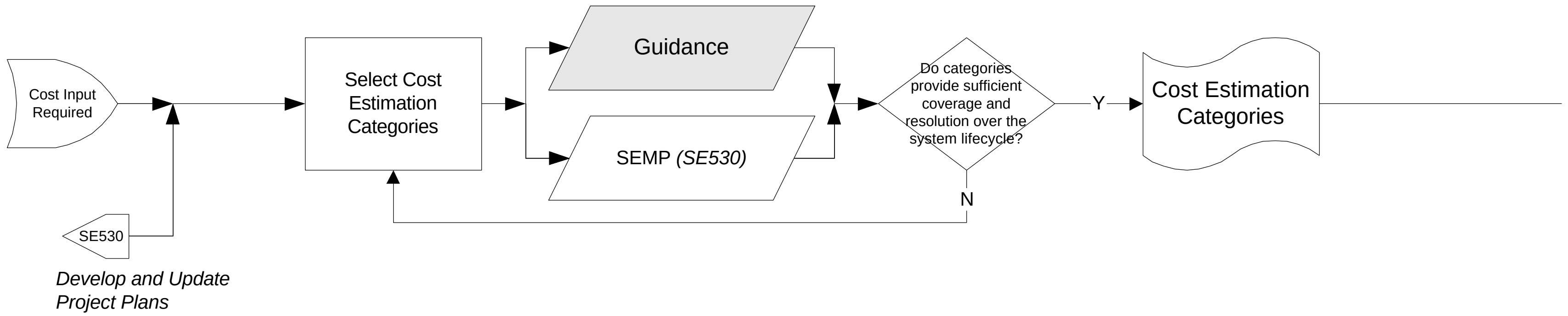

Perform Sensitivity Analysis
Trade Study Alternatives (SE110, SE130, SE210, SE220, SE310, SE320 or SE510)
Trade Study Selection (SE410)
Trade Study Criteria (SE410)
Trade Study Metrics (SE410)
Trade Study Criteria Weighting Factors (SE410)
Does a small scoring variation have a significant effect on selection?
N
Y
ACTION: Perform detailed analysis to assess sensitivity
Sensitivity Analysis Report


ACTION: Produce Trade Study Report
Engineering Specialty Inputs
Trade Study Alternatives (SE110, SE130, SE210, SE220, SE310, SE320 or SE510)
Trade Study Type and Scope (SE410)
Trade Study Criteria (SE410)
Trade Study Metrics (SE410)
Trade Study Criteria Weighting Factors (SE410)
Trade Study Alternative Risk Factors (SE410)
Trade Study M&S Data (SE410)
Trade Study Option Rejection (SE410)
Trade Study Selection (SE410)
Sensitivity Analysis Report (SE410)
Trade Study Report
SE110
Define and Assess Operational Environment
SE130
Identify Constraints and Analyze Operational Requirements
SE210
Functional Definition
SE220
Verify Functional Architecture
SE310
Sythesize Multiple Physical Architectures
SE320
Evaluate and Select Preferred Architecture
SE510
Technical Management

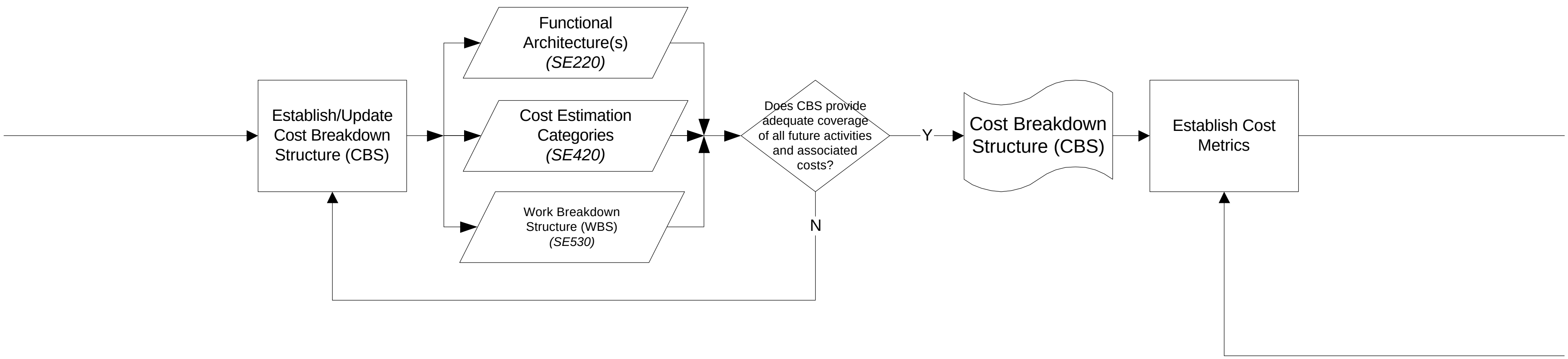
SE420- Lifecycle Cost Analysis
LAST EDIT DATE: 9/22/99

Note: Cost Estimation Categories may vary from project to project. An example of selected categories is Research and Development Cost, Production and Deployment Cost, and Operations and Support Cost. Another example would be to break the cost into the following categories:

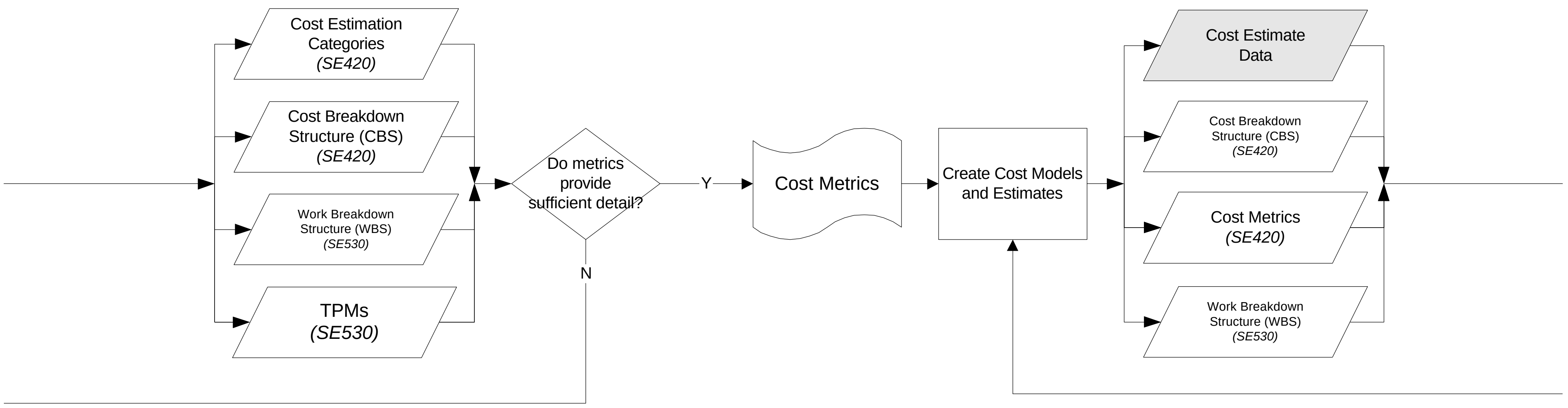
- Acquisition cost
- Operations cost
- Maintenance cost
- Software cost
- Technical Data cost
- Training cost
- Production Distribution cost
- Test and Support Equipment cost
- Supply Support cost
- Retirement and Disposal cost



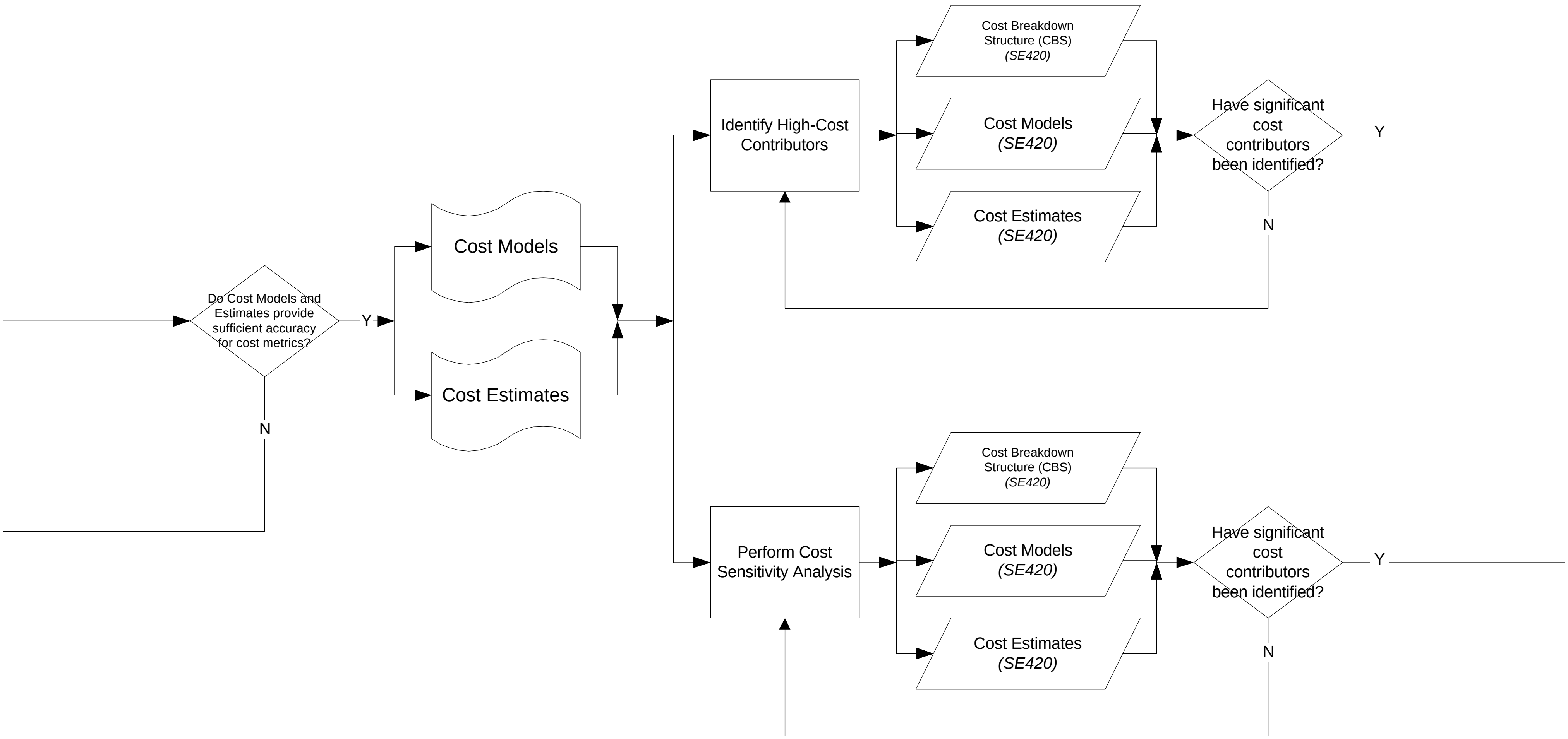
Note: Adapted from INCOSE Systems Engineering Handbook, Rev. 1.0, Section 4.5.4 and Appendix B of Systems Engineering Management by Ben Blanchard

