Electrical Power and Propulsion System Preliminary and Contract Design Process

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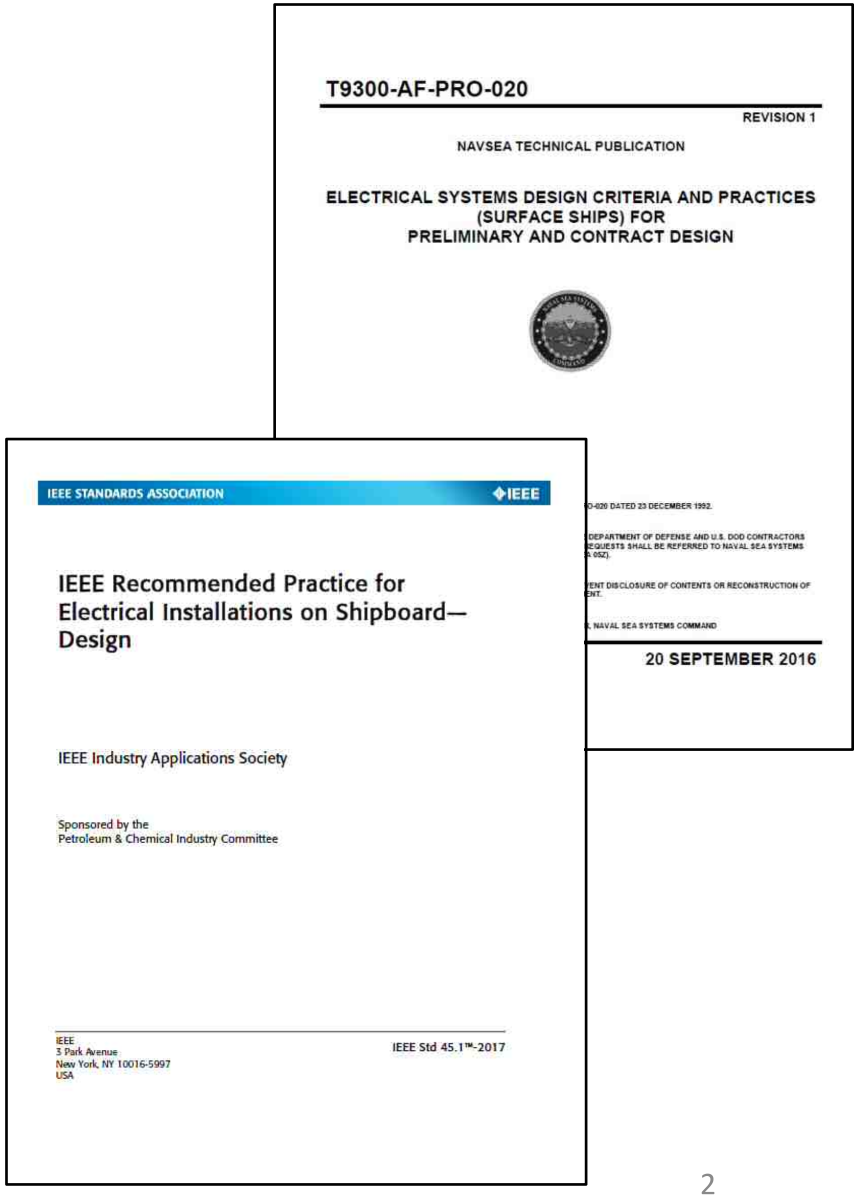
Problem Statement

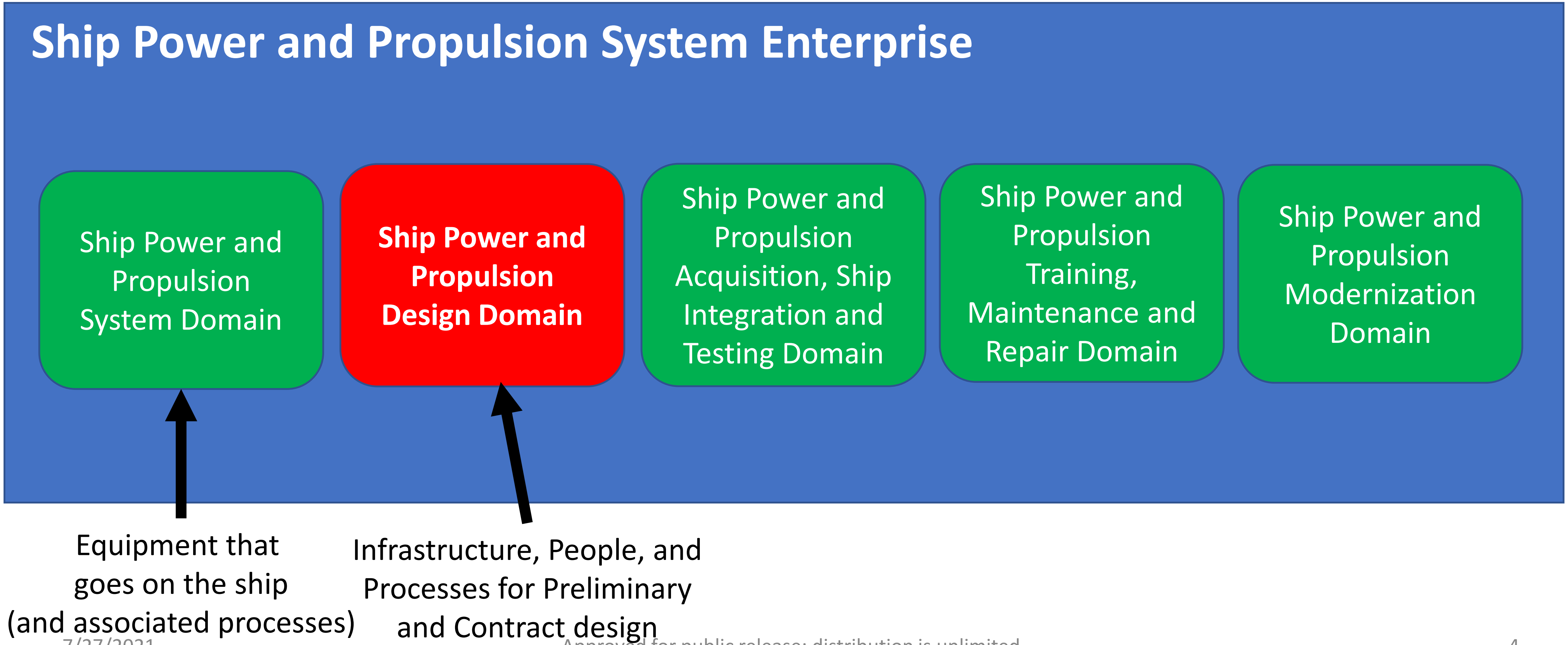
- Design requirements exist for the electrical and propulsion systems on a ship.
  - IEEE 45 series
  - T9300-AF-PRO-020
- Little to no guidance exists for how to organize or conduct Preliminary and Contract Design.
  - What activities should be included?
  - What order?
  - How should iteration be addressed?
  - How much should be budgeted?
  - How should a resource loaded schedule be developed?
  - What should statements of work look like?
- Effort began in 2020 to model the design process.
  - Build off previous efforts from ~10-15 years ago.



Why model?

