



# Constellation Program (CxP)

## Model-Based Systems Engineering Capability

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CONSTELLATION



# Agenda

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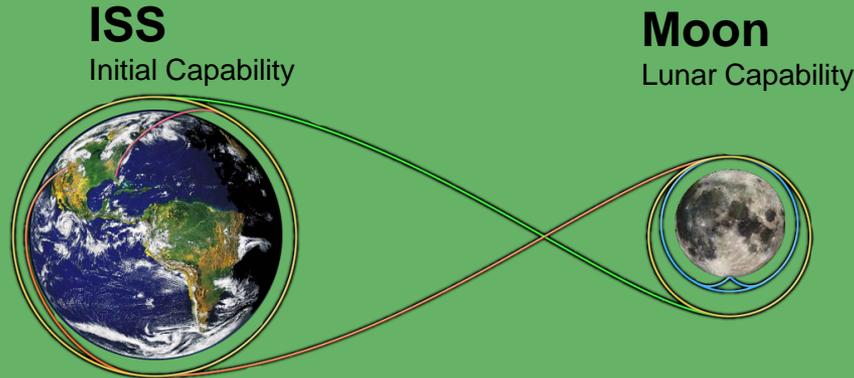
- ◆ **Introduction**
- ◆ **CxP Overview and Team Charter**
- ◆ **CxP Systems Engineering Tools**
  - Demonstration of Access to Collaborative Environment
- ◆ **CxP Systems Engineering Process**
  - Demonstration of Systems Engineering Tool
- ◆ **Lessons Learned**
- ◆ **Adapting SE Capability to Support New Direction**



# Constellation Program



## Missions



## Systems



Ares I Launch Vehicle

Launch Suit



Orion Crew Vehicle



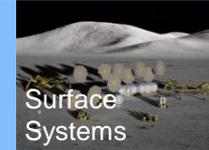
Ground Operations

Mission Operations



Ares V Launch Vehicle

EVA

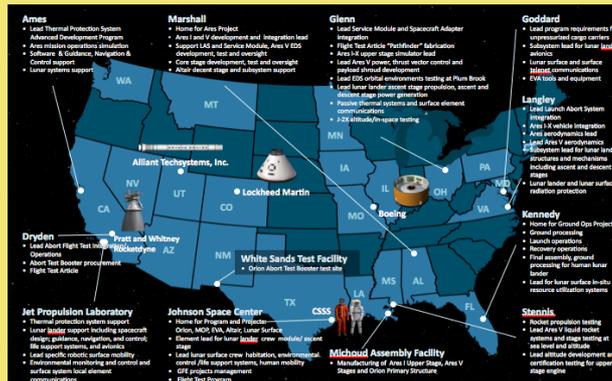


Surface Systems



Altair Lunar Lander

## Team





# Applied Systems Engineering Team (ASET)

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## ◆ Team Chartered by CxP Program Management to:

- Define Model-Based Systems Engineering process that addresses:
  - Requirements Definition and Management
  - Concept of Operations Development and Traceability to Requirements and Lower Level ConOps for Projects
  - Interface Definition and Management
  - Physical Architecture Definition and Management
  - Verification Definition and Management
- Coordinate implementation of SE process in program-selected tools
  - Tools were selected at HQ-Level during early program formulation period
  - Others introduced as teams formed
- Support teams in execution of SE process
  - Level 2 Peer Organizations and Level 3 Project Teams
  - Type of Support Provided:
    - Training (in cooperation with training organization)
    - Capture and Modeling of Information (Requirements, Interfaces, ConOps, etc.)
    - Queries, Reports, Document Production
    - Special support leading up to program/project milestones such as design reviews, baseline releases, etc.



# CxP SE Capability Accomplishments to Date

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- ◆ **A Model-Based Systems Engineering Process consisting of:**
  - A tool-agnostic process definition that can be implemented in any tool of choice
  - Work Instruction-level procedures to guide engineers in execution of SE process *in program-selected tools*
  - Automated audits/metrics to ensure process compliance and identification of issues
  - Work Instruction-level procedures to maintain data integrity
- ◆ **System Engineering tools accessible to nation-wide team (via ICE), configured to support the defined systems engineering process**
- ◆ **Formal Training organized along systems engineering process areas**
  - Approximately 10 training classes available
  - Over 100 training classes conducted with hundreds of engineers trained



# Constellation Program Management Support for MBSE and Collaborative Environments



## ◆ Top-Level Program Management Support

- Program and Deputy Program Managers
- Level 2 Systems Engineering & Integration and Info Sys Office Managers

## ◆ Issued Two Key Management Directives

- Use an IT collaborative environment for generating, using and managing program information assets
  - End user has immediate access to all authorized Program/Project data, regardless of their organization (gov't or contractor)
  - Consistent Interface to program/project data
  - Established best practices
  - Facilitate Traceability/Compliance across systems
- Use a single systems engineering database as the authoritative source for:
  - Technical requirements, verification data
  - Design Reference Mission data and Operations Concepts data
  - Operational, functional, and physical architecture data
  - Functional analysis data
  - Linkage/Traceability of the above

**CxP Program Management wanted to realize benefits from: 1) a collaborative environment and 2) a model-based systems engineering approach.**



# Partial List of Constellation Information Assets

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- ◆ **Requirements (Architecture/System/Element/Operational)**
- ◆ **Operational Concepts**
- ◆ **Design Reference Missions**
- ◆ **Physical Architecture (Systems, Interfaces)**
- ◆ **Verification**
- ◆ **Functional/Performance data**
- ◆ **Risks**
- ◆ **Hazards**
- ◆ **Design Compliance**
- ◆ **Product Structures**
- ◆ **Drawings**
- ◆ **Trade Studies**
- ◆ **Schedules**
- ◆ **Models and Simulations**
- ◆ **Documents**



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# CxP Systems Engineering Tools



# Constellation IT Infrastructure - Integrated Collaborative Environment (ICE)



ICE Portal > ICE Portal Home

EXPLORATION SYSTEMS  
ICE Portal

Moon, Mars, and Beyond...

Search this Site... Search

ICE Portal: Welcome Jody Fluhr | ICE Home | Help | Site Map | My Account

ICE Portal Home ICE Training/Support ICE Applications Sites Reviews My Pages

ICE Portal Home

ICE Portal Home

ICE Calendar

Today This Week This Month

Friday June 25, 2010

June 2010						
S	M	T	W	Th	F	Sa
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30			

NASA News

**NASA Breaking News**

- Lofts In Space: NASA Challenges College Students To Design Inflatable Space Habitats
- Space Economic Task Force Seeks Florida Public Comments
- NASA Astronaut T.J. Creamer Available for TV Interviews on Challenges of Living and Working Aboard the Space Station
- NASA Awards Contract Modification To EG&G Technical Services
- NASA Awards Launch Services Contract For OCO-2 Mission

Active Risk Manager

Action Tracking System

CAIT

Calendar

Citrix Applications (All)

Cradle (Web)

IRMA

Primavera Web

RID Tool (All)

SIP

ThinkTank

Wiki

Windchill

Insight (Web)

**UPCOMING ACTIVITIES:**

- CRADLE WEB UI Training:** Three more training sessions scheduled for Cradle Web UI training. [More info...](#)
- ThinkTank 3.0:** Check out the newest evolution in structured collaboration tools by Group Systems, Thinktank 3.0. With a new look and feel, ThinkTank 3.0 provides much of the same

ICE Portal Sites

**ICE Portal Sites**

The ICE Portal is organized into different "Sites" that are comprised of ESMD Organizations, Programs, Projects, and cross cutting activities. Below is a description of each portal site with a link to that site. You can use the navigation item **Sites** in the menu above that appears on every portal page to quickly access the content in each site.