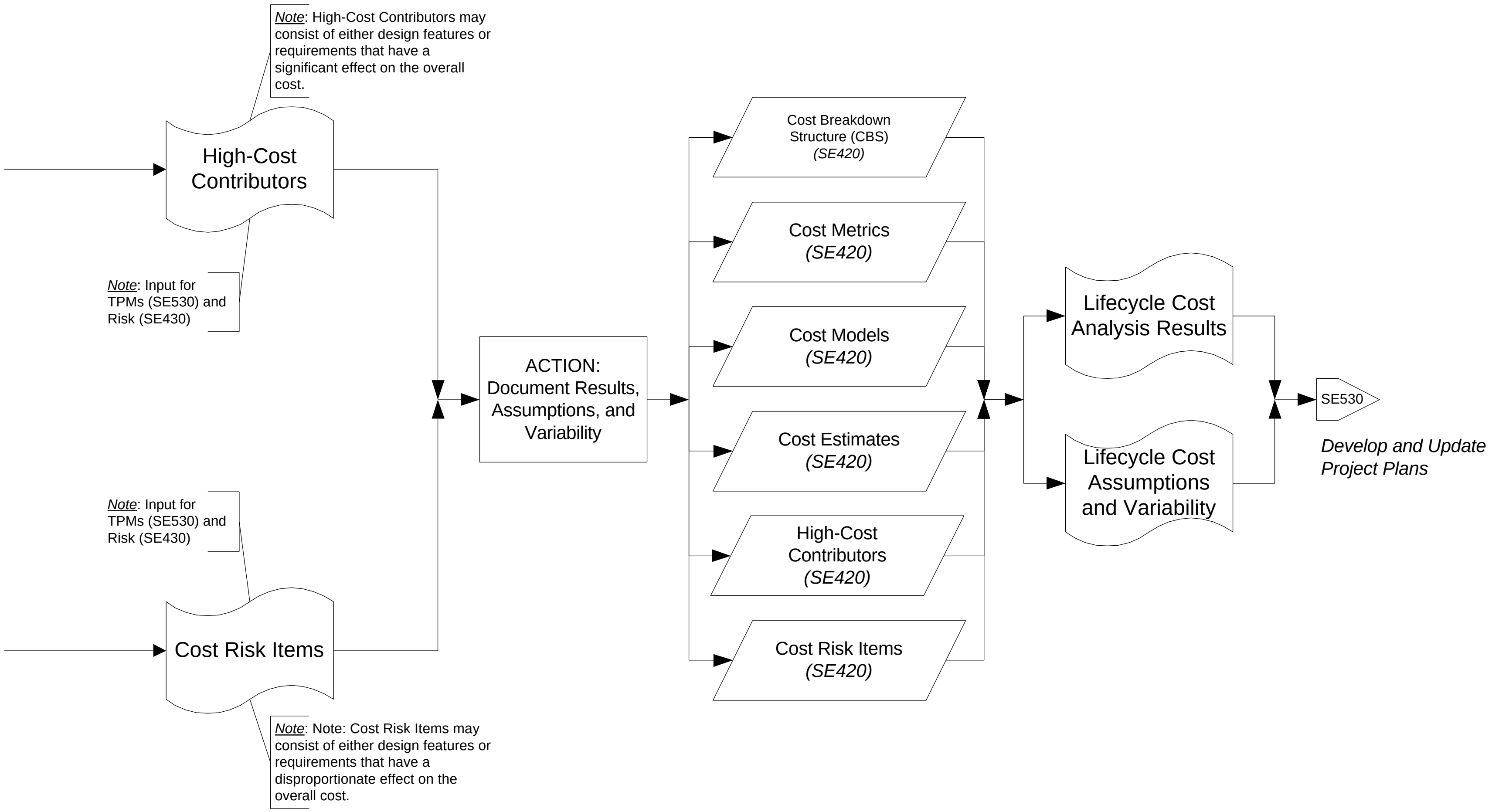


Establish/Update Cost Breakdown Structure (CBS)
Functional Architecture(s) (SE220)
Cost Estimation Categories (SE420)
Work Breakdown Structure (WBS) (SE530)
Does CBS provide adequate coverage of all future activities and associated costs?
Y
N
Cost Breakdown Structure (CBS)
Establish Cost Metrics



Cost Estimation Categories (SE420)
Cost Breakdown Structure (CBS) (SE420)
Work Breakdown Structure (WBS) (SE530)
TPMs (SE530)
Do metrics provide sufficient detail?
Y
N
Cost Metrics
Create Cost Models and Estimates
Cost Estimate Data
Cost Breakdown Structure (CBS) (SE420)
Cost Metrics (SE420)
Work Breakdown Structure (WBS) (SE530)

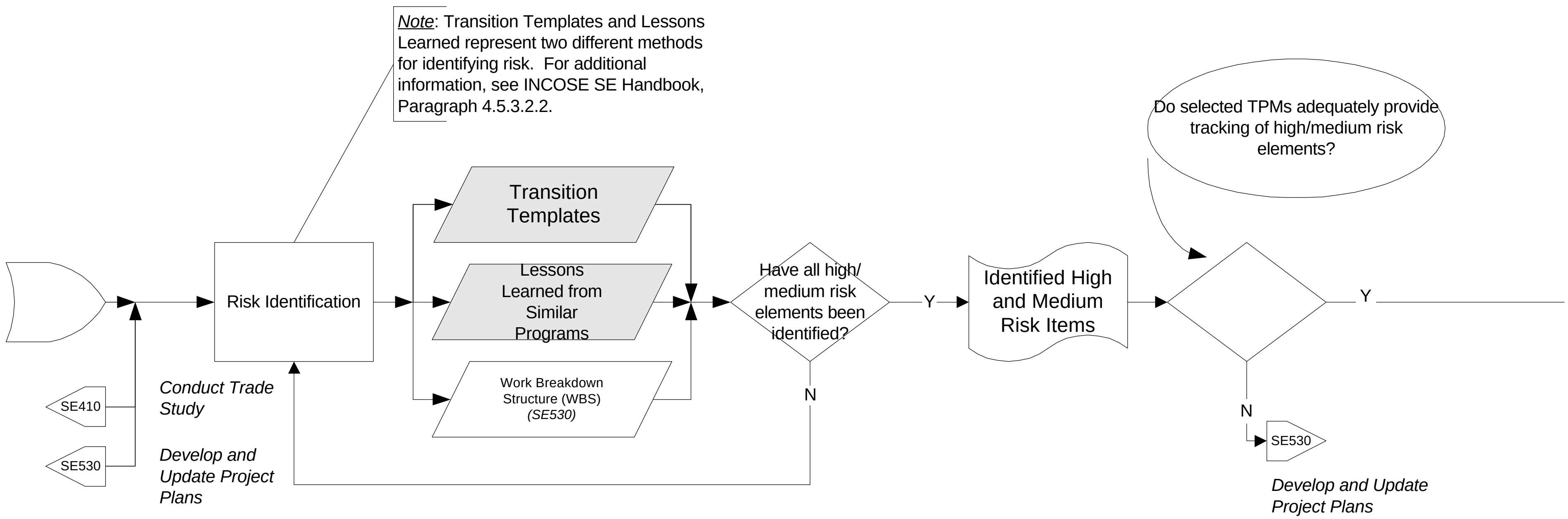

Do Cost Models and Estimates provide sufficient accuracy for cost metrics?
Y
N
Cost Models
Cost Estimates
Identify High-Cost Contributors
Cost Breakdown Structure (CBS) (SE420)
Cost Models (SE420)
Cost Estimates (SE420)
Have significant cost contributors been identified?
Y
N
Perform Cost Sensitivity Analysis
Cost Breakdown Structure (CBS) (SE420)
Cost Models (SE420)
Cost Estimates (SE420)
Have significant cost contributors been identified?
Y
N

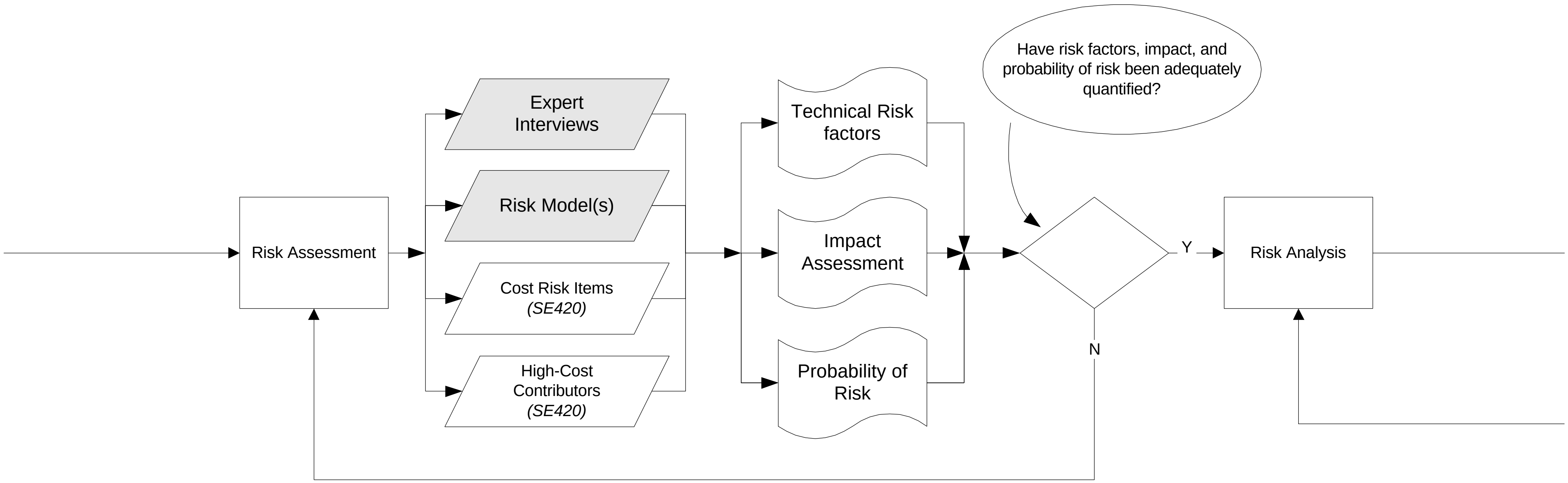

Note: High-Cost Contributors may consist of either design features or requirements that have a significant effect on the overall cost.
High-Cost Contributors
Note: Input for TPMs (SE530) and Risk (SE430)
Note: Input for TPMs (SE530) and Risk (SE430)
Cost Risk Items
Note: Note: Cost Risk Items may consist of either design features or requirements that have a disproportionate effect on the overall cost.
ACTION: Document Results, Assumptions, and Variability
Cost Breakdown Structure (CBS) (SE420)
Cost Metrics (SE420)
Cost Models (SE420)
Cost Estimates (SE420)
High-Cost Contributors (SE420)
Cost Risk Items (SE420)
Lifecycle Cost Analysis Results
Lifecycle Cost Assumptions and Variability
SE530
Develop and Update Project Plans