- To determine the required budget and duration of the preliminary and contract design of the power and propulsion system of a surface combatant. (execute models directly)
- To assist in developing Tasking Documents (standard statements of work) for Design Activities.
- To assist in the management of the design process as it executes.
- To promote continuous process improvement in the design process. (perform trade-offs in how to conduct the design process)

The Ship Power and Propulsion Design Domain is part of a Ship Power and Propulsion Enterprise (System of Systems)



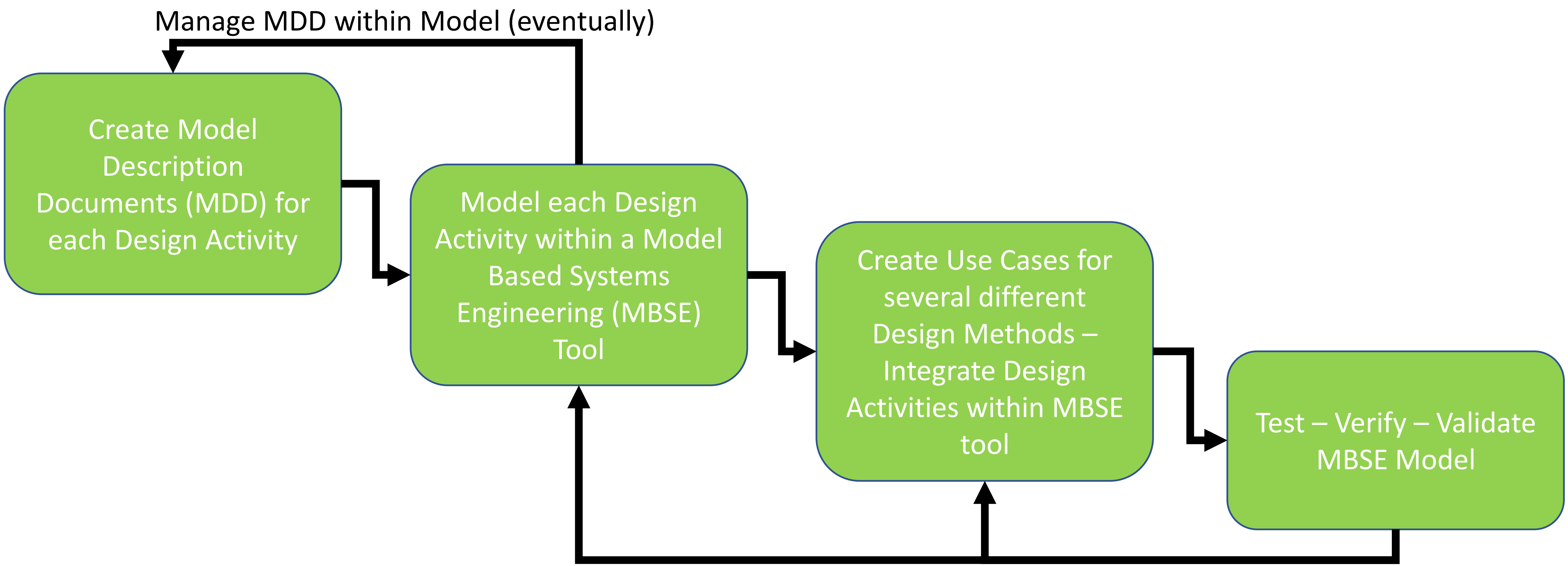
Products of Ship Power and Propulsion Design Domain

- Shipbuilding Specification Sections
- Cost Estimates
  - Detail Design and Construction
  - Operating and Support
- Analyses and tests demonstrating that a system adhering to the shipbuilding specification will meet requirements allocated from ship requirements
- Data necessary for integrating the power and propulsion system into the overall ship
- Data necessary for product support over the ship's lifecycle

Products of the Design Process Model

- Estimate of duration and cost of conducting Preliminary and Contract Design (Ship Power and Propulsion Design)
  - Design activity interdependence
  - Rate of convergence of iterative design process
- Resource loaded schedule
- Standard Statements of work
- Improved understanding of design
  - Enable modeling different design processes implementing different design methods to understand schedule and cost trade-offs.
  - Model Description Documents provide understanding of inter-relationships between design activities.
  - Enable continuous process improvement.

Modeling Method



Modeling Assumptions

- Overall Ship Design Process will employ a Product Data Environment (PDE)
  - All Design Activities get inputs from PDE and store results into PDE
- Based on a 1 week design increment
  - Base current weeks work on data in PDE at start of week.
  - Update current weeks work no later than end of week.
- Does not model all SWBS 200 and 300 groups (for now)
- Treat "Rest of System" as a black box
  - Model interaction via "Requirement Variables"

SWBS = Ship Work Breakdown Structure

- Does not model (need to budget for these items separately)
  - Financial Management
  - Risk Management (Other than identify risks)
  - Program Management
  - Contracting
  - Technical, Programmatic, and Financial Reviews
  - Establishment of Test Facilities and procurement of Test articles and test equipment
  - Procurement of hardware or software for conducting simulations or other analysis

Design Activities

Design Activities are Building Blocks for Constructing a Design Process

- 100 Develop Power System Architectures
- 200 Electric Power Load Analysis (EPLA)
- 300 Load List
- 400 Primary Power System Design
- 500 Zonal Power System Design
- 600 Propulsion System Design
- 700 Casualty Power System Design
- 800 ES Concept of Operations
- 900 Electric Plant and Propulsion Controls
- 1000 Endurance and Annual Fuel
- 1100 Dynamic Simulation
- 1200 Reliability Analysis
- 1300 Quality of Service Analysis
- 1400 Vulnerability and Recoverability Analysis
- 1500 Arc Flash Analysis
- 1600 System Safety Analysis and Hazard Analysis
- 1700 Cybersecurity Analysis
- 1800 Product Support Analysis
- 1900 Human Engineering Analysis
- 2000 Develop Specifications
- 2100 Develop strategy for power system flexibility
- 2200 Assess Power System flexibility
- 2300 Electrical System and Propulsion System Development Testing
- 2400 Develop mission System - Power System Interface
- 2500 Cost Engineering Analysis
- 2600 Develop Configurations
- 2700 Set Reduction

Specification Sections

Specification Sections	PRODUCT
Section 200: General Requirements for Machinery Plant	2000-200
Section 202: Electric and Propulsion Control System	2000-202
Section 235: Electric Propulsion System	2000-235
Section 300: General Requirements for Electric Plant	2000-300
Section 302: Electric Motors and Associated Electric Equipment	2000-302
Section 303: Protective Devices for Electric Circuits	2000-303
Section 304: Electric Cable	2000-304
Section 305: Electrical and Electronic Designating and Marking	2000-305
Section 310: Power Generation	2000-310
Section 313: Energy Storage	2000-313
Section 314: Electric Power Supply Conversion Equipment	2000-314
Section 320: General Requirements for Electric Power Distribution Systems	2000-320
Section 322: Medium Voltage Switchboards	2000-322
Section 324: Low Voltage load centers and panels for power and lighting	2000-324
Section 331: Lighting Systems – Distribution and Control	2000-331
Section 332: Illumination Requirements	2000-332

Requirements

Power System Requirements	R010
Ship Operating Conditions	R020
Margin and Service Life Allowance Policy	R030
Ambient condition Profile	R040
Machinery Arrangements	R050
General Arrangements	R060
Master Equipment List	R070
Combat Systems Design	R080
Other Distributed System Design	R090
Speed Power Curve	R100
Survivability Requirements	R110
QOS Requirements	R120
Endurance Requirements	R130
Operational Profiles	R140
System Safety Plan	R150
Security Controls (from Risk Management Framework)	R160
Product Support Analysis Plan	R170
Flexibility Requirements	R180
Build Plan	R190
Zone Boundaries	R200
SDM Guidance	R210