**ICE Portal**

This is the main site for general information about ICE including "What's New", ICE Tools Help/Training and other top level information about ESMD.

[+ Read More](#)

**Headquarters Portal**

The Headquarters portal contains ESMD content and information about each of the Headquarters offices. The ESMD HQ Guide is a one-stop information source for ESMD HQ personnel, including administrative operations and directorate policies and procedures.

[+ Headquarters Portal](#)  
[+ ESMD HQ Guide](#)

**Constellation Portal**

ICE Portal provides access to applications used to manage information assets.



# Constellation SE Tool Usage Metrics



Application	# Users	# Records	Related Info
Trades/Analyses Management Tool	1048	2083	Includes TDS and BEAs
Risk Management Tool	2116	3904	Includes CxP Risks
Systems Engineering Tool	1326	382,000	CxP Database only; does not include LMCO/others
Change Management Tool	50	2824	Includes CRs, Products, Documents and Revisions
FMEA/CIL Tool	114	4759	Includes FMEAs and CILs
Hazards Database	688	381	Hazard database size is rapidly growing
MAS-PRACA	3891	13308	Includes Cx, ISS, and ARC PRACA
Windchill	TBS	TBS	ICE only - does not include center DDMS



# Systems Engineering Tool Metrics



METRIC	MAY-07	DEC-07	MAY-08	FEB-10	NOTES / COMMENTS
<b>Total Items (includes previous B/L)</b>	<b>90,316</b>	<b>110,000</b>	<b>173,506</b>	<b>381,582</b>	Includes ALL REVISIONS of ALL Items
Frames	410,091	624,000	1,069,453	4,217,386	Pieces of information
<b>Total Cross-References (Links)</b>	<b>464,994</b>	<b>1,000,000</b>	<b>4,268,151</b>	<b>9,553,268</b>	Links between items
<b>Operational Concept Statements (OPS CONS)</b>	<b>165</b>	<b>2,682</b>	<b>3,794</b>	<b>4,269</b>	Reflects Projects OCD development
<b>Requirements (REQ-CONST)</b>	<b>25,425</b>	<b>33,000</b>	<b>52,816</b>	<b>90,068</b>	Includes ALL REVISIONS of a Requirement
<b>Verification Requirements</b>	<b>14,397</b>	<b>22,000</b>	<b>35,181</b>	<b>69,574</b>	Includes ALL REVISIONS of a Verification Requirement
Doc Sections	11,634	18,000	23,065	44,643	Includes ALL REVISIONS of a Document Section
Issues	4,932	7,553	10,735	13,153	Includes ALL REVISIONS of an Issue
<b>Test Verification Reports (TVR)</b>	<b>N/A</b>	<b>1,832</b>	<b>7,109</b>	<b>40,223</b>	Reflects Program transition to Design Validation - including below Element DVO content
<b>TEST</b>	<b>129</b>	<b>1,168</b>	<b>3,428</b>	<b>9,034</b>	Reflects Program transition to Design Validation
Analysis (TDS)	0	0	943	3,174	Supplied by CAIT; two-way interchange operational
<b>Architecture Components - ADD</b>	<b>0</b>	<b>0</b>	<b>252</b>	<b>540</b>	Includes Conceptual, Block Configuration, and External Systems
Cradle-EXPL Interfaces to/from other CxP tools/processes	0	2	6	11	ARM, CAIT, CART, DAGGR, IRMA, RID Tool, non-EXPL Project Databases, Primavera, SIP
Number of Audits (Documented)	4	39	114	218	REQ, VR, ISSUES, OPS CON, Generic DB audits
Cradle Processes (Approved)	0	10	25	53	Includes approved Cradle Methodology, Procedures and Tip Sheets



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# CxP Systems Engineering Process



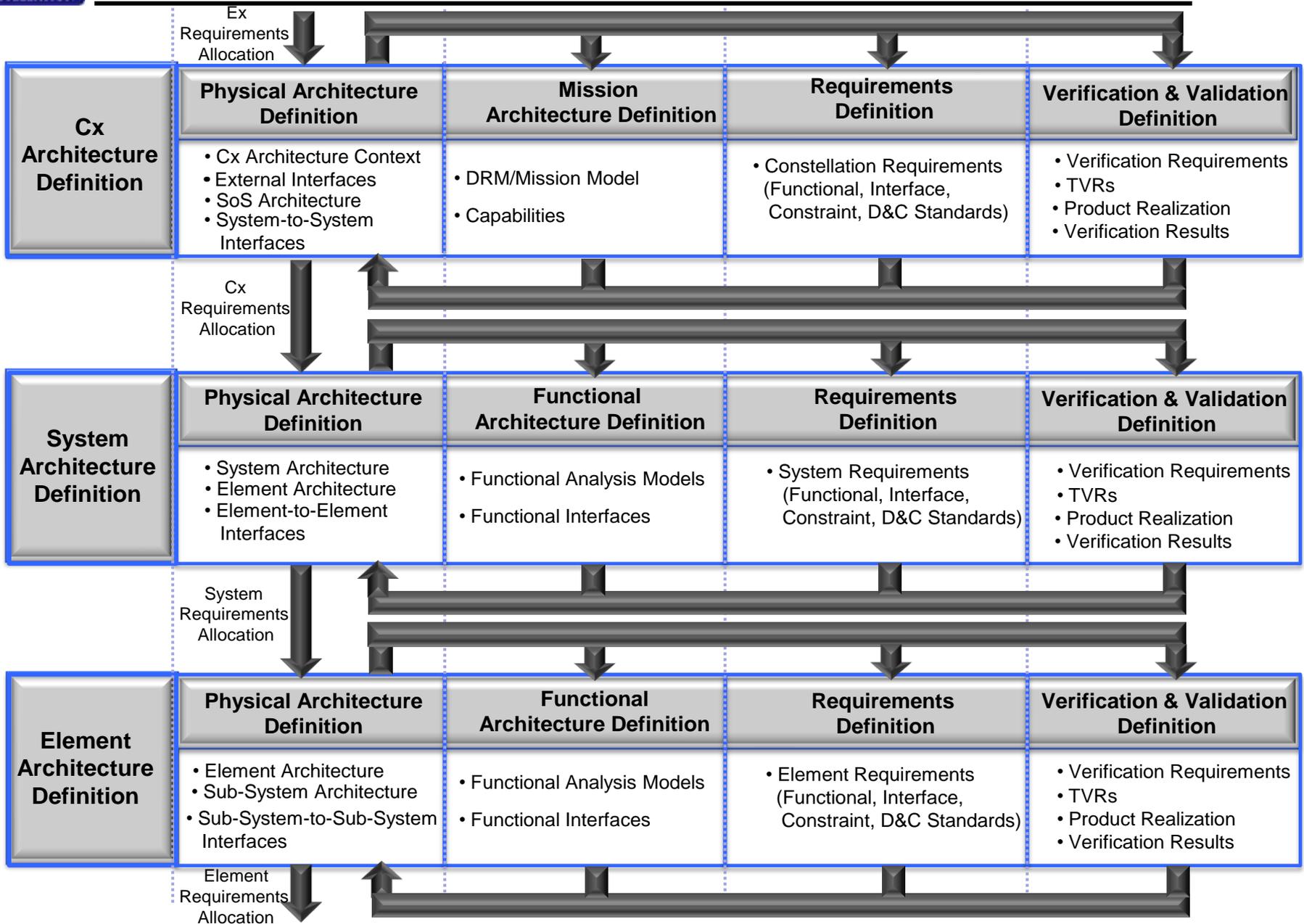
# Model-Based Systems Engineering (MBSE)