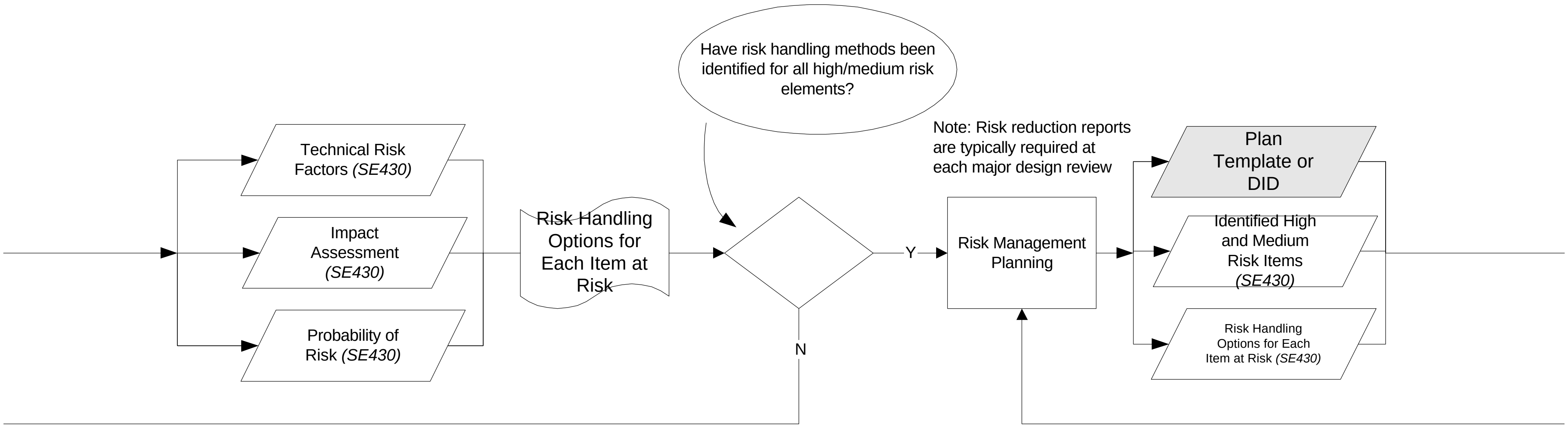
SE430- Risk Management
LAST EDIT DATE: 9/22/99

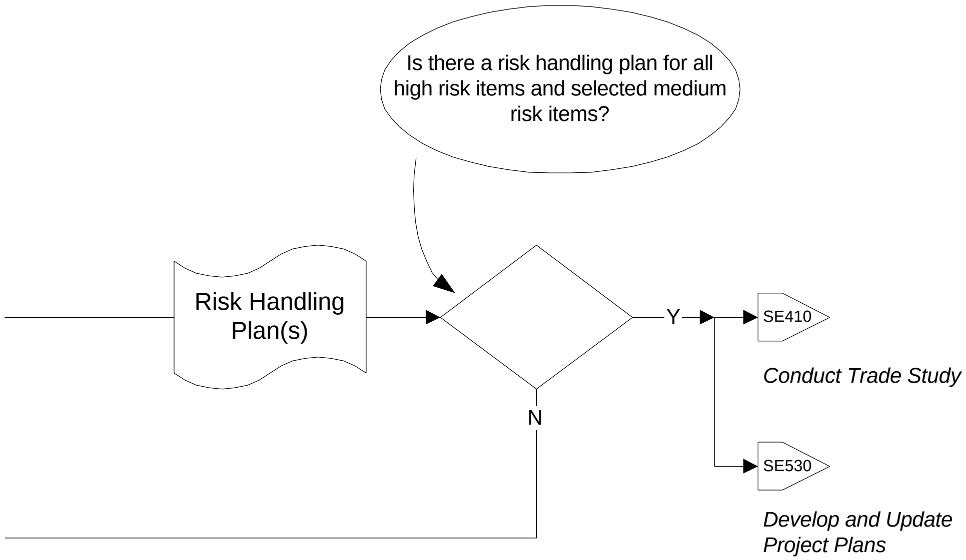
Note: Risk planning documentation and associated requirements described in this OSD are based in part on DoD Data Item Description (DID) UDI-E-G007.

Note: Risk Management is comprised of Planning, Identification, Assessment, Analysis, and Handling. This OSD addresses the first four processes. The fifth item, handling, is an on-going activity throughout the Systems Engineering Process. Accordingly, risk handling activities (such as risk avoidance) are addressed in various locations in the SE process OSDs.




Risk Assessment
Expert Interviews
Risk Model(s)
Cost Risk Items
(SE420)
High-Cost Contributors
(SE420)
Technical Risk factors
Impact Assessment
Probability of Risk
Have risk factors, impact, and probability of risk been adequately quantified?
Y
N
Risk Analysis


Have risk handling methods been identified for all high/medium risk elements?
Technical Risk Factors (SE430)
Impact Assessment (SE430)
Probability of Risk (SE430)
Risk Handling Options for Each Item at Risk
Y
N
Note: Risk reduction reports are typically required at each major design review
Risk Management Planning
Plan Template or DID
Identified High and Medium Risk Items (SE430)
Risk Handling Options for Each Item at Risk (SE430)


Is there a risk handling plan for all high risk items and selected medium risk items?
Risk Handling Plan(s)
Y
N
SE410
Conduct Trade Study
SE530
Develop and Update Project Plans

500 SERIES – CONTROL

Description

The first segment of the Control series of the OSDs deals with Technical Management. Technical Management involves the evaluation or implementation of proposed changes to previously baselined decisions, requirements, functions, or designs. Reviews and Audits outlines the process by which reviews are performed at a local or informal level as well as the process by which requirements, functions, and designs are baselined. Develop and Update Project plans concerns the establishment and update of the Work Breakdown Structure, the Systems Engineering master Schedule, the Systems Engineering Detailed Schedule, and the Systems Engineering Management Plan. Technical Performance Measures are defined, and project progress against those measures is tracked.

OSD Notes

SE510 – Technical Management

This OSD is derived primarily from the INCOSE Systems Engineering Handbook, Release 1.0, Section 4.6.

[Information Requirement] CCB Decision

This Information Requirement is produced by the Configuration Control Board, external to the systems engineering process depicted here.

SE520 – Reviews and Audits

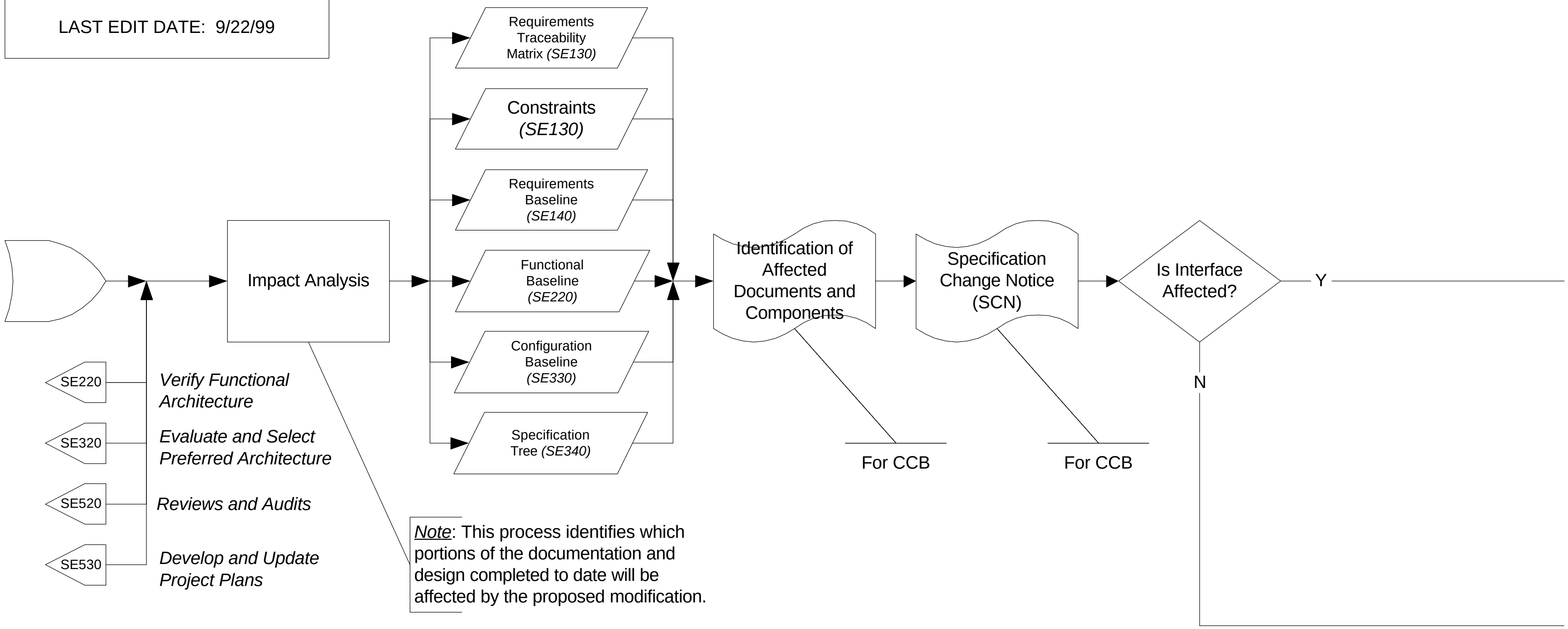
[Information Requirement] CCB Decision

This Information Requirement is produced by the Configuration Control Board, external to the systems engineering process depicted here.