Requirements connect this part of the overall design process to the rest of the design process

Design Activities and their products

Activity	Product	Product ID
Develop and Manage Power System Conceptual Architectures	Architecture Descriptions and List of Power and Propulsion System Conceptual Architectures	100
Perform Electric Power Load Analysis	EPLA – Power	200
	EPLA – Energy	210
	EPLA – In-Rush	220
	EPLA – Pulse	230
Develop and Maintain Load List	Electric Load List	300
Develop and Maintain Primary Power System Element Design	Primary Power System Element Design and Operating Methods	400
Develop and Maintain Zonal System Element Design	Zonal Power System Element Design and Operating Methods	500
Develop and Maintain Propulsion System Design	Propulsion System Design	600
Develop and Maintain Casualty Power System Design	Casualty Power System Design	700
Develop and Maintain Electrical Power System Concept of Operation and Propulsion System Concept of Operation	Electrical Power System Concept of Operation	800
	Propulsion Plant Concept of Operation	810
Develop and Maintain Electric Plant and Propulsion Control System Design	Electrical and Propulsion Control System Design	900
Perform Endurance Fuel and Annual Energy Usage Calculations	Endurance and Annual Fuel Calculations	1000
Perform Dynamic Simulation	Transient Analysis	1100
	Stability Analysis	1110
	Dynamic Response Analysis	1120
	Common Mode Current Analysis	1130
	Fault Current Analysis and Protective Device Coordination Study	1140
	Harmonic and Non-Fundamental Frequency Analysis	1150
	Thermal Analysis	1160

Perform Reliability Analysis	Reliability Analysis Report	1200
Perform Quality of Service Analysis	QOS Analysis Report	1300
Perform Vulnerability and Recoverability Analysis	Zonal Survivability Analysis Report	1400
	Compartment Survivability Analysis Report	1410
Perform Arc Flash Analysis	Arc Flash Analysis Report	1500
Perform System Safety Analysis and Hazard Analysis	System Safety and Hazard Analysis Report	1600
Perform Cybersecurity Analysis	Security Assessment Plan and Assessment	1700
Perform Product Support Analysis	Product support Analysis Report and Logistics Product Data	1800
Perform Human Engineering Analysis	Human Engineering Analysis Report	1900
Develop Specification Sections	Specification Sections (see Appendix C)	2000
Develop Power System Flexibility Strategy	Power System Flexibility Strategy	2100
Assess Power System Flexibility	Power System Flexibility Assessment	2200
Perform Electrical System and Propulsion System Development Test & Evaluation	DT&E Test Plan, Procedures, and Reports	2300
Develop Mission System - Power System Control Interface	PPD: Mission System - Power System Control Interface	2400
Perform Cost Engineering Analysis	Cost Engineering Analysis Report	2500
Develop Configurations	Configuration Descriptions	2600
Perform Set Reduction	Design Space Classification Report	2700

Some Design Activities can Produce Multiple Outputs

Building a Design Process using the Set of Design Activities

Use cases (Design Integration)

- A specific use case is anticipated for each specific design effort.
  - Design Method: (Set-Based Design – Point-Based Design – Modified Repeat, etc)
  - Initial Design Space for consideration
  - Ship level requirements
- Provides the order of and linkages between Design Activities
- Based on achieving design convergence by managing Quality
  - Quality is the degree that variables are not likely to change in the future
  - Measured as real number between 0 (highly likely to change) and 5.0 (not likely to change)
- Defines the Design Management functions
- “Templates” for different categories of use cases to enable rapid development of design cost and schedule estimates
  - Must be easily customizable

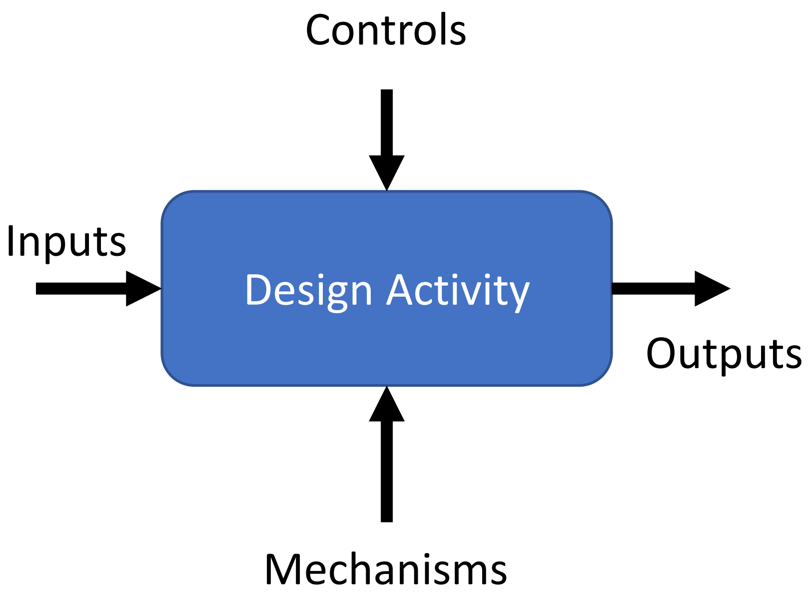
Design Activity Model

- Calculate the amount of workload (employee-weeks) needed to produce product
  - Based on the capability of a single senior engineer and a size factor
  - Adjusted for several different Adjustment Factors
  - Separate values calculated for different levels of precision
  - Setup vs Recurring Work
- Calculate the effective amount of work applied to the activity in a given week
  - Labor Categories Assigned (junior and senior)
  - Number of employees assigned
- Calculate the fraction of workload that is accomplished during the week and update the total fraction of workload that has been accomplished to date
- Update the quality of the outputs based on the quality of the inputs and the workload accomplished

Design Activity Model analyzes Work, Workload, and Quality

Model Description Document (MDD)

- Introduction / Purpose
- Inputs
- Outputs
- Controls
  - Triggers
  - Size Factors
  - Workforce Composition options
  - Modeling Precision options
- Mechanisms
  - Algorithms and coefficients for estimating workload
  - References
  - Tools
- Quality
  - Algorithms for calculating quality
    - Number between 0 and 5
    - Function of input quality, precision, and work accomplished
- Application notes



An MDD is created for each Activity Model

Estimating activity workload (employee-hours)

Inspired by the COSYSMO Estimation Equation

$$W_{setup\_x}(output) = A_{setup\_x}(output) \prod_{k=0}^{K-1} F_{setup\_k}$$

Setup workload must be completed
Before starting recurring workload

$$W_{recurring\_x}(output) = A_{1\_x}(output)\, f_{size}(N_0, N_1, N_2, \dots, N_n) \prod_{k=0}^{K-1} F_k$$

Where

W_{setup_x} = setup workload for activity precision x

$W_{recurring\_x}$ = recurring workload for activity precision x

output = output variable

x = level of precision *1: imprecise* → *2: moderately precise* → *3: highly precise*

A_{setup_x} = Nominal workload to setup the activity

K = number of adjustment factors

F_{setup} = adjustment factors for setup

A_{1_x} = Nominal workload to complete first item (recurring) for precision x

$N_0, N_1, N_2, \dots, N_n$ = Size Measures

$f_{size}(\cdot)$ = Size Adjustment Function based on size metrics (e.g. learning curve)

F_k = adjustment factors for recurring

Defines the minimum amount of employee-hours needed to accomplish activity with all inputs of high quality

Adjustment Factors

- Enable adjusting workload for other than normal conditions
  - Up to five levels defined (0 to 4)
  - Level 2 considered "normal" with an adjustment factor of 1.0
  - For a given process model, user defines which level to use.
- Each activity model can have a different set of adjustment factors.
- Typical adjustment factors
  - System Novelty
  - Personnel Experience
  - Tool Support
  - Process Capability (based on CMMI?)