- ◆ **MBSE ensures traceability and completeness of typically distinct and “silo” systems engineering products**
  - Missions and Operations needs and capabilities [Mission Models]
  - System through Component Functions [Functional Models]
  - Architecture-System through Component Requirements [Requirements/Traceability]
  - Conceptual and Deliverable Architecture Definition [Physical Architecture Models]
  - Verification Needs, Planning, Events [Verifications/Traceability]
- ◆ **MBSE is an approach to systems engineering where *information* about the *system* is:**
  - Contained in an accessible database or repository
  - Captured in a standardized, methodical manner
  - Captured in graphical models when appropriate
  - Related and linked in standardized ways
  - Capable of being queried and reported
- ◆ **Contrast to “Document-Based” Systems Engineering**
  - Equivalent of data ‘silos’
  - Manual correlation of data
  - Outdated Information – Lack of Access to latest Data



# Cx Systems Engineering Process Overview

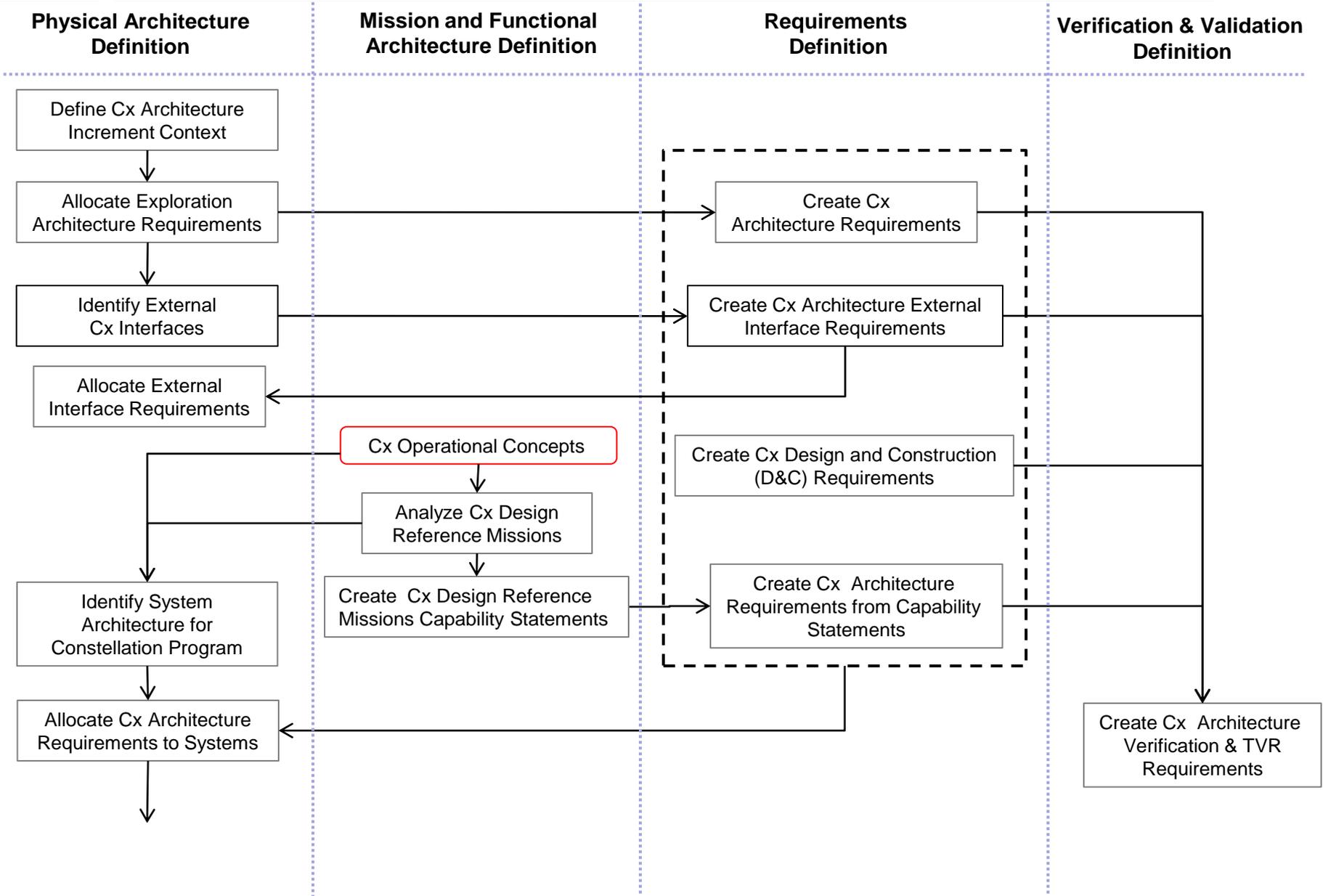




- ◆ ***Process Description:*** A tool-agnostic process definition that can be implemented in any tool of choice
  - MS Word Document: CxP 75000
  - Team Wiki
  
- ◆ ***Detailed Procedures:*** Work Instruction-level procedures to guide engineers in execution of SE process *in program-selected tools*
  - MS Word Documents: CxP 75000-xx
  - Team Wiki