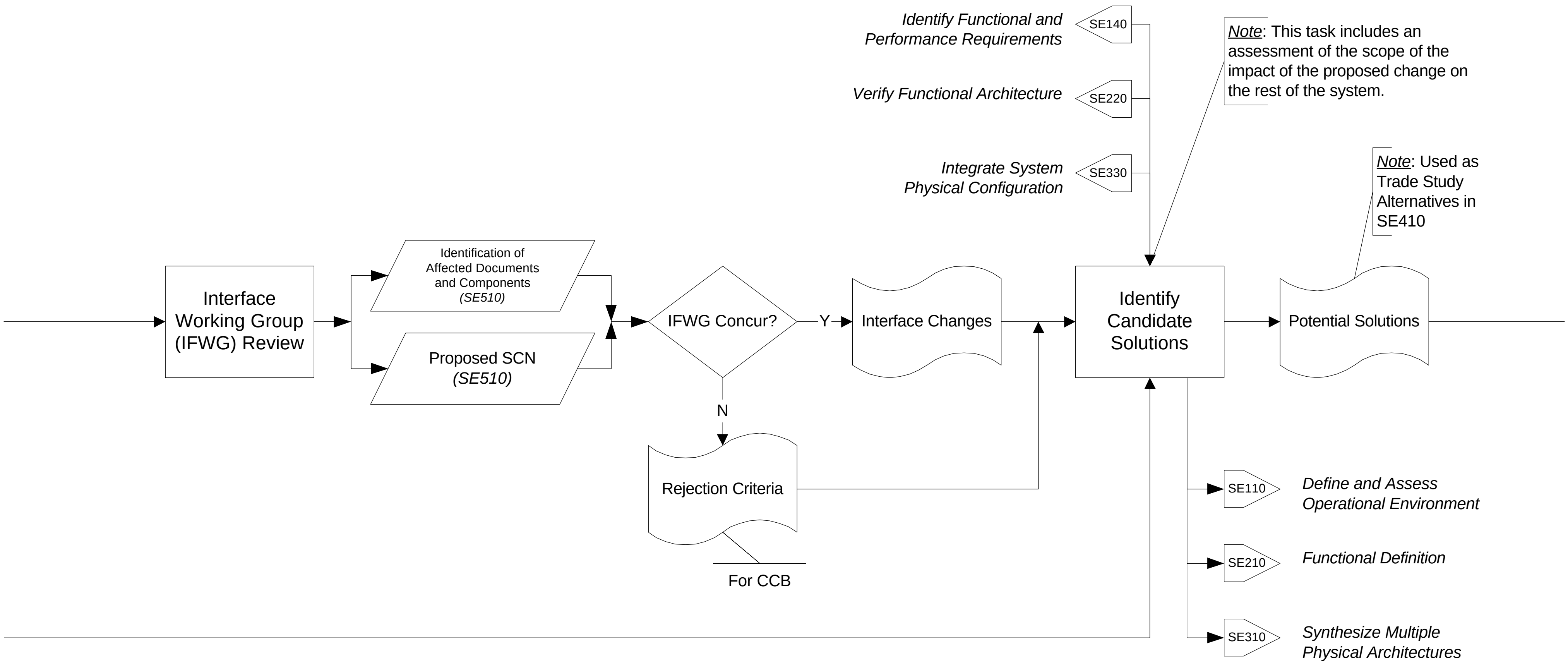
SE530 – Develop and Update Project Plans

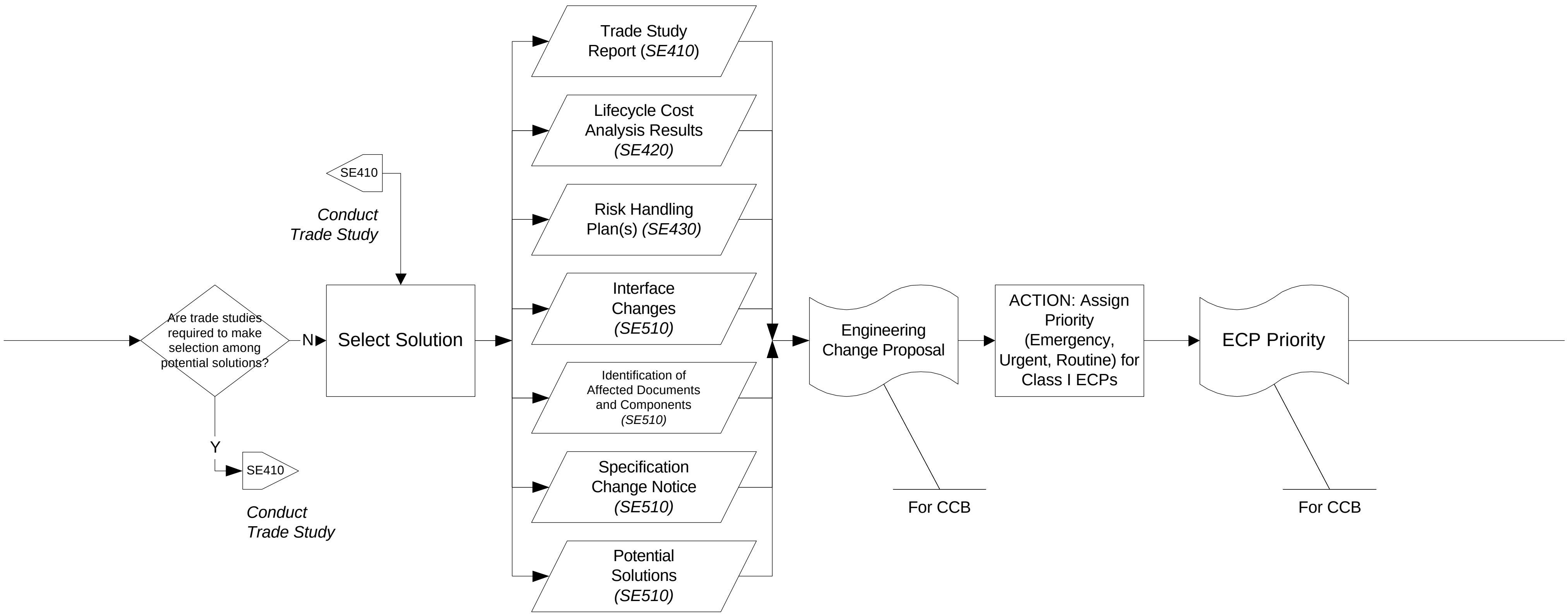
SE510- Technical Management

LAST EDIT DATE: 9/22/99

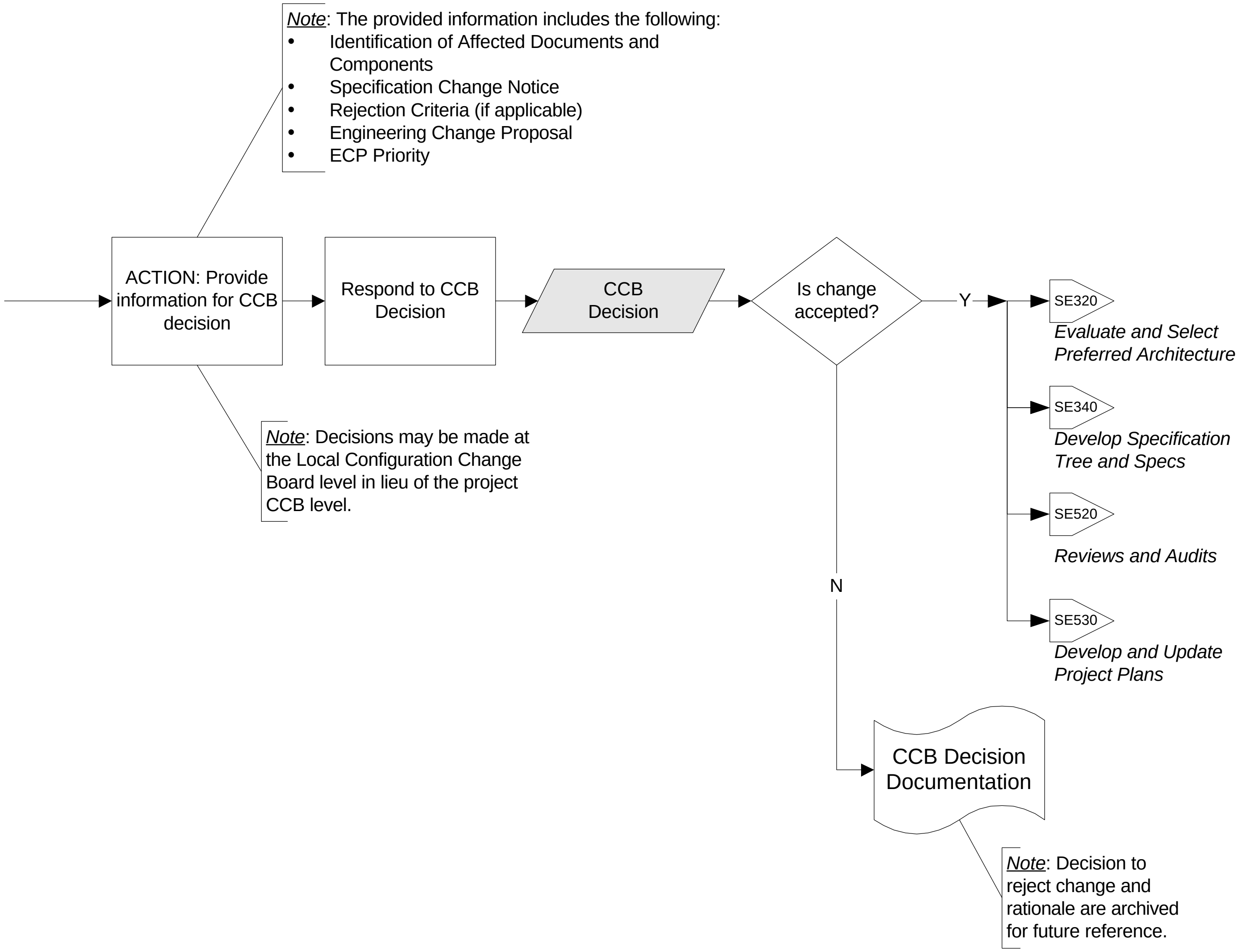


Note: Adapted from INCOSE Systems Engineering Handbook, Rev. 1.0, Section 4.6


Identify Functional and Performance Requirements
SE140
Verify Functional Architecture
SE220
Integrate System Physical Configuration
SE330
Note: This task includes an assessment of the scope of the impact of the proposed change on the rest of the system.
Note: Used as Trade Study Alternatives in SE410
Interface Working Group (IFWG) Review
Identification of Affected Documents and Components (SE510)
Proposed SCN (SE510)
IFWG Concur?
Y
N
Interface Changes
Identify Candidate Solutions
Potential Solutions
Rejection Criteria
For CCB
SE110
Define and Assess Operational Environment
SE210
Functional Definition
SE310
Synthesize Multiple Physical Architectures