Labor Categories

- Amount of work that can be accomplished in a week for a given task depends on the number and mix of individuals of possibly multiple labor categories.
- Cost for different labor categories also varies.
- Used for resource loading the schedule

id	code	weekly rate	Description
0	eng_gen	$8,000.00	General Engineer
1	arch_sr	$8,000.00	Senior Power System Architect
2	arch_jr	$6,000.00	Junior Power System Architect
3	epla_sr	$8,000.00	Senior EPLA Engineer
4	epla_jr	$6,000.00	Junior EPLA Engineer
5	powr_sr	$8,000.00	Senior Power System Engineer
6	powr_jr	$6,000.00	Junior Power System Engineer
7	psim_sr	$8,000.00	Senior Power System Simulation Engineer
8	psim_jr	$6,000.00	Junior Power System Simulation Engineer
9	pwr_sim	$8,000.00	Power and Propulsion System Integration Manager
10	prop_sr	$8,000.00	Senior Propulsion System Engineer
11	prop_jr	$6,000.00	Junior Propulsion System Engineer
12	surv_sr	$8,000.00	Senior Survivability Engineer
13	surv_jr	$6,000.00	Junior Survivability Engineer
14	cost_sr	$8,000.00	Senior Cost Engineer
15	cost_jr	$6,000.00	Junior Cost Engineer
16	test_sr	$8,000.00	Senior Test Engineer
17	test_jr	$6,000.00	Junior Test Engineer
18	rma_sr	$8,000.00	Senior Reliability Engineer
19	rma_jr	$6,000.00	Junior Reliability Engineer
20	safe_sr	$8,000.00	Senior Safety Engineer
21	safe_jr	$6,000.00	Junior Safety Engineer
22	log_sr	$8,000.00	Senior Logistician
23	log_jr	$6,000.00	Junior Logistician
24	ctrl_sr	$8,000.00	Senior Control Engineer
25	ctrl_jr	$6,000.00	Junior Control Engineer

Work accomplished by a team

- Junior Engineers are assumed less effective than Senior Engineers.

  (Effective work force: Nbr of effective engineers)

- The effective work accomplished by each effective engineer is approximated by:

( )

For $n_{FTE} > 1$

$$f_{FTE}(n_{FTE}) = \frac{B_0}{n_{FTE}} + B_1 + B_2 n_{FTE} + B_3 n_{FTE}^2$$

$B_0 = 0.3631$
$B_1 = 0.6369$
$B_2 = 0.0$
$B_3 = 0.0$

For $n_{FTE} \leq 1$

$$f_{FTE}(n_{FTE}) = 1.0$$

( )

Mao A, Mason W, Suri S, Watts DJ (2016) "An Experimental Study of Team Size and Performance on a Complex Task. PLoS ONE 11(4): e0153048. doi:10.1371/journal.pone.0153048

Design Structure Matrix (DSM)

Design data	Block Number	Subblock Number	Predecessor Block Number	100	300	400	500	2100	200	210	220	600	700	800	810	900	1000	1100	1110	1120	1130	1140	1150	1160	1200	1300	1400	1410	1500	1600	1700	1800	1900	230	2200	2300	2400	2500	2600	2700
100	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
300	2	1	1	S	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	W	0
400	2	2	1	S	0	2	0	W	W	0	0	0	W	W	W	0	W	W	W	W	W	W	W	W	W	W	W	0	W	W	W	W	W	0	W	W	0	W	W	0
500	2	3	1	S	W	0	3	W	W	0	0	0	W	W	0	0	0	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	0	W	W	0	W	W	0
2100	2	4	1	S	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
200	3	0	2	S	S	0	0	0	5	0	0	0	0	W	W	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	S	0
210	3	0	2	S	S	0	0	0	0	6	0	0	0	W	W	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	S	0
220	3	0	2	S	S	0	0	0	0	0	7	0	0	W	W	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	S	0
600	3	0	2	S	0	W	0	0	0	0	0	8	0	0	S	0	W	0	0	S	S	0	S	S	W	W	0	0	0	W	W	W	W	0	0	W	0	W	0	0
700	3	0	2	0	S	S	S	0	S	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	W	W	0	0	0	0	0	0	0	0	0	0	0	0
800	3	0	2	S	0	S	S	0	0	0	0	S	0	10	0	S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	S	0
810	3	0	2	S	0	S	0	0	0	0	0	S	0	0	11	S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	S	0
900	3	0	2	S	S	S	S	S	0	0	0	S	W	S	S	12	0	S	0	S	S	S	S	S	S	S	W	W	0	0	S	0	W	0	W	W	S	W	S	0
1000	3	0	2	0	0	S	W	0	S	0	0	S	0	S	S	0	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	S	0
1100	3	0	2	0	S	S	S	0	0	0	0	S	0	S	S	S	0	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	W	0	0	S	0
1110	3	0	2	0	S	S	S	0	0	0	0	S	0	S	S	S	0	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	W	0	0	S	0
1120	3	0	2	0	S	S	S	0	0	0	0	S	0	S	S	S	0	0	0	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	W	0	0	S	0
1130	3	0	2	0	S	S	S	0	0	0	0	S	0	S	S	S	0	0	0	0	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	W	0	0	S	0
1140	3	0	2	0	S	S	S	0	0	0	0	S	0	S	S	S	0	0	0	0	0	18	0	0	0	0	0	0	0	0	0	0	0	0	0	W	0	0	S	0
1150	3	0	2	0	S	S	S	0	0	0	0	S	0	S	S	S	0	0	0	0	0	0	19	0	0	0	0	0	0	0	0	0	0	0	0	W	0	0	S	0
1160	3	0	2	0	S	S	S	0	0	0	0	S	0	S	S	S	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	W	0	0	S	0
1200	3	0	2	0	0	S	S	0	0	0	0	S	W	S	S	S	0	0	0	0	0	0	0	0	21	0	0	0	0	0	0	0	0	0	0	0	0	0	S	0
1300	3	0	2	0	S	S	W	0	S	S	S	0	0	S	0	0	0	W	W	0	0	0	W	0	S	22	0	0	0	0	0	0	0	S	0	0	0	0	S	0
1400	3	0	2	0	S	S	S	0	S	0	0	S	S	S	S	W	0	0	0	0	0	0	0	0	0	0	23	0	0	0	0	0	0	0	0	0	0	0	S	0
1410	3	0	2	0	S	S	S	0	S	0	0	S	S	S	S	W	0	0	0	0	0	0	0	0	0	0	0	24	0	0	0	0	0	0	0	0	0	0	S	0
1500	3	0	2	0	0	S	S	0	0	0	0	S	0	S	S	0	0	0	0	0	0	0	0	0	0	0	0	0	25	0	0	0	0	0	0	0	0	0	S	0
1600	3	0	2	0	0	S	S	0	0	0	0	S	W	S	S	S	0	0	0	0	0	0	0	0	0	0	0	0	0	26	0	0	0	0	0	0	0	0	S	0
1700	3	0	2	0	0	S	S	0	0	0	0	S	W	S	S	S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27	0	0	0	0	0	0	0	S	0
1800	3	0	2	0	0	S	S	0	0	0	0	S	W	S	S	S	0	0	0	0	0	0	0	0	S	0	0	0	0	0	0	28	S	0	0	0	0	0	S	0
1900	3	0	2	0	0	S	S	0	0	0	0	S	W	S	S	S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29	0	0	0	0	0	S	0
230	3	0	2	S	S	0	0	0	0	0	0	0	0	W	W	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	0	0	0	0	S	0
2200	3	0	2	S	0	S	S	S	S	0	0	S	0	0	0	S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	31	0	0	0	S	0
2300	3	0	2	0	0	S	S	0	0	0	0	S	W	0	0	W	0	W	W	W	W	W	W	W	0	0	0	0	0	0	0	0	0	0	0	32	0	0	S	0
2400	3	0	2	W	W	W	W	0	0	0	0	0	0	S	0	S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33	0	0	0
2500	3	0	2	0	0	S	S	0	0	0	0	S	W	0	0	S	0	0	0	0	0	0	0	0	S	0	0	0	0	0	0	S	0	0	0	0	0	34	S	0
2600	3	0	2	S	W	S	S	0	S	0	0	S	W	0	0	W	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	35	S
2700	3	0	2	0	0	0	0	0	S	S	S	0	0	0	0	0	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	0	S	S	36