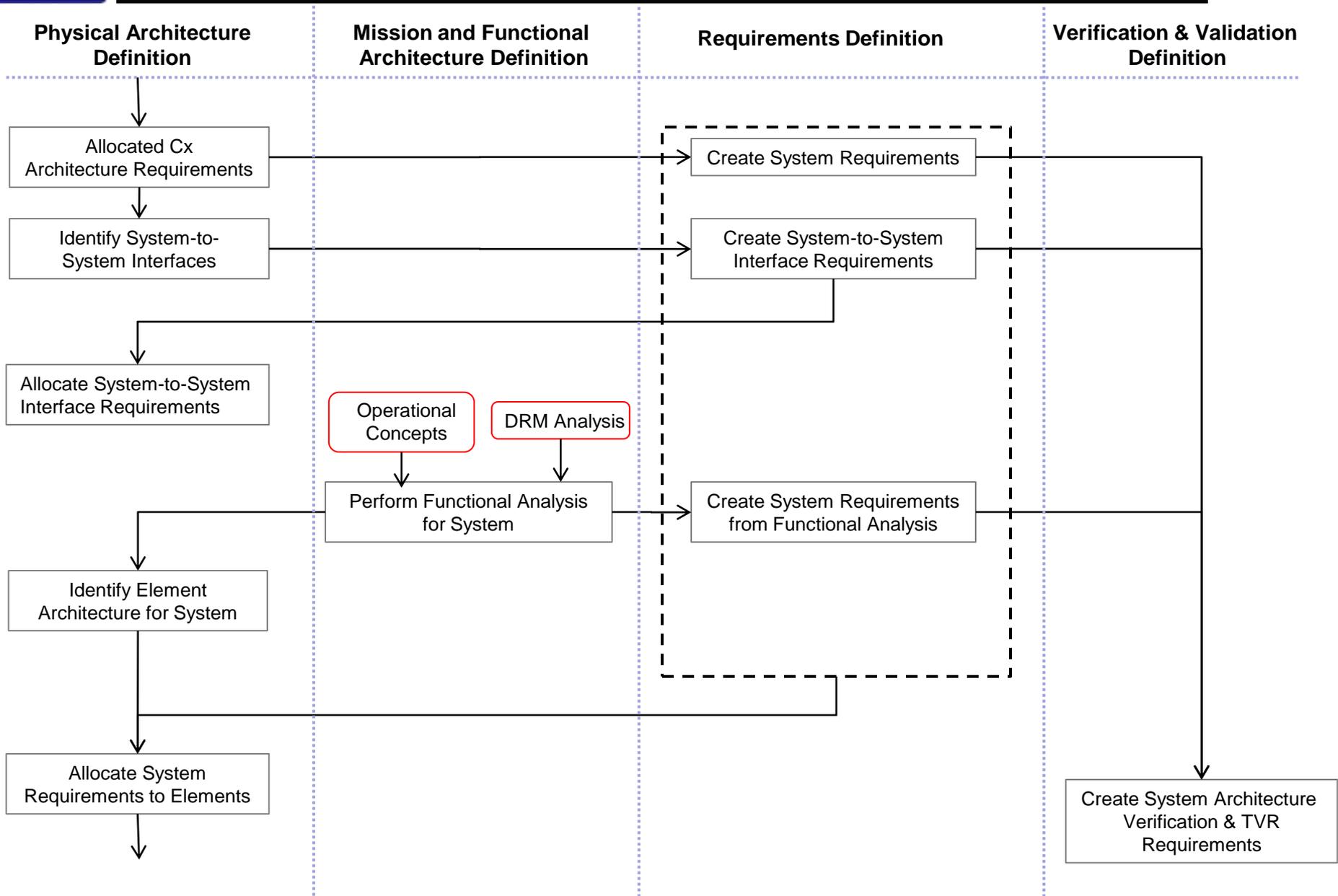


# Cx Architecture-Level SE Process Summary



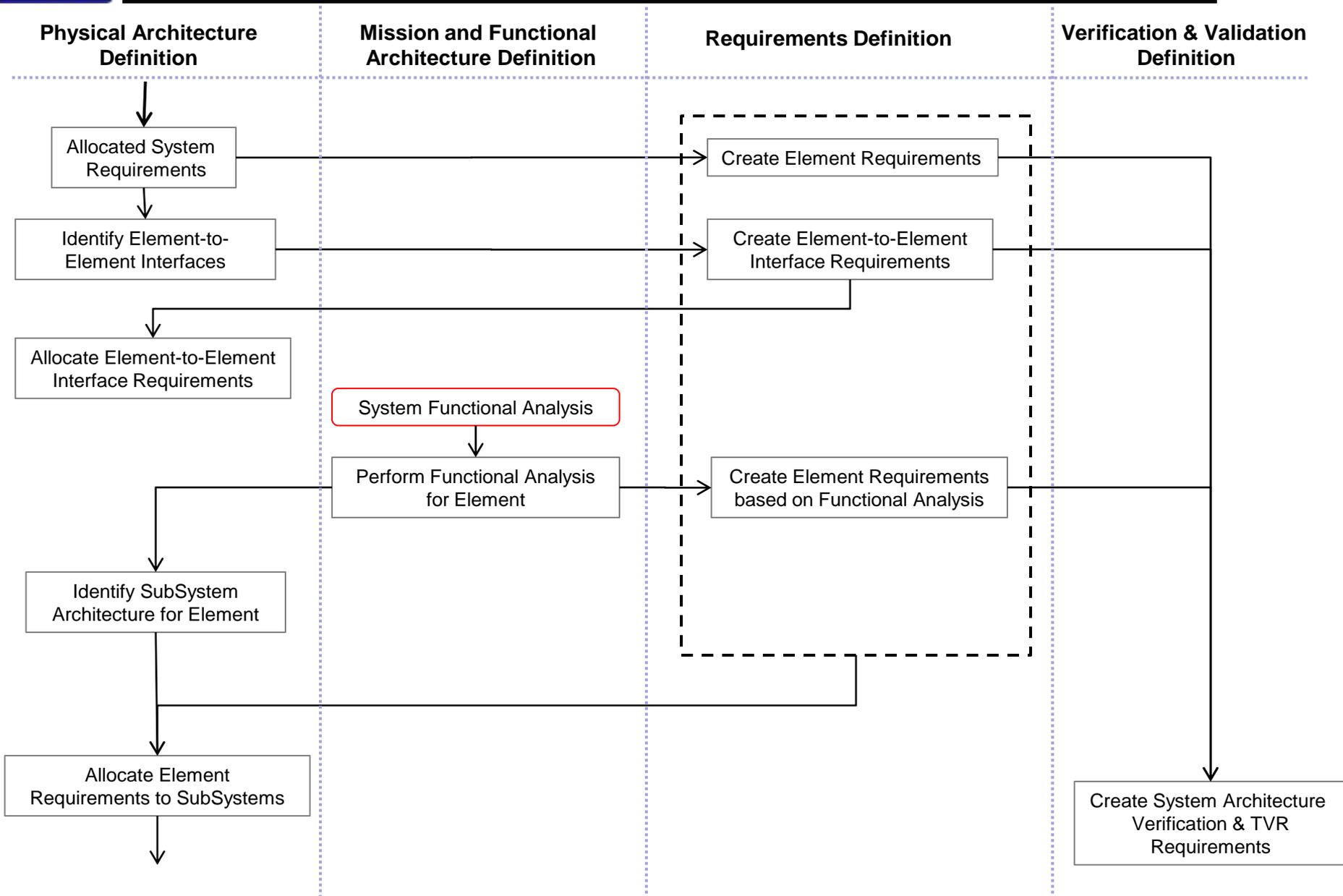


# System Architecture-Level SE Process Summary



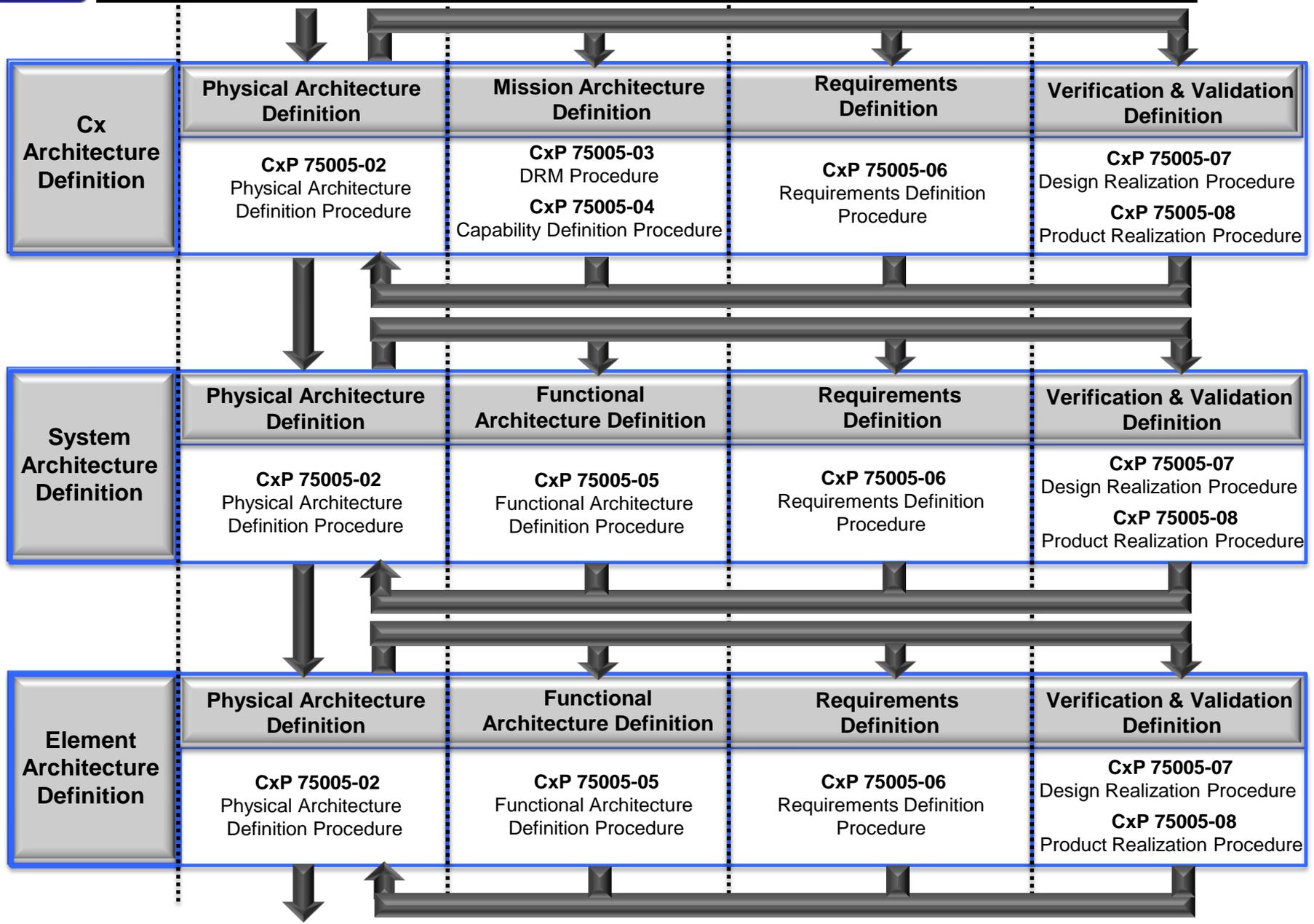


# Element Architecture-Level SE Process Summary





# Cx Systems Engineering Design Process Procedure Mapping





# Cx Process – Cradle Schema Correlation

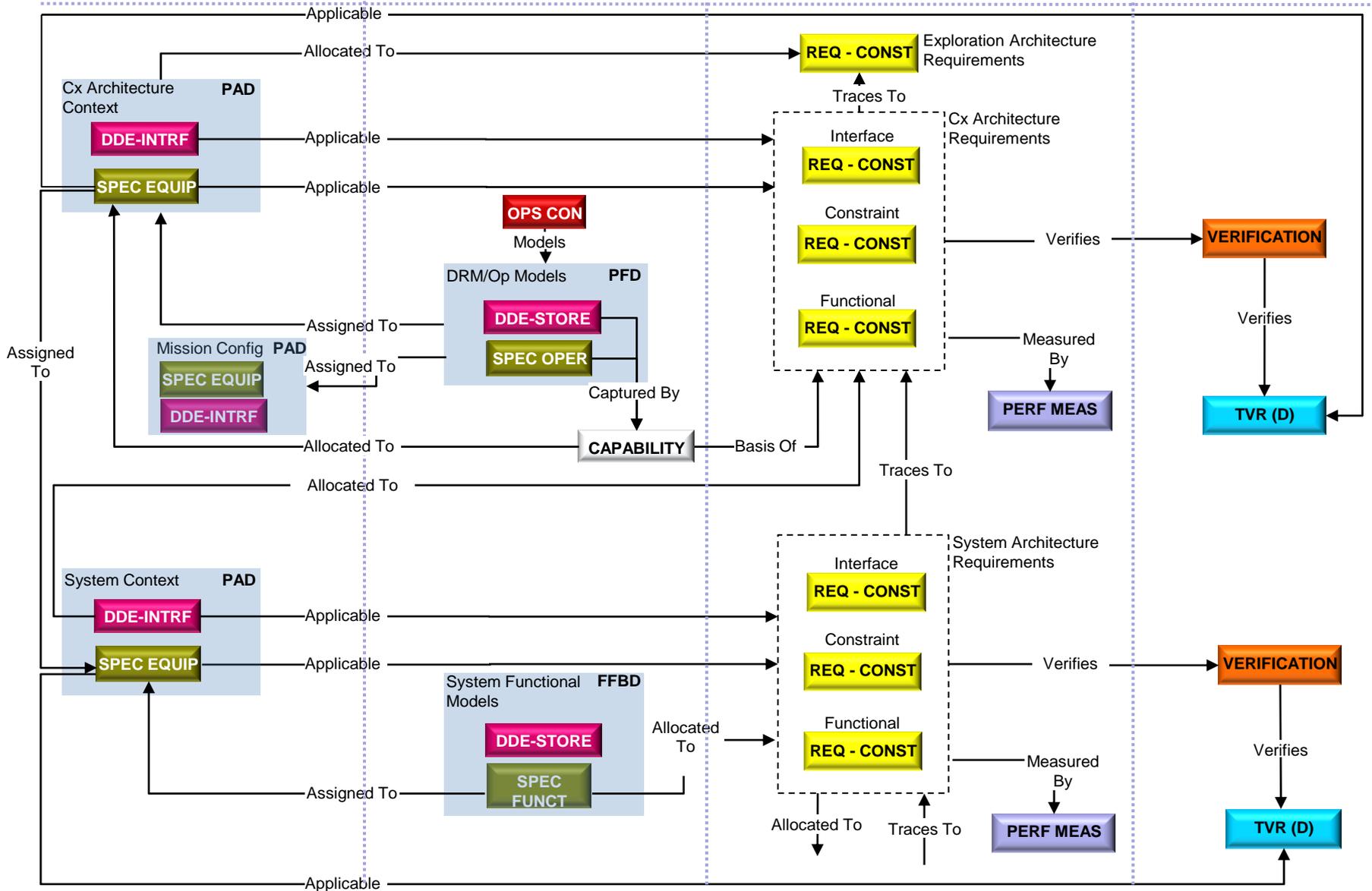


## Physical Architecture Definition

## Mission and Functional Architecture Definition

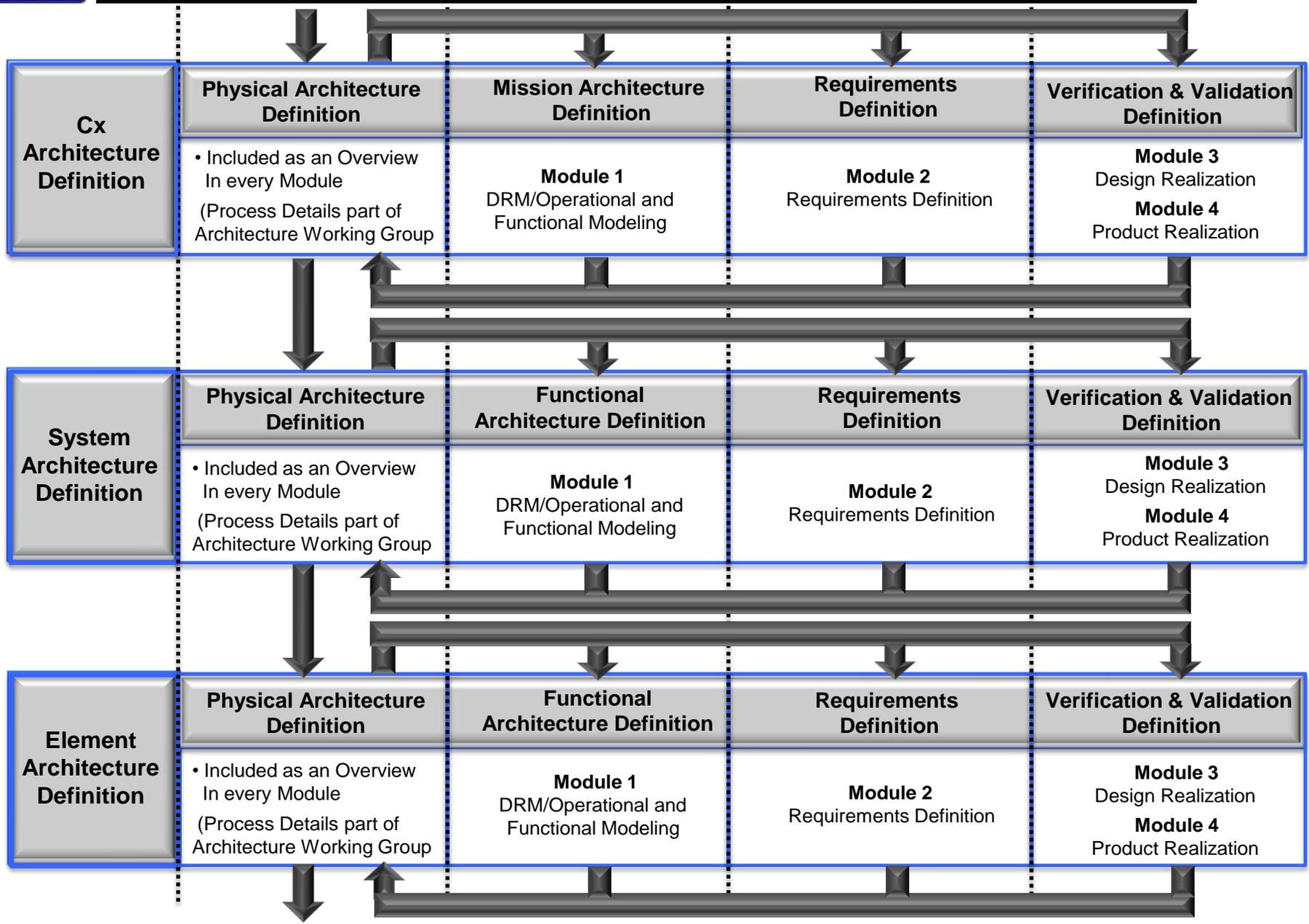
## Requirements Definition

## Verification & Validation Definition





# Cx Systems Engineering Process Training Module Mapping





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# Lessons Learned