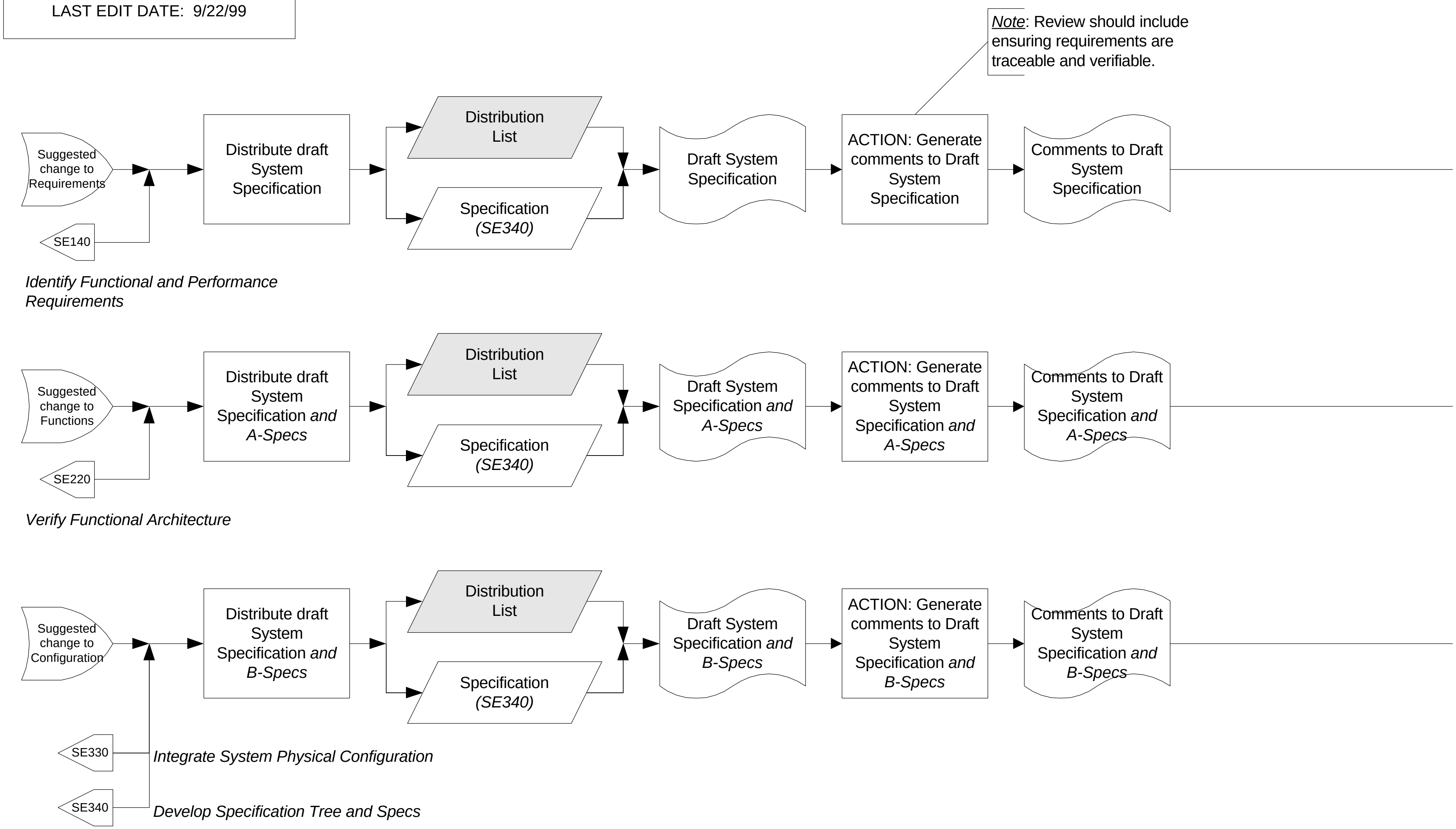
Are trade studies required to make selection among potential solutions?
N
Y
SE410
Conduct Trade Study
SE410
Conduct Trade Study
Select Solution
Trade Study Report (SE410)
Lifecycle Cost Analysis Results (SE420)
Risk Handling Plan(s) (SE430)
Interface Changes (SE510)
Identification of Affected Documents and Components (SE510)
Specification Change Notice (SE510)
Potential Solutions (SE510)
Engineering Change Proposal
For CCB
ACTION: Assign Priority (Emergency, Urgent, Routine) for Class I ECPs
ECP Priority
For CCB

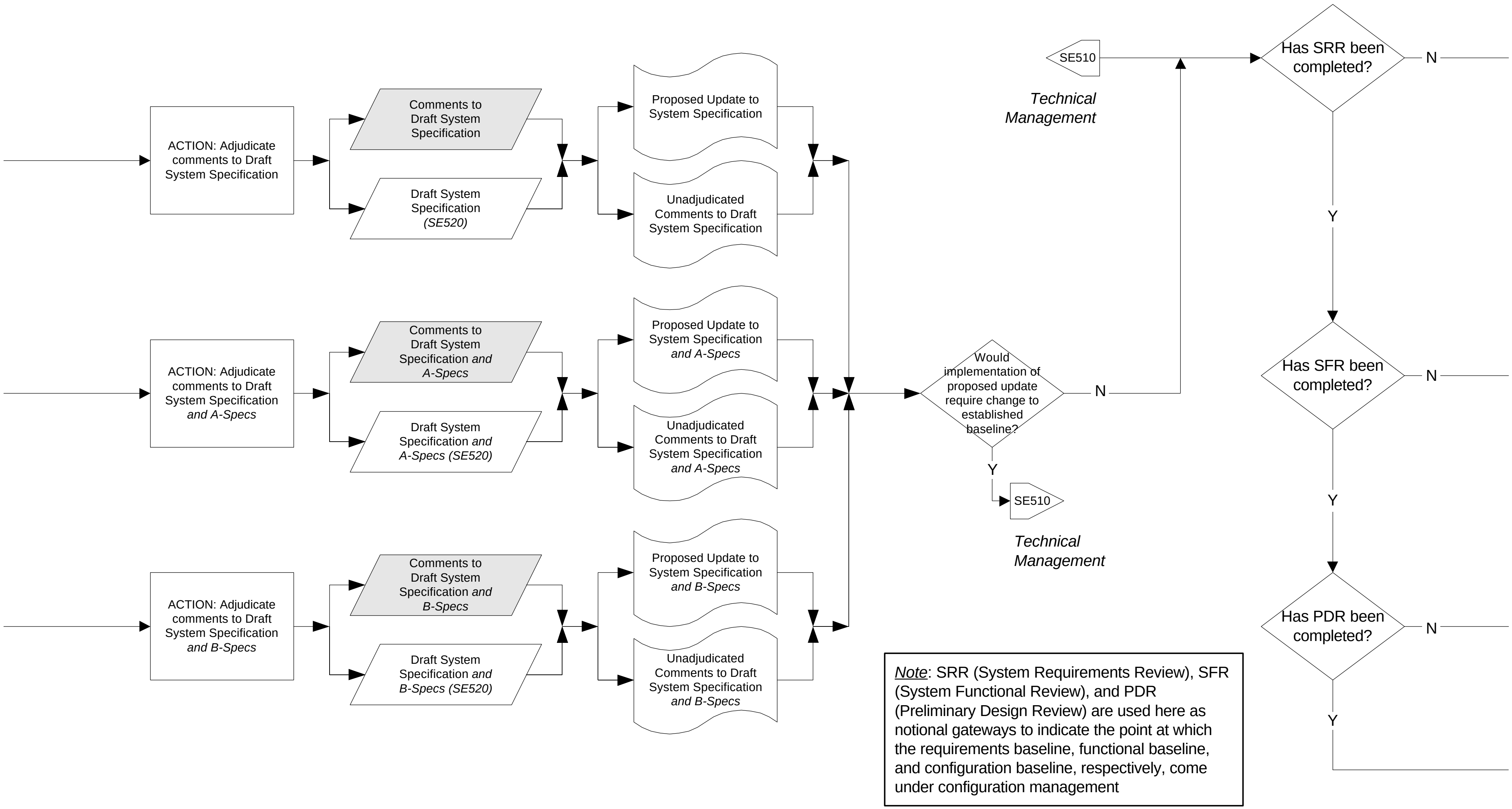

Note: The provided information includes the following:
• Identification of Affected Documents and Components
• Specification Change Notice
• Rejection Criteria (if applicable)
• Engineering Change Proposal
• ECP Priority
ACTION: Provide information for CCB decision
Respond to CCB Decision
CCB Decision
Is change accepted?
Y
N
SE320
Evaluate and Select Preferred Architecture
SE340
Develop Specification Tree and Specs
SE520
Reviews and Audits
SE530
Develop and Update Project Plans
Note: Decisions may be made at the Local Configuration Change Board level in lieu of the project CCB level.
CCB Decision Documentation
Note: Decision to reject change and rationale are archived for future reference.