Iteration is required and challenging with traditional scheduling tools

Quality

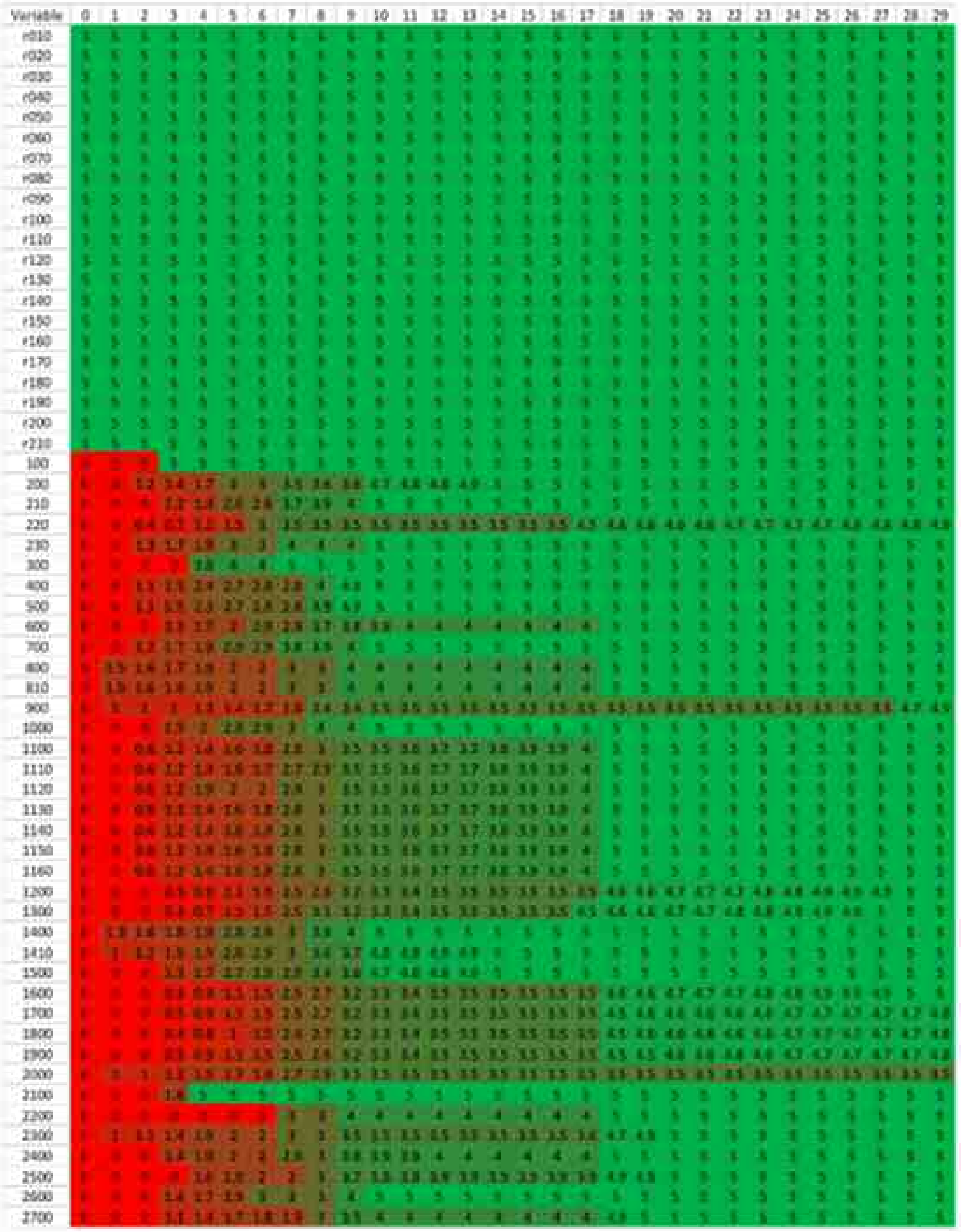
- Rework may be required if inputs do not have sufficient quality.
  - Garbage in – Garbage out
  - Amount of work that must be applied will be greater than the calculated workload.
- DSM tells us if we can wait for inputs to have sufficient quality before starting.
- Usually have to proceed with imperfect quality inputs because other design activities need products as inputs.
  - Iteration
- Quality is used to estimate how close design variables (design activity products and requirements) are to their converged value.
  - Real number between 0 (low) and 5 (high).
  - Enables estimating when the design will converge (without actually conducting the design)

Are We Done Yet?

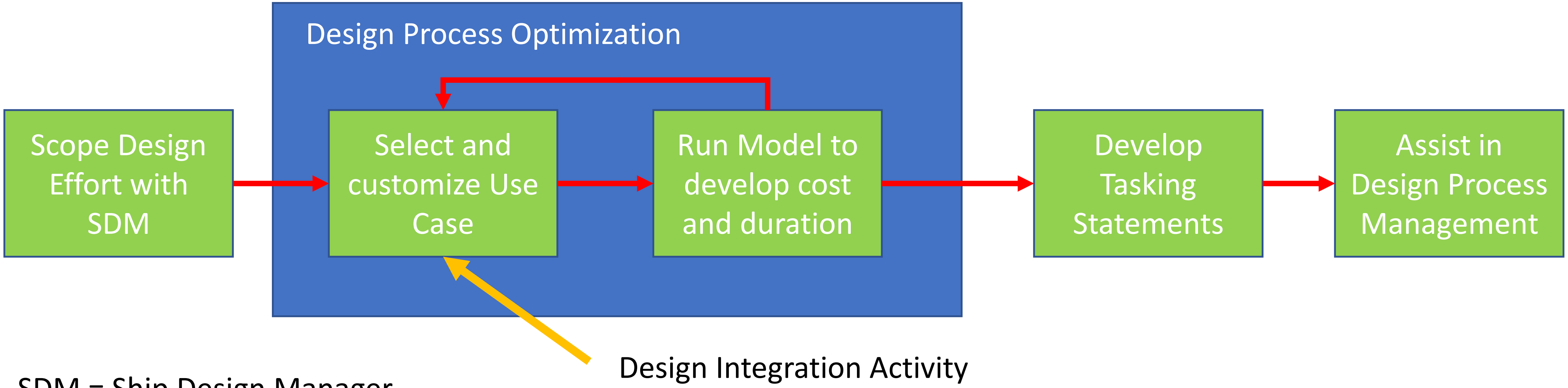
Quality Calculation

- If no recurring work accomplished, quality of product is 0.
- If recurring work accomplished at imprecise level:
  - quality ranges from 0 to 1.5
- If recurring work accomplished at moderate level:
  - quality ranges from 1.0 to 3.5
- If recurring work accomplished at highly precise level:
  - quality ranges from 1.0 to 5.0

Quality is a function of the level of precision, recurring work accomplished and the quality of the inputs.