# Lessons Learned (Partial Listing)

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- ◆ **Define Processes and Guidance prior to Tool Deployment as much as possible.**
- ◆ **Processes and Guidance development teams need active participation at all levels. Ownership and Buy-In is critical.**
- ◆ **Having documented process and detailed procedures is good, but guidance for consistent approaches to modeling was still.**
- ◆ **Common Data Model needs to be defined and managed early in the program, no one tool does it all.**
- ◆ **Stress Data (Model) Centric approach over Document-Centric.**
  - But accommodations can be made for Document-type views of model information.
  - Stress Consistent document/report production.
- ◆ **Accommodate all Stakeholders, ensure access to information.**
  - Web User Interface
- ◆ **Training became more effective once the Process/Procedures were available and incorporated into training material.**



# Adapting SE Capability to Support New Direction

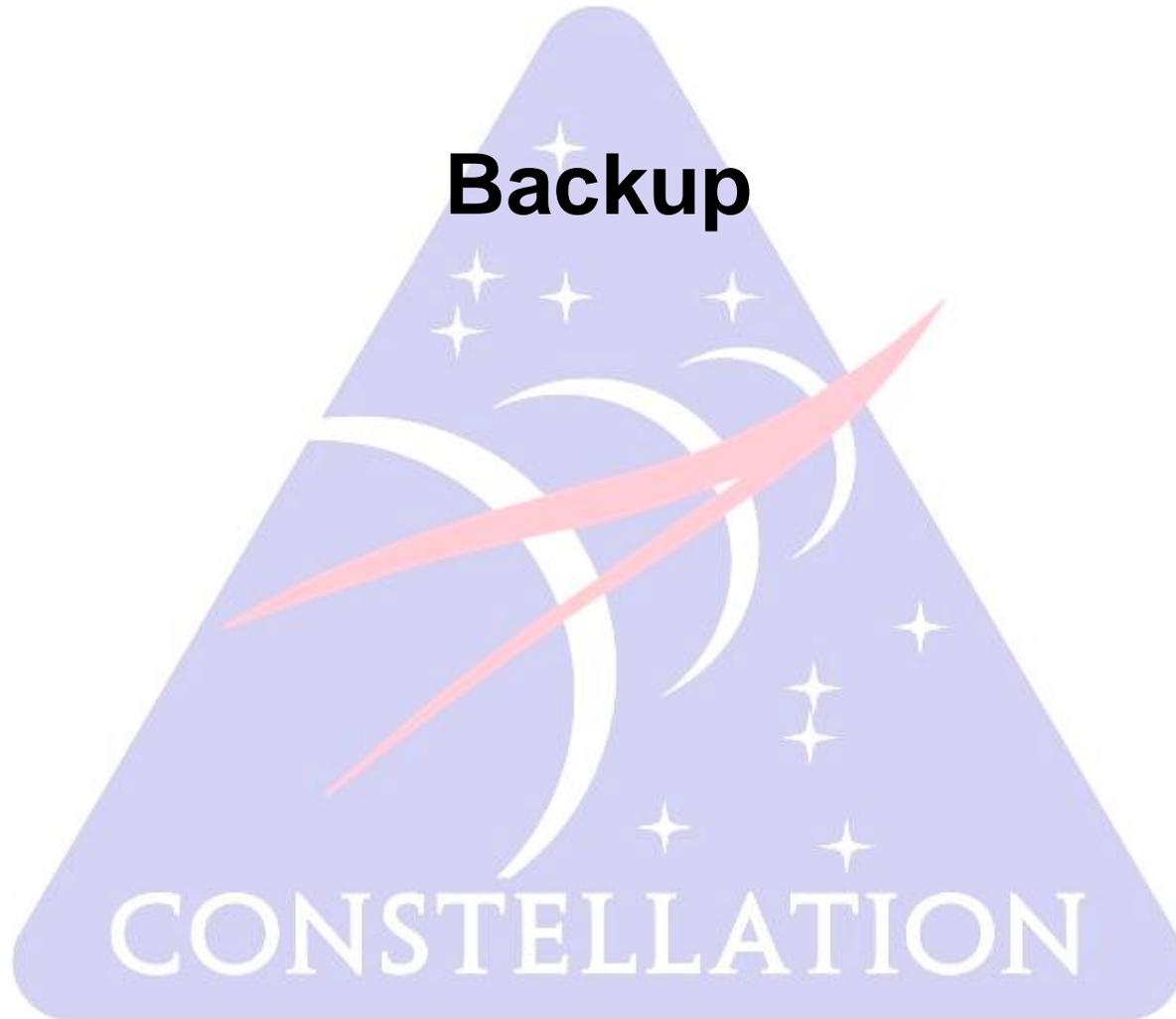
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- ◆ **Many Lesson Learned from CxP experience can be leveraged for new program(s)**
  - Timing of Tool Deployment
  - Schema Layout
  - Tool Integration, Standards
- ◆ **Existing Process and Procedures can be leveraged as starting point for next program(s). The needs the CxP MBSE Capability addresses are pretty standard for spaceflight programs:**
  - Mission Definition
  - Requirements Definition and Management
  - Physical Architecture Definition
  - Verification
- ◆ **Exploration IT Infrastructure represents a significant investment which can be leveraged to shorten program start-up.**