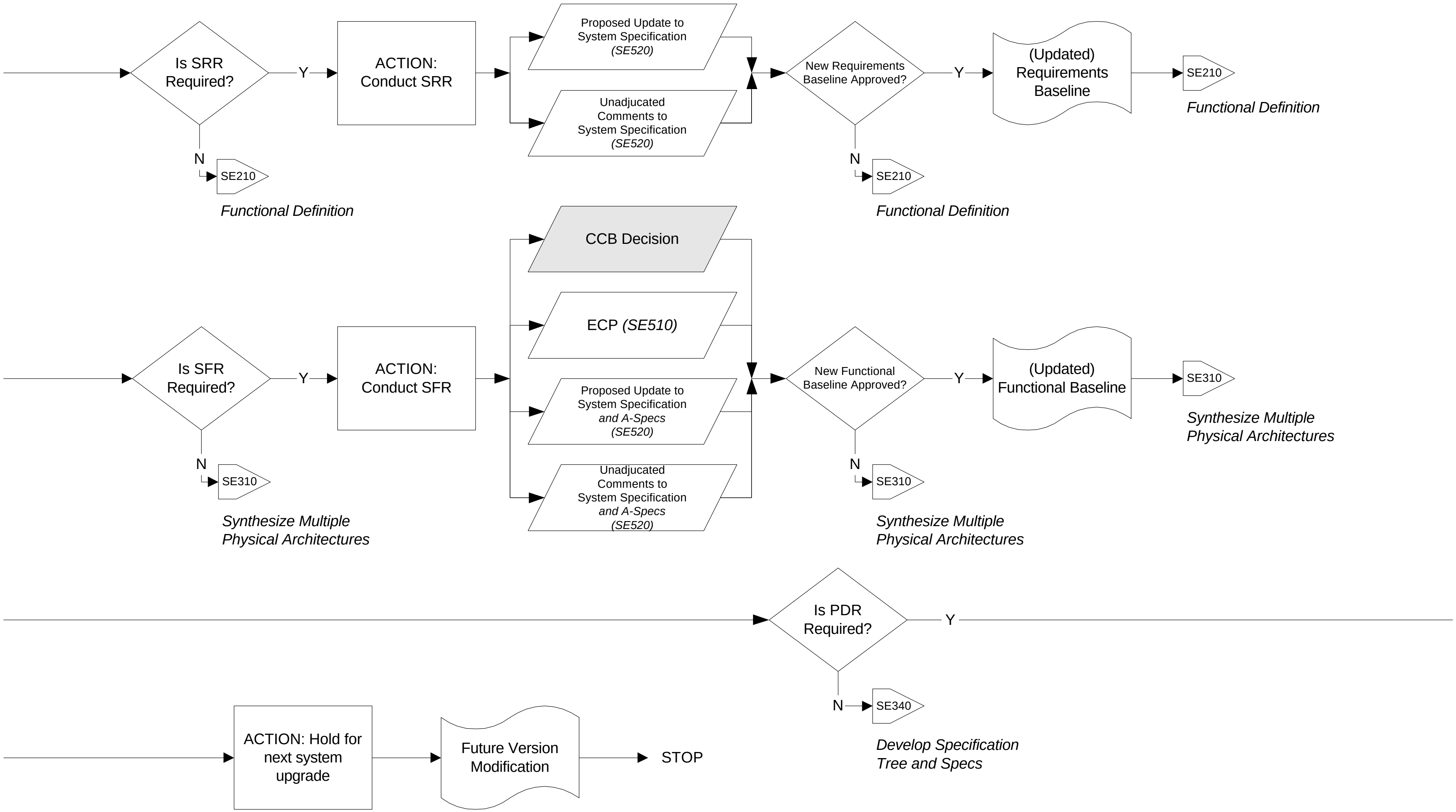
SE520- Reviews and Audits

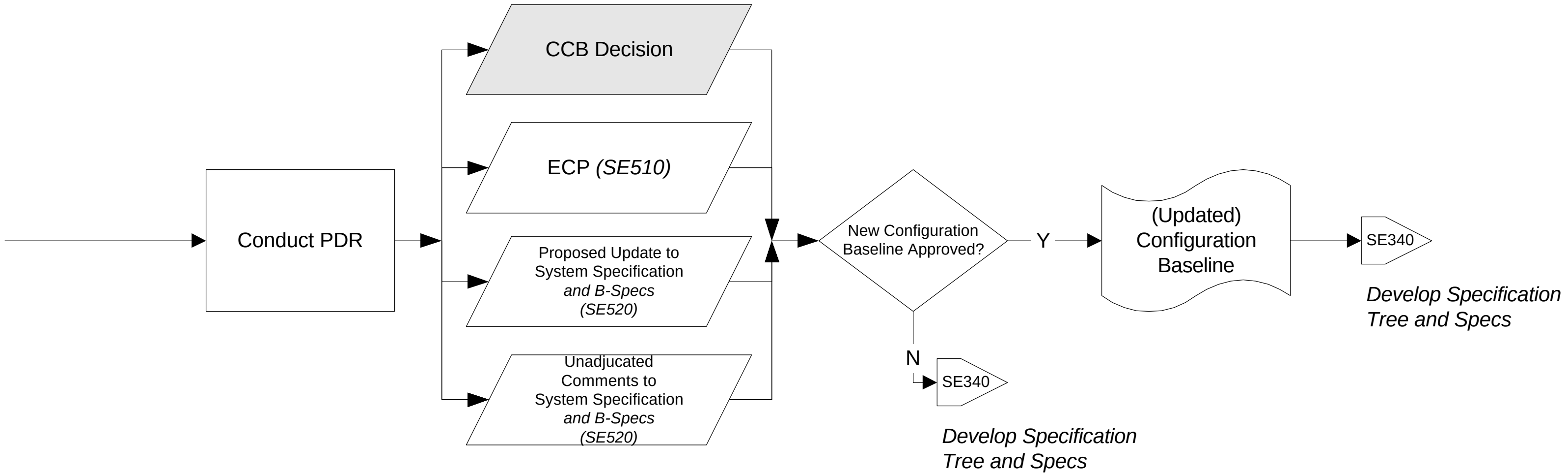
LAST EDIT DATE: 9/22/99

Note: The Review and Audit process and its associated products can vary highly between programs.




ACTION: Adjudicate comments to Draft System Specification
Comments to Draft System Specification
Draft System Specification (SE520)
Proposed Update to System Specification
Unadjudicated Comments to Draft System Specification
ACTION: Adjudicate comments to Draft System Specification and A-Specs
Comments to Draft System Specification and A-Specs
Draft System Specification and A-Specs (SE520)
Proposed Update to System Specification and A-Specs
Unadjudicated Comments to Draft System Specification and A-Specs
ACTION: Adjudicate comments to Draft System Specification and B-Specs
Comments to Draft System Specification and B-Specs
Draft System Specification and B-Specs (SE520)
Proposed Update to System Specification and B-Specs
Unadjudicated Comments to Draft System Specification and B-Specs
Would implementation of proposed update require change to established baseline?
N
Y
SE510
Technical Management
SE510
Technical Management
Has SRR been completed?
N
Y
Has SFR been completed?
N
Y
Has PDR been completed?
N
Y
Note: SRR (System Requirements Review), SFR (System Functional Review), and PDR (Preliminary Design Review) are used here as notional gateways to indicate the point at which the requirements baseline, functional baseline, and configuration baseline, respectively, come under configuration management


Is SRR Required?
Y
N
ACTION: Conduct SRR
Proposed Update to System Specification (SE520)
Unadjucated Comments to System Specification (SE520)
New Requirements Baseline Approved?
Y
N
(Updated) Requirements Baseline
SE210
Functional Definition
SE210
Functional Definition
SE210
Functional Definition
CCB Decision
ECP (SE510)
Is SFR Required?
Y
N
ACTION: Conduct SFR
Proposed Update to System Specification and A-Specs (SE520)
Unadjucated Comments to System Specification and A-Specs (SE520)
New Functional Baseline Approved?
Y
N
(Updated) Functional Baseline
SE310
Synthesize Multiple Physical Architectures
SE310
Synthesize Multiple Physical Architectures
SE310
Synthesize Multiple Physical Architectures
Is PDR Required?
Y
N
SE340
Develop Specification Tree and Specs
ACTION: Hold for next system upgrade
Future Version Modification
STOP



Conduct PDR
CCB Decision
ECP *(SE510)*
Proposed Update to
System Specification
and B-Specs
(SE520)
Unadjucated
Comments to
System Specification
and B-Specs
(SE520)
New Configuration
Baseline Approved?
Y
N
(Updated)
Configuration
Baseline
SE340
Develop Specification
Tree and Specs
SE340
Develop Specification
Tree and Specs

From Section 4.7.3 of EIA/IS-632:
System Requirements Review (SRR). SRR is conducted to demonstrate progress in converging on viable, traceable system requirements that are balanced with cost, schedule, and risk by confirming that:

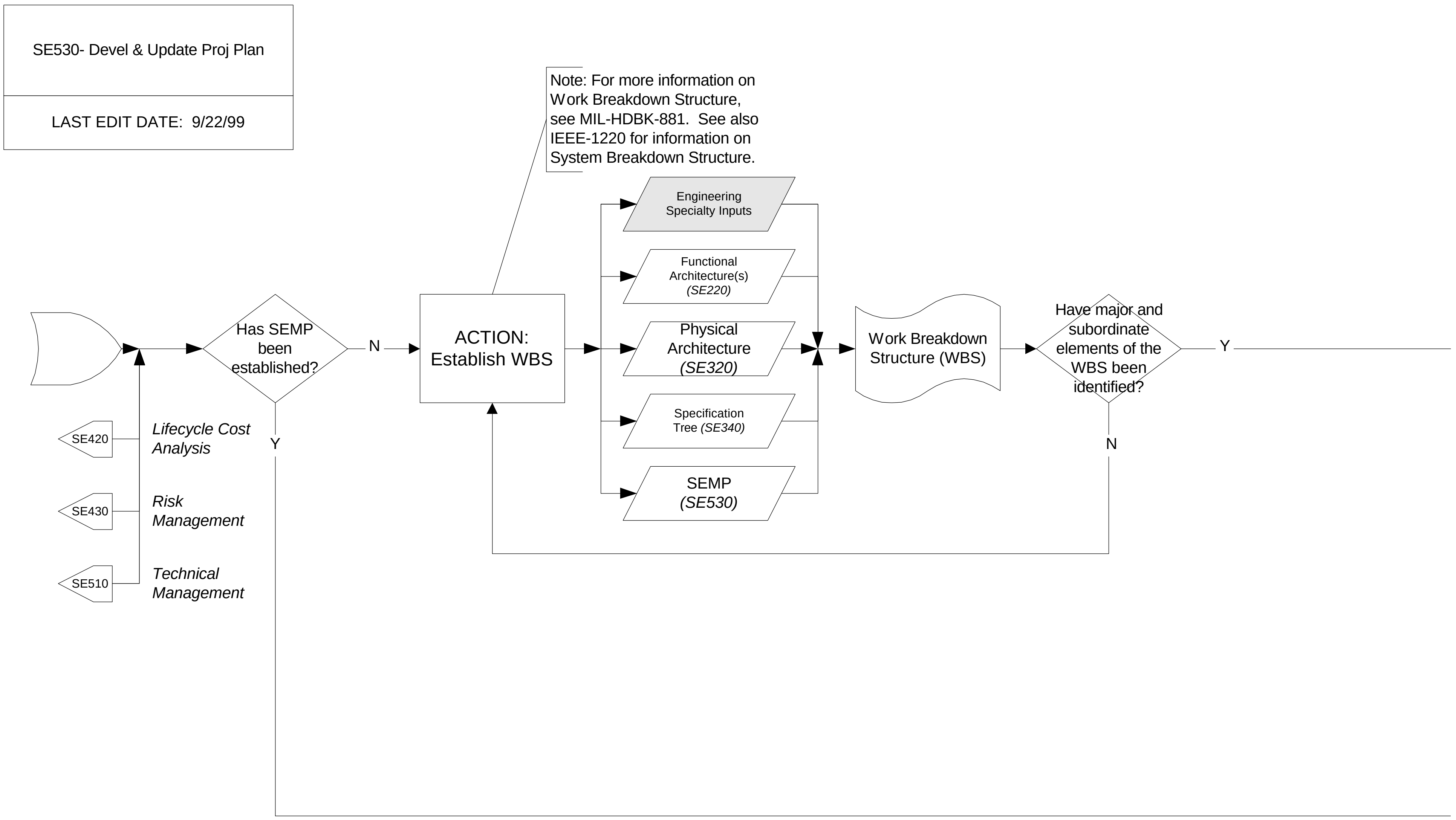
a. customer requirements (including environments, usage modes, and other pertinent factors) were analyzed and translated into system-specific functional and performance requirements;
b. technology validation and demonstration plans are complete and closure plans on technical demonstrations and maturations are achieving required progress;
c. critical technologies for people, product, and process solutions have been identified and assessed;
d. risks are identified and quantified, and risk mitigation actions are achieving required progress; and
e. the total system approach to satisfying requirements (including interfaces) for the primary system functions has been identified (draft system and initial development specifications).