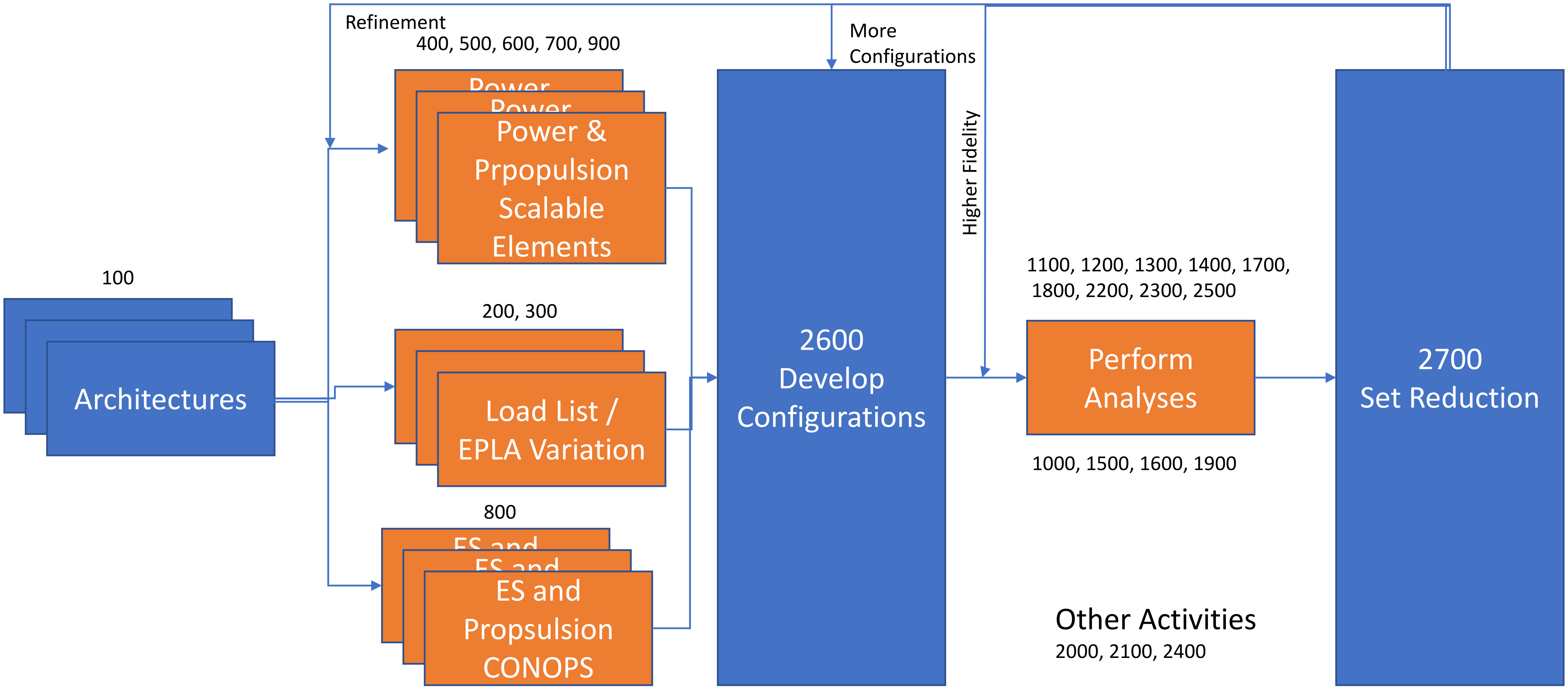
Overall Ship Power and Propulsion Design Domain model usage process



SDM = Ship Design Manager

Accomplished within a Model Based Systems Engineering (MBSE) Environment

Use Case to Support Set-Based Design



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Use Case / Design Integration

- User needs to ….
  - Specify how requirement quality evolves over time
    - Requirement Events
  - Determine which output products are needed (and their quality)
  - Specifies maximum number of weeks
  - Specify Adjustment Factors for each activity model
  - Select template for initial activity model network
    - Starting week, Ending week and controls for executing activities – Activity Events
  - Adjust activity events (activity model network) as needed

Activity Model Network is a set of Requirement Events and Activity Events

Schedule (Gantt Chart)

- Schedule is an input to the modeling effort.
- The quality charts help identify which activities can be shortened or eliminated, and which should be lengthened.
- Resource loading can be provided.

Weekly Dependency Report

- List every activity (and associated output) that is worked upon each week
- Lists the dependency of each listed activity on requirements and activity variables
- Tracks the quality of the requirements and activity variables
- Tracks the workload accomplished at each level of precision for each listed activity

End of Week	Factor	Precision		100	200	210	220	230	300	400	500	600	700	800	810	900	1000	1100	1110	1120	1130	1140	1150	1160
19	Quality			5	5	5	4.58	5	5	5	5	5	5	4.98	4.98	3.5	5	4.99	4.99	4.99	4.99	4.99	4.99	4.99
20	Quality			5	5	5	4.61	5	5	5	5	5	5	4.98	4.98	3.5	5	4.99	4.99	4.99	4.99	4.99	4.99	4.99
20	w_setup	low		0	1	1	1	1	0	0	0	1	0	0	0	1	1	1	1	1	1	1	1	1
20	w_setup	moderate		0	1	1	1	1	0	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1
20	w_setup	high		1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1
20	w_recurring	low		0	1	1	1	1	0	0	0	1	0	0	0	1	1	1	1	1	1	1	1	1
20	w_recurring	moderate		0	1	0.96	1	1	0	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1
20	w_recurring	high		1	1	1	0.22	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1
End of Week	Activity Event	Activity	Trigger	100	200	210	220	230	300	400	500	600	700	800	810	900	1000	1100	1110	1120	1130	1140	1150	1160
20	119	24msps	start	L					L	L	L			H		H								
20	108	20spec	start	L	H	H	H	H	L	H	H	H	H	H	H	H	L	L	L	L	L	L	L	L
20	34	08cnps	electrical	H						H	H	H		1	0	H								
20	1	01arch	start	1																				
20	36	08cnps	propulsion	H						H		H		0	1	H								
20	112	21flxs	start	H																				
20	4	02epla	power	H	1	0	0	0	H					L	L									
20	38	09pcon	start	H					H	H	H	H	L	H	H	1		H		H	H	H	H	H
20	85	14surv	compartment		H				H	H	H	H	H	H	H	L								
20	19	03load	start	H					1															
20	82	14surv	zonal		H				H	H	H	H	H	H	H	L								
20	55	11dsim	dra						H	H	H	H		H	H	H		0	0	1	0	0	0	0
20	63	11dsim	fault						H	H	H	H		H	H	H		0	0	0	0	1	0	0
20	51	11dsim	stability						H	H	H	H		H	H	H		0	1	0	0	0	0	0
20	17	02epla	pulse	H	0	0	0	1	H					L	L									
20	67	11dsim	frequency						H	H	H	H		H	H	H		0	0	0	0	0	1	0
20	59	11dsim	common_mode						H	H	H	H		H	H	H		0	0	0	1	0	0	0
20	47	11dsim	transient						H	H	H	H		H	H	H		1	0	0	0	0	0	0
20	125	26cnfg	start	H	H				L	H	H	H	L			L								
20	71	11dsim	thermal						H	H	H	H		H	H	H		0	0	0	0	0	0	1
20	127	27strd	start		H	H	H	H										H	H	H	H	H	H	H
20	44	10fuel	start		H					H	L	H		H	H		1							
20	114	22flxa	start	H	H					H	H	H				H								
20	123	25cost	start							H	H	H	L			H								
20	9	02epla	energy	H	0	1	0	0	H					L	L									
20	22	04prip	start	H	L					1			L	L	L		L	L	L	L	L	L	L	L
20	25	05zone	start	H	L				L		1		L	L				L	L	L	L	L	L	L
20	29	06prop	start	H						L		1			H		L			H	H		H	H
20	32	07casp	start		H				H	H	H		1											
20	12	02epla	in-rush	H	0	0	1	0	H					L	L									
20	97	17cybr	start							H	H	H	L	H	H	H								
20	105	19phea	start							H	H	H	L	H	H	H								
20	93	16safe	start							H	H	H	L	H	H	H								
20	75	12rela	start							H	H	H	L	H	H	H								
20	101	18ppsa	start							H	H	H	L	H	H	H								
20	79	13qosa	start		H	H	H	H	H	H	L			H				L	L				L	
20	117	23test	start							H	H	H	L			H		L	L	L	L	L	L	L
20	90	15arcf	start							H	H	H		H	H									