**Backup**





# Systems Engineering Processes – NASA SE Handbook

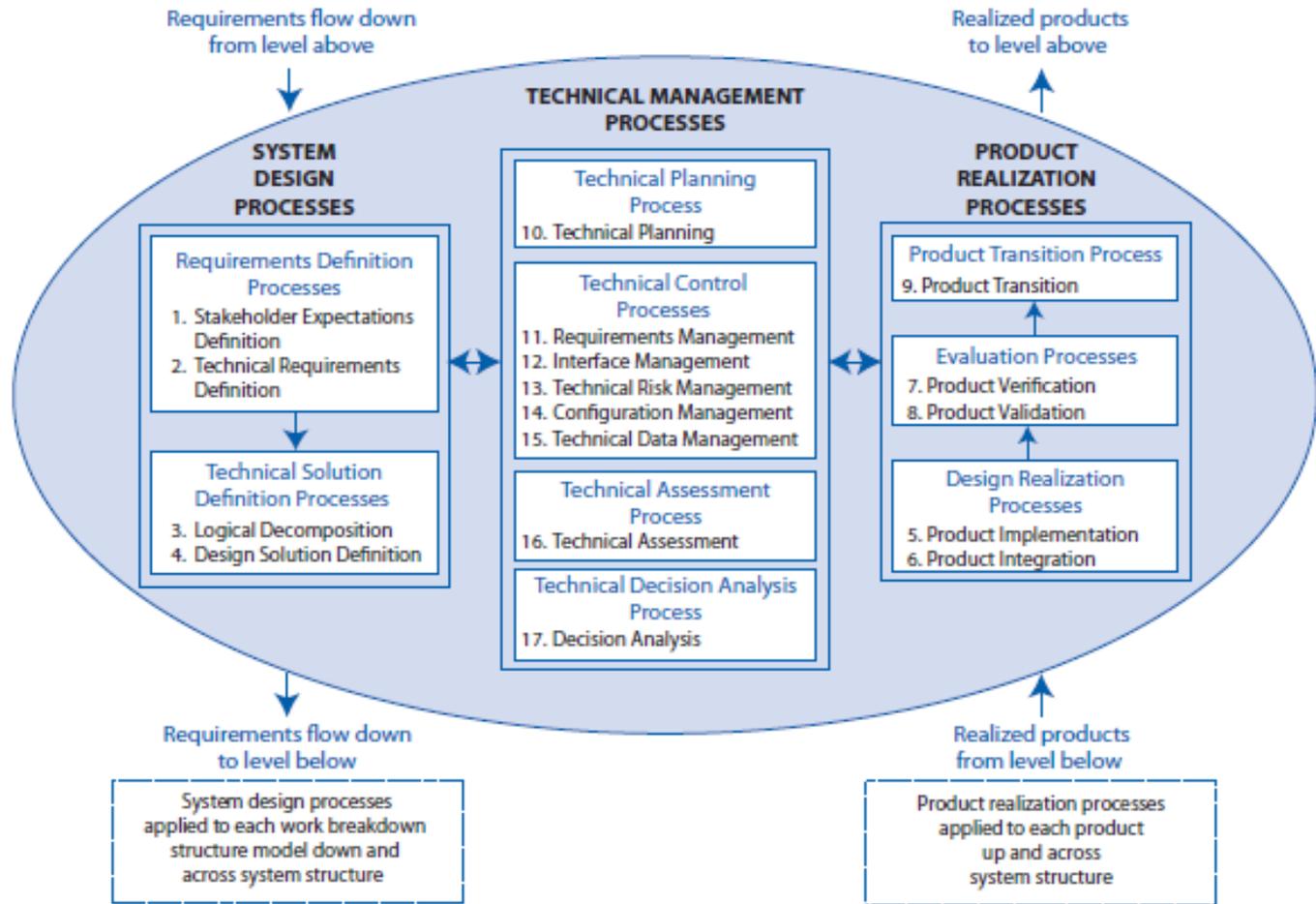
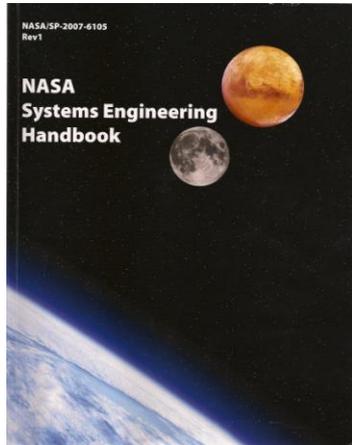