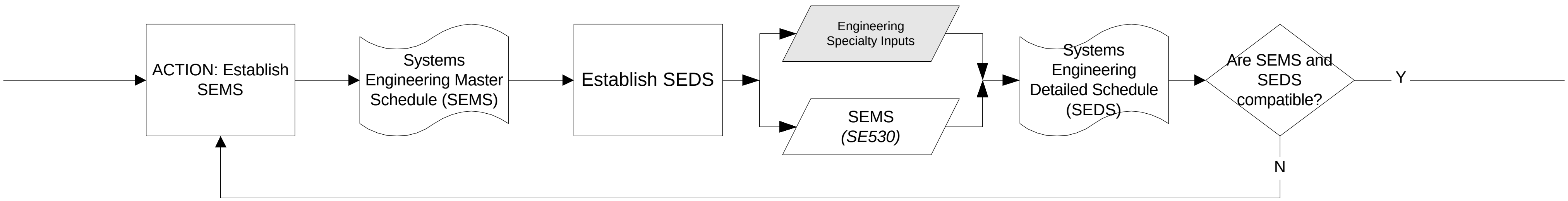
From Section 4.7.4 of EIA/IS-632:
System Functional Review (SFR). SFR is conducted to demonstrate convergence on and achievability of system requirements and readiness to initiate preliminary design by confirming that:

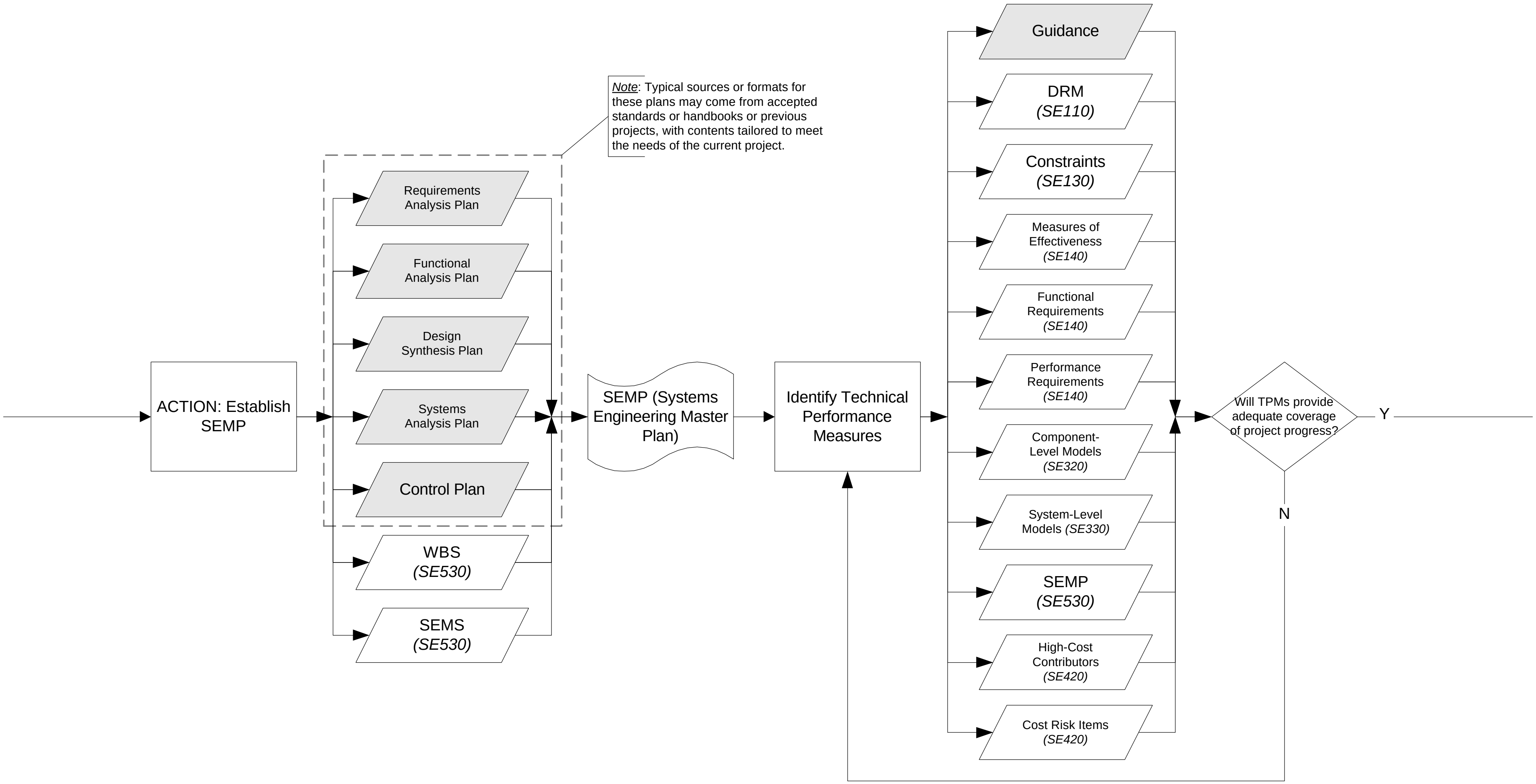
a. system functional and performance requirements have converged and characterize a system design approach that satisfies established customer needs and requirements;
b. the system's physical architecture and draft allocated configuration documentation establish the adequacy, completeness, and achievability of functional and performance requirements (sufficient design and systems analyses including assessment and quantification of cost schedule, and risk);
c. critical technologies for people, product and process solutions have been verified for availability, achievability, needed perfomance, and readiness for transition;
d. the process completely defined system functional and performance requirements including that
   (1) system solutions for people, products, and processes satisfy all primary system functions,
   (2) an audit trail from SRR is established with changes substantiated,
   (3) risks are mitigated and remaining risks acceptable, and
   (4) the system functional baseline can be established;
e. the specification tree represents the physical architecture applicable for the next phase or engineering effort;
f. the WBS is compatible with the specification tree;
g. the risk handling approach has been defined for the next phase or technical effort;
h. pre-planned product and process improvement and evolutionary development requirements and plans have been defined;
i. implementation requirements for technology transition have been defined; and
j. the critical accomplishments, success criteria, and metrics have been defined for the next phase or continued technical effort

From Section 4.7.5 of EIA/IS-632:
Preliminary Design Review (PDR). PDR is conducted to confirm that the approach for system detailed design (as an integrated composite of people, product, and process solutions) satisfies the functional baseline; risks are mitigated with closure plans for remaining risks demonstrating required progress; and the total system is ready for detailed design. PDR confirms that:

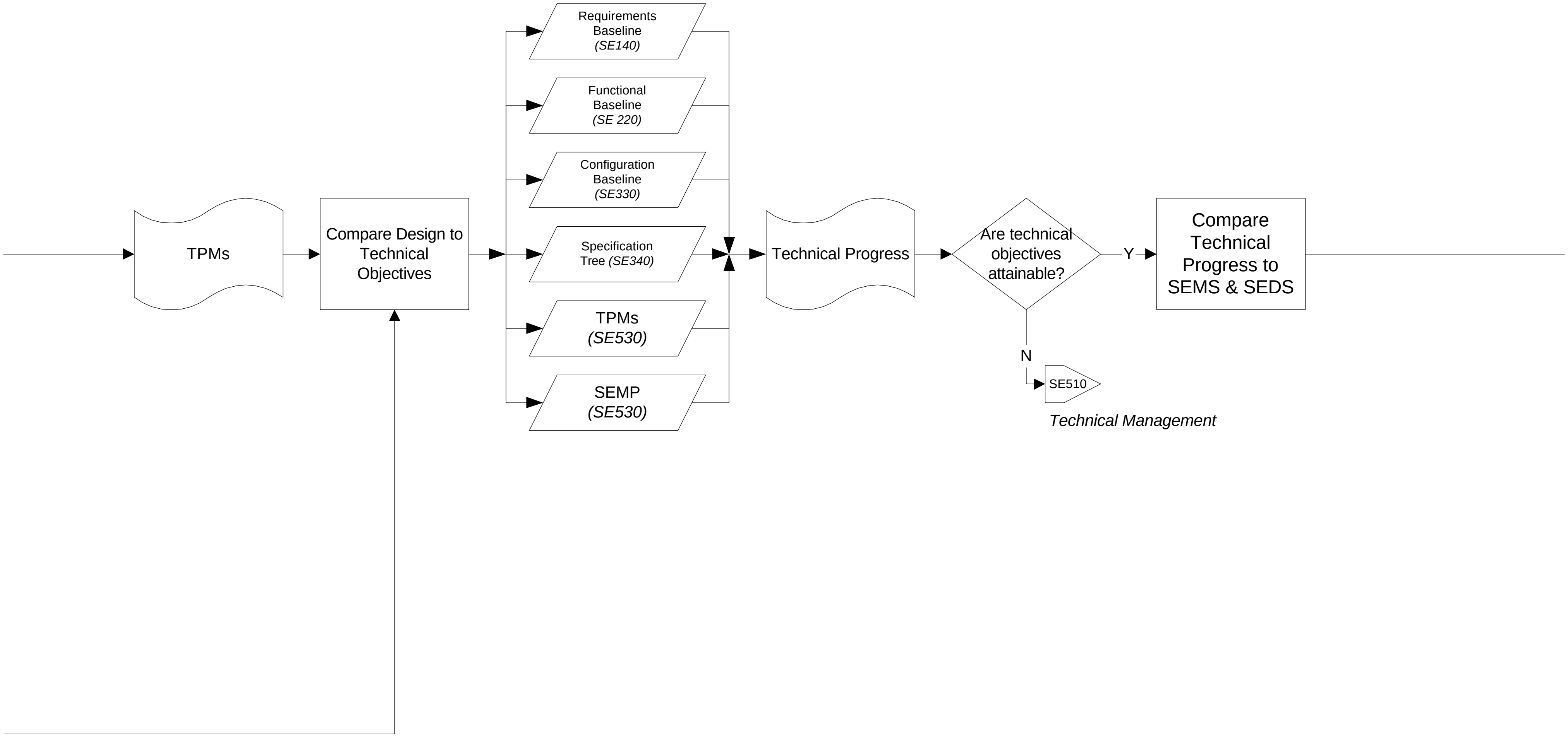
a. the process completely defined the system requirements for detailed design including that
   (1) the design approach is balanced across cost, schedule, performance, and risk for the life cycle,
   (2) the system physical architecture is an integrated design for people, products, and processes which satisfies requirements, including interoperability and interfaces,
   (3) an audit trail from SFR is established with changes substantiated,
   (4) the system design approach is consistent with Test and Evaluation results,
   (5) risks are mitigated and remaining risks acceptable, and
   (6) the allocated baselines for subsystems are defined;
b. issues for system, functional areas, and subsystems are resolved;
c. sufficient design has been accomplished to verify the completeness and achievability of defined requirements;
d. the risk handling approach is refined for the next phase or technical effort;
e. pre-planned product and process improvement and evolutionary development requirements and plans have been refined; and
f. critical accomplishments, success criteria, and metrics are valid for continued technical effort.