Modeling Environment

- Model is currently implemented in a proof of concept program.
  - Enables testing algorithms
  - Enables developing parameters for equations
  - Develop example schedules, costs, etc.
- Model Description Documents implemented as Microsoft Word Documents.
- Standard Statement of Work implemented as a template that draws from MDDs.
- Plan to use a Model Based Systems Engineering Environment to at least manage MDDs and Standard Statements of Work.
- May also use MBSE environment to set up the simulation of the Design Activity Model.
  - May use an external simulation environment to simulate the Design Activity Model in order to calculate work, workload, and quality.

Questions?

BREAK

Design Activities

- 100 Develop Power System Architectures
- 200 Electric Power Load Analysis (EPLA)
- 300 Load List
- 400 Primary Power System Design
- 500 Zonal Power System Design
- 600 Propulsion System Design
- 700 Casualty Power System Design
- 800 ES Concept of Operations
- 900 Electric Plant and Propulsion Controls
- 1000 Endurance and Annual Fuel
- 1100 Dynamic Simulation
- 1200 Reliability Analysis
- 1300 Quality of Service Analysis
- 1400 Vulnerability and Recoverability Analysis
- 1500 Arc Flash Analysis
- 1600 System Safety Analysis and Hazard Analysis
- 1700 Cybersecurity Analysis
- 1800 Product Support Analysis
- 1900 Human Engineering Analysis
- 2000 Develop Specifications
- 2100 Develop strategy for power system flexibility
- 2200 Assess Power System flexibility
- 2300 Electrical System and Propulsion System Development Testing
- 2400 Develop mission System - Power System Interface
- 2500 Cost Engineering Analysis
- 2600 Develop Configurations
- 2700 Set Reduction

01arch: Develop and Manage Power System Conceptual Architectures

D

Description

- Develop one or more conceptual architectures
- Define electrical zone assignment of power and propulsion components
- Define expected range of ratings for each power system component
- Identify any special CONOPS considerations

Inputs

- R200 Zone Boundaries (High)
- R210 SDM Guidance (High)

Outputs

- 100 List and description of power and propulsion conceptual architectures

References

- T9300-AF-PRO-020 Revision 1
- Preliminary Electrical System DPC MVDC Supplement

A

02epla: Perform Electric Power Load Analysis

Description

- Perform a generalized EPLA
- Determine required power and energy rating of power system components
  - Power Generation
  - Power Conversion Modules
  - Energy Storage Modules
  - Power Distribution
- Power Capacity Analysis
  - Traditional EPLA
  - Load Flow Analysis (for main bus)
  - 24 Hour average load
- Energy Storage Analysis
  - Adequacy of energy and power rating based on quasi-steady state analysis
- In-Rush Current Analysis
  - Adequacy of sources to provide in-rush current to loads based on quasi-steady state analysis
- Pulsed Load analysis
  - Adequacy of sources and distribution to provide pulsed power to loads. Based on quasi-steady state analysis.

Inputs

- R020 Ship Operating Conditions(High)
- R030 Margin and Service Life Allowance Policy (High)
- R040 Ambient Condition Profile (Low)
- 100 List & Description of Power and Propulsion System Conceptual Architectures (High)
- 300 Load List (High)
- 800 Electrical Power system CONOPS (Low)
- 810 Propulsion System CONOPS (low)
- 2600 Configuration Descriptions (High)

Outputs

- 200 EPLA – Power
- 210 EPLA – Energy
- 220 EPLA – In-Rush
- 230 EPLA - Pulsed

References

- T9070-A3-DPC-010/310-1
- T9300-AF-PRO-020 Revision 1
- Preliminary Electrical System DPC MVDC Supplement

D

03load: Develop and Maintain Load List

Description

- Determine properties of all electric loads of a ship configuration
- Update properties as needed

Inputs

- R020 Ship Operating Conditions (High)
- R050 Machinery Arrangements (High)
- R060 General Arrangements (High)
- R070 Master Equipment List (High)
- R080 Combat Systems Design (High)
- R090 Other Distributed System Design (High)
- R200 Zone Boundaries (High)
- 100 List and Description of Power and Propulsion System Conceptual Architectures (High)
- 2600 Configuration Descriptions (Low)

Outputs

- 300 Electric Lod List

References

- T9300-AF-PRO-020 Revision 1
- T9070-A3-DPC-010/310-1

04prip: Develop and Maintain Primary Power System Element Design

D

Description

- Determine the size, weight, center of gravity, thermal load, control system needs, maintenance envelopes, efficiency, etc. of power system components comprising the primary power generation and distribution system including:
  - Power Generation Modules (PGMs)
  - Power Conversion Modules (PCMs)
  - Energy Storage Modules (ESMs)
  - Power Distribution Modules (PDMs)
- Does not include PCM that connects to in-zone distribution
- Typically Medium Voltage (either a.c. or d.c.) for larger ships
- Can be Low Voltage (either a.c. or d.c.) for smaller ships

Inputs

- R030, R050, R060 (Low)
- 100 (High)
- 200, 700, 800, 810, 1000, 1100 (low)
- 1110, 1120, 1130, 1140, 1150 (low)
- 1160, 1200, 1300, 1400, 1500 (low)
- 1600, 1700, 1800, 1900, 2100 (low)
- 2200, 2300, 2500, 2600 (low)

Outputs

- 400 Primary Power System Element Design and Operating Methods

- References
  - T9300-AF-PRO-020 Revision 1
  - Preliminary Electrical System DPC MVDC Supplement

05zone: Develop and Maintain Zonal Power System Element Design

D

Description

- Determine the size, weight, center of gravity, thermal load, control system needs, maintenance envelopes, efficiency, etc of power system components comprising a zonal power distribution system including:
    - Power Conversion Modules (PCMs)
    - Energy Storage Modules (ESMs)
    - Power Distribution Modules (PDMs)
- Typically low voltage (either a.c. or d.c.)
- Assumes the required rating of each power system element is specified as either a single value or as a range of values
    - Provides scalable solutions for each element that spans this range
    - This range is compared later to the results of the EPLA to determine which rating value along the scalable range will be employed for a particular configuration.