Figure 2.1-1 The systems engineering engine



# Why Model-Based Systems Engineering?



## ◆ Benefits of investing in MBSE

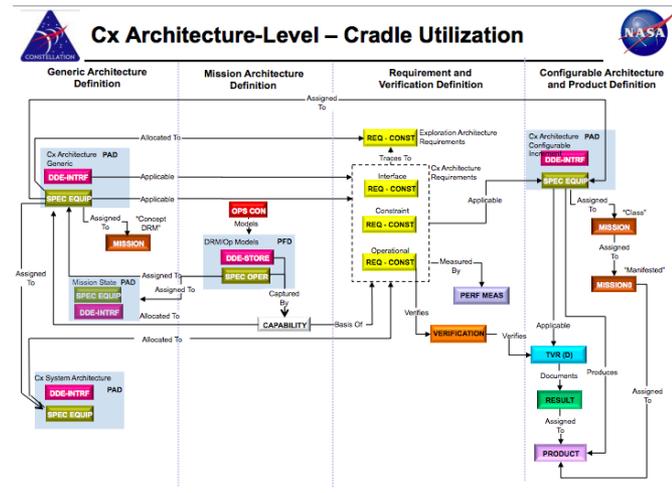
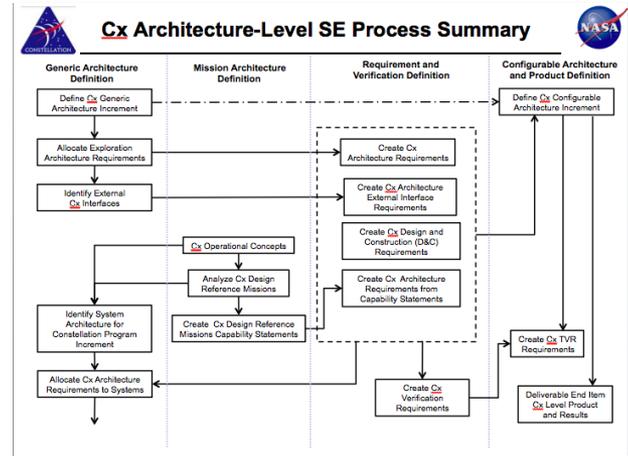
- **Reduces program schedule** by reducing amount of rework attributed to missed functional allocations and requirement deficiencies
  - Example – Altair SRD was developed using MBSE and missing CARD requirements identified
- **Minimizes program risk** by:
  - Improving integration/traceability/insight between Mission Definition, Requirements, Verification and Architecture
  - Improved Data Management, Accessibility and Quality
    - Maintain “freshest” data in model DB
    - Mutual benefit to both NASA and Contractors
    - Capabilities to query the data, do advanced checks, improve integration
- **Reduces program cost** by reducing cost of documentation and complimentary standing army
  - Data is captured once in an authoritative data source (repository/database) and is extracted to produce the content of a document
  - Content integrity between documents and artifacts



# CxP Systems Engineering Process & Procedures



- ◆ Process & Procedures documented and available via Team Wiki
- ◆ Process involves development in four key areas for each level of the architecture:
  - Requirements (and Associated Verifications)
  - Mission Definition
  - Physical Architecture
  - Functional Architecture





# Constellation SE Process Wiki



Cx SE Process 4 - Cx SE&I PRIMO ASET... +

**EXPLORATION SYSTEMS**  
**ICE Confluence Wiki**

Moon, Mars, and Beyond...

Dashboard > Cx SE&I PRIMO ASET > ... > Cx SE Process 1 > Cx SE Process 4

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## Cx SE Process 4

Edit Add Tools

Added by [Robert Crain](#), last edited by [Arthur Ingoldsby](#) on Oct 21, 2009 ([view change](#))

 [ASET Home](#) [Cx SE Tech Process](#) [Proc Input-Output Diagram](#) [Item Types](#) [Link Rules and Attributes](#) [Schema Report](#)  
[CSUW Home](#) [Cx SE Tech Mgmt Process](#) [Cx SE Procedures](#) [Relational Diagrams](#) [Document Tree](#) [Document Prefix Tags](#)  
[Training](#) [Cradle Reports Definition](#) [Change Process Flow](#) [Cx SE Process Overview](#) [Schema Change Requests](#) [Acronyms](#)

1.0	<a href="#">Introduction</a>
2.0	<a href="#">Documents</a>
3.0	<a href="#">SE Process Overview</a>
4.0	<a href="#">Process Steps</a>
App	<a href="#">Appendix</a>
	<a href="#">CxP_75005-01_Systems_Engineering_Process.doc</a>

## 4.0 Process Steps

This section includes the major steps used to execute the Constellation Systems Engineering process to develop model(s) used to define and manage the Architecture.

Note: Text in uppercase and enclosed in "<>" brackets (ex. <REQ-CONST>) identify the corresponding Cradle data item that captures the metadata associated with that step of the Cx SE process. Text in uppercase and in quotations "" (ex. "ALLOCATED TO") identify the Link Type used to establish the relationship between Cradle data items. All Data Definition Entry (DDE)s, SPECIFICATIONS, and DIAGRAMs referenced in this process are located in the Implementation Domain of Cradle.

### 4.1 CX Architecture Definition For Constellation

The following steps achieve the Cx Architecture Definition of the Constellation Program. .



# Detailed Procedures Available via Wiki



EXPLORATION SYSTEMS  
ICE Confluence Wiki

Dashboard > Cx SE&I PRIMO ASET > ... > Constellation Schema Utilization Wiki > CSUW Procedures

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## CSUW Procedures

Edit Add ▾ Tools ▾

Added by Aaron Powell(Disabled) , last edited by Arthur Ingoldsby on Apr 20, 2010 (view change)



- |                           |   |   |  |   |                                      |
|---------------------------|---|---|--|---|--------------------------------------|
| <a href="#">ASET Home</a> | <a href="#">Cx SE Tech Process</a>        | <a href="#">Proc Input-Output Diagram</a> | <a href="#">Item Types</a>             | <a href="#">Link Rules and Attributes</a> | <a href="#">Schema Report</a>        |
| <a href="#">CSUW Home</a> | <a href="#">Cx SE Tech Mgmt Process</a>   | <a href="#">Cx SE Procedures</a>          | <a href="#">Relational Diagrams</a>    | <a href="#">Document Tree</a>             | <a href="#">Document Prefix Tags</a> |
| <a href="#">Training</a>  | <a href="#">Cradle Reports Definition</a> | <a href="#">Change Process Flow</a>       | <a href="#">Cx SE Process Overview</a> | <a href="#">Schema Change Requests</a>    | <a href="#">Acronyms</a>             |

### Technical Procedures

- [CxP 75005-01 - Constellation Program Systems Engineering Process](#)
- [CxP 75005-02 - Constellation Program Cradle Physical Architecture Definition Procedure](#)
- [CxP 75005-03 - Constellation Program Cradle Design Reference Mission Procedure](#)
- [CxP 75005-04 - Constellation Program Cradle Capability Definition Procedure](#)
- [CxP 75005-05 - Constellation Program Cradle Functional Architecture Definition Procedure](#)
- [CxP 75005-06 - Constellation Program Cradle Requirements Definition Procedure](#)
- [CxP 75005-07 - Constellation Program Cradle Design and Product Realization Procedure](#)
- [CxP 75005-09 - Constellation Program Cradle Verification & Validation Mission Realization Procedure](#)
- [CxP 75005-10 - Constellation Program Cradle Manifested Mission Configuration Definition Procedure](#)

### Technical Management Support Procedures

- [CxP 75006-09 Cradle ISSUE Procedure](#)
- [CxP 75006-10 Cradle Role Assignment TEPOC Procedure](#)
- [CxP 75006-11 Cradle Requirement Design Compliance Procedure](#)
- [CxP 75006-12 Cradle DOCUMENT Procedure](#)
- [CxP 75006-13 Cradle Programmatic Baseline Procedure](#)