SE530- Devel & Update Proj Plan
LAST EDIT DATE: 9/22/99
Note: For more information on Work Breakdown Structure, see MIL-HDBK-881. See also IEEE-1220 for information on System Breakdown Structure.
Engineering Specialty Inputs
Functional Architecture(s) (SE220)
Physical Architecture (SE320)
Specification Tree (SE340)
SEMP (SE530)
Has SEMP been established?
N
Y
ACTION: Establish WBS
Work Breakdown Structure (WBS)
Have major and subordinate elements of the WBS been identified?
Y
N
SE420
Lifecycle Cost Analysis
SE430
Risk Management
SE510
Technical Management

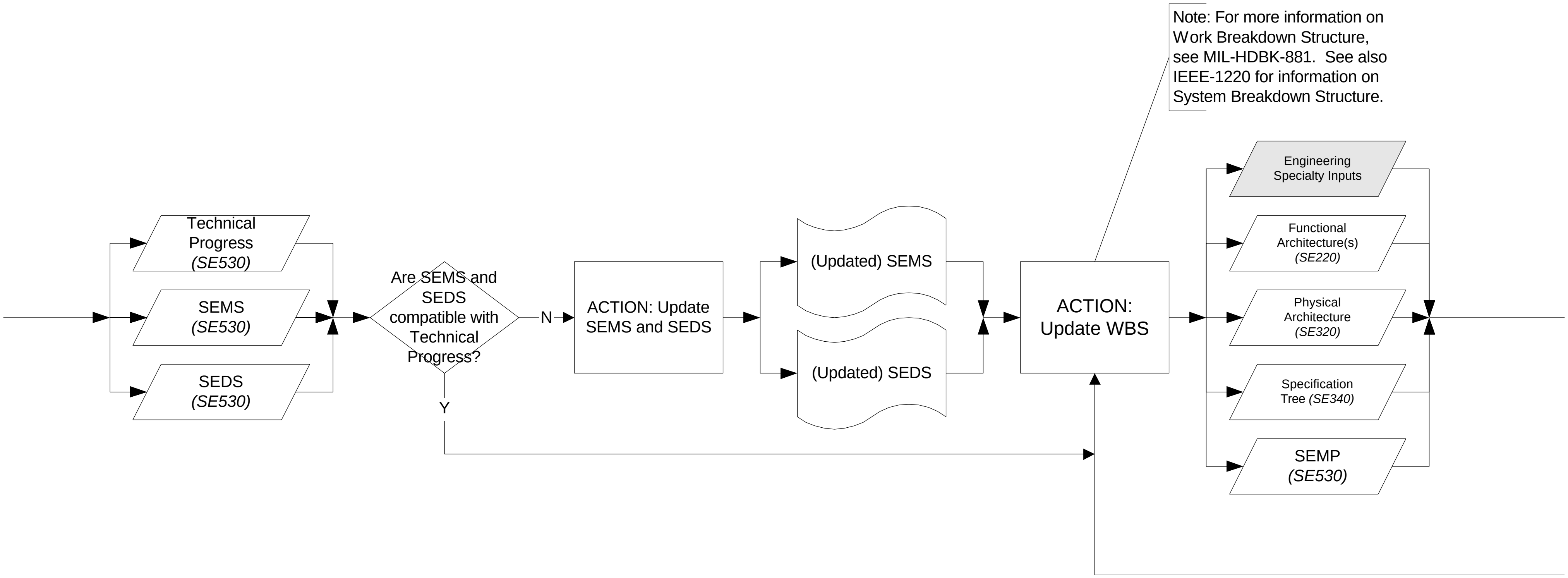

ACTION: Establish SEMS
Systems Engineering Master Schedule (SEMS)
Establish SEDS
Engineering Specialty Inputs
SEMS
(SE530)
Systems Engineering Detailed Schedule (SEDS)
Are SEMS and SEDS compatible?
Y
N

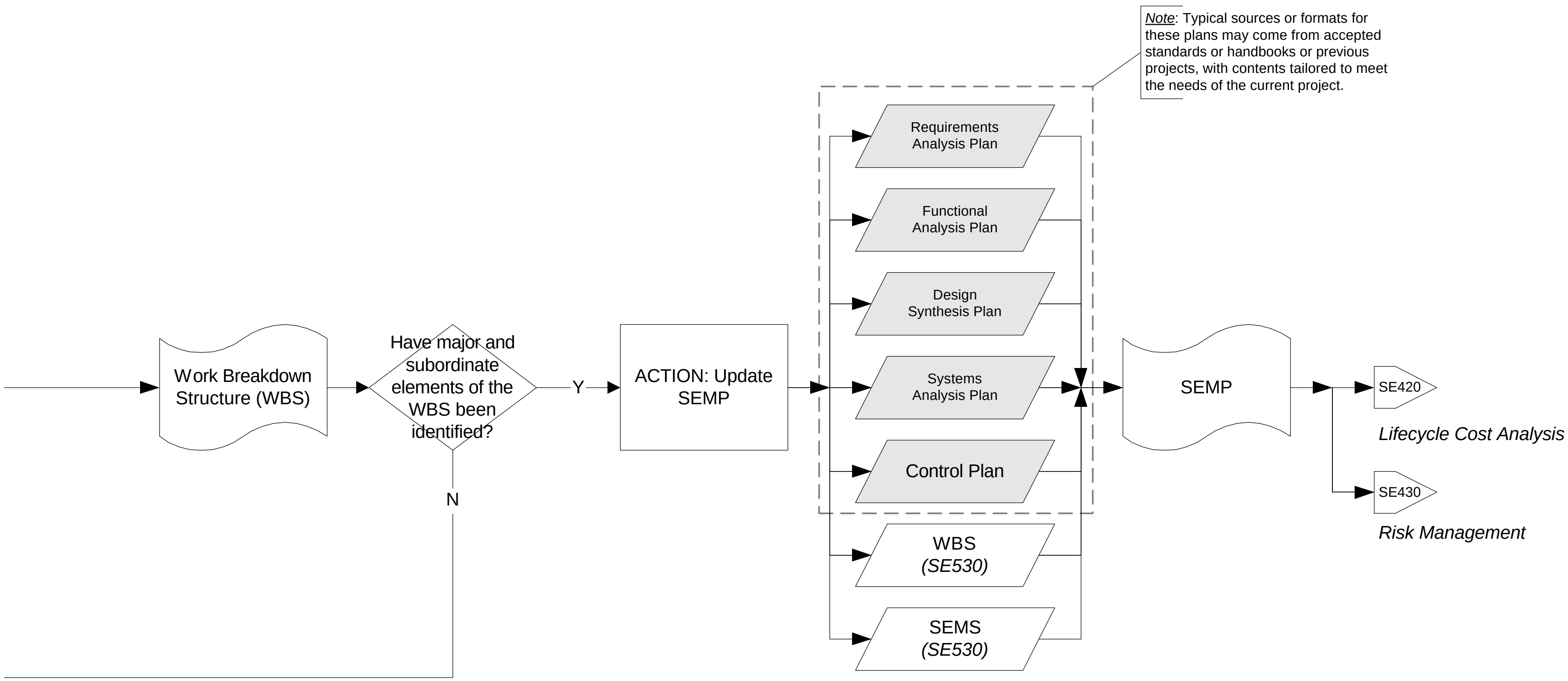


ACTION: Establish SEMP
Note: Typical sources or formats for these plans may come from accepted standards or handbooks or previous projects, with contents tailored to meet the needs of the current project.
Requirements Analysis Plan
Functional Analysis Plan
Design Synthesis Plan
Systems Analysis Plan
Control Plan
WBS (SE530)
SEMS (SE530)
SEMP (Systems Engineering Master Plan)
Identify Technical Performance Measures
Guidance
DRM (SE110)
Constraints (SE130)
Measures of Effectiveness (SE140)
Functional Requirements (SE140)
Performance Requirements (SE140)
Component-Level Models (SE320)
System-Level Models (SE330)
SEMP (SE530)
High-Cost Contributors (SE420)
Cost Risk Items (SE420)
Will TPMs provide adequate coverage of project progress?
Y
N



TPMs
Compare Design to Technical Objectives
Requirements Baseline (SE140)
Functional Baseline (SE 220)
Configuration Baseline (SE330)
Specification Tree (SE340)
TPMs (SE530)
SEMP (SE530)
Technical Progress
Are technical objectives attainable?
Y
N
Compare Technical Progress to SEMS & SEDS
SE510
Technical Management


Note: For more information on Work Breakdown Structure, see MIL-HDBK-881. See also IEEE-1220 for information on System Breakdown Structure.
Technical Progress (SE530)
SEMS (SE530)
SEDS (SE530)
Are SEMS and SEDS compatible with Technical Progress?
N
Y
ACTION: Update SEMS and SEDS
(Updated) SEMS
(Updated) SEDS
ACTION: Update WBS
Engineering Specialty Inputs
Functional Architecture(s) (SE220)
Physical Architecture (SE320)
Specification Tree (SE340)
SEMP (SE530)



Note: Typical sources or formats for these plans may come from accepted standards or handbooks or previous projects, with contents tailored to meet the needs of the current project.
Work Breakdown Structure (WBS)
Have major and subordinate elements of the WBS been identified?
Y
N
ACTION: Update SEMP
Requirements Analysis Plan
Functional Analysis Plan
Design Synthesis Plan
Systems Analysis Plan
Control Plan
WBS (SE530)
SEMS (SE530)
SEMP
SE420
Lifecycle Cost Analysis
SE430
Risk Management