Inputs

- R030, R050, R060 (Low)
- 100 (High)
- 200, 300, 700, 800, 1100 (Low)
- 1110, 1120, 1130, 1140 (Low)
- 1150,1160, 1200, 1300 (Low)
- 1400, 1410, 1500, 1600 (Low)
- 1710, 1800, 1900, 2100 (Low)
- 2200, 2300, 2500, 2600 (Low)

Outputs

- 500 Zonal Power System Element Design and Operating Methods

References

- T9300-AF-PRO-020 Revision 1

06prop: Develop and Maintain Propulsion System Element Design

D

Description

- Determine the size, weight, center of gravity, thermal load, control system needs, maintenance envelopes, efficiency, etc. of components comprising the propulsion system including :
  - Propulsion Motor Modules (PMM) for electric drive
  - Propulsion prime movers and reduction gears for mechanical drives
  - Hybrid electric drives
  - Thrust bearings, shafting, and shaft bearings
- The PMM (if employed) includes input transformers (if necessary), motor drives, dynamic braking resistors, and the propulsion motors. PMMs may also include azimuth thrusters (pods).

Inputs

- R030, R050, R100 (High)
- 100 (High)
- 400 (Low)
- 810 (High)
- 1000 (Low)
- 1120, 1130, 1150, 1160 (High)
- 1200, 1300, 1600, 1700, 1800, 1900 (Low)
- 2300 (High)
- 2500 (Low)

Outputs

- 600 Propulsion System Element Design

References

- T9300-AF-PRO-020 Revision 1

07casp: Develop and Maintain Casualty Power System Design

D

Description

- Determine the size, weight, center of gravity, thermal load, control system needs, maintenance envelopes, efficiency, etc of components comprising the casualty power system as well as interfaces required in other power system components and loads.
- The casualty power system includes casualty power terminals, cables, stowage racks, and connectors in switchboards, load centers, and individual loads.
- Casualty power system component designs currently exist for 440 VAC and MVDC distribution systems.
    - The MVDC system can be used for LVDC.
    - An MVAC system is currently in design.

Inputs

- R110 Survivability Requirements (high)
- 200 EPLA – Power (high)
- 300 Load List (high)
- 400 Primary Power System Element Design (high)
- 500 Zonal Power System Element Design (high)
- 1400 Zonal Survivability Analysis Report (Low)
- 1410 Compartment Survivability Analysis Report (low)
- 2600 Configuration Descriptions (high)

Outputs

- 700 Casualty Power System Design

References

- T9300-AF-PRO-020 Revision 1

08cnps: Develop and Maintain Electrical Power System Concept of Operation and Propulsion System Concept of Operation

D

Description

- Document the required behaviors of the electrical power system and propulsion system based on the expected use of the ship
- Describe normal operations and how the electrical power system and how the propulsion system are intended to operate
- Describe restorative operations and how the electrical power system and propulsion system return to normal operations when the system is disturbed due to equipment failures

Inputs

- R110 Survivability Requirements (low)
- 100 Architectural Descriptions and List of Power and Propulsion System Conceptual Architectures (High)
- 400 Primary Power System Element Design (High)
- 500 Zonal Power System Element Design (High for 800 only)
- 600 Propulsion System Element Design (High)
- 900 Electric Plant and Propulsion Control System Design (High)
- 2600 Configuration Descriptions (High)

Outputs

- 800 Electrical Power System CONOPS
- 810 Propulsion System CONOPS

References

- T9300-AF-PRO-020 Revision 1
- IEEE Std. 45.3

09pcon: Develop and Maintain Electric Plant and Propulsion Control System Design

D

Description

- Determine the physical characteristics of components comprising the control system hardware as well as the design and initial code implementation of the control system software

Inputs

- 100, 300, 400, 500, 600 (High)
- 700 (Low)
- 800, 810, 1100, 1110, 1120 (High)
- 1130, 1140, 1150, 1160, 1300 (High)
- 1400, 1410 (Low)
- 1700 (High)
- 1900 (Low)
- 2100 (High)
- 2200, 2300 (Low)
- 2400 (High)
- 2500 (Low)
- 2600 (High)

Outputs

- 900 Electrical and Propulsion Control System Design

References

- T9300-AF-PRO-020 Revision 1

10fuel: Perform Endurance Fuel and Annual Energy Usage Calculations

A

Description

- Determine the required fuel tankage for electrical power generation and for propulsion
- Calculate annual fuel consumption

- Inputs
  - R030, R100, R130 (High)
  - 200, 400 (High)
  - 500 (Low)
  - 600, 800, 810, 2600 (High)
- Outputs
  - 1000 Endurance and Annual Fuel calculations
- References
  - T9070-AW-DPC-010/200-1
  - T9070-AW-DPC-020/200-2

A

11dsim: Perform Dynamic Simulation

Description

- Demonstrate the electrical power and propulsion systems
  - are stable
  - meet power system dynamic interface standards
  - achieves ship performance requirements in specific areas
- Analyses include:
  - Transient Analysis
  - Stability Analysis
  - Dynamic Response Analysis
  - Common mode Current Analysis
  - Fault Current Analysis and Protective Device Coordination Study
  - Harmonic and Non-fundamental frequency analysis
  - Thermal analysis

Inputs

- R020 (High)
- 300, 400, 500, 600, 800, 810, 900 (High)
- 2300 (Low) 2600 (High)

Outputs

- 1100 Transient Analysis
- 1110 Stability Analysis
- 1120 Dynamic Response Analysis
- 1130 Common Mode Current Analysis
- 1140 Fault Current Analysis and Protective Device Coordination Study
- 1150 Harmonic and non-fundamental frequency analysis
- 1160 Thermal Analysis

References

- NAVSEA T9300-AF-PRO-020 Revision 1
- IEEE 45.3 IEEE 399   IEEE 519
- NAVSEA T9070-A1-DPC-020/320-2 Revision 1
- ABS Guidance Notes on Control of Harmonics in Electrical Power Systems

A

12rela: Reliability Analysis

Description

- Demonstrate the electrical power and propulsion system meet reliability and availability requirements

Inputs

- 400 Primary Power System Element Design (high)
- 500 Zonal Power System Element Design (high)
- 600 Propulsion System Element Design (High)
- 700 Casualty Power System Design (low)
- 800 Electrical Power System CONOPS (High)
- 810 Propulsion System CONOPS (High)
- 900 Electrical and Propulsion Control System Design (High)
- 2600 Configuration Descriptions (High)

Outputs

- 1200 Reliability Analysis Report

References

- NAVSEA T9300-AF-PRO-020 Revision 1
- IEEE 45.3
- MIL-HDBK-217, MIL-HDBK-251, MIL-HDBK-338, MIL-HDBK-781
- DOD Guide for Achieving Reliability, Availability, and Maintainability

A

13qosa: Perform Quality of Service Analysis

Description

- Demonstrate the electrical power and propulsion system meet Quality of Service (QOS) requirements

Inputs

- R120 (High)
- 200, 210, 220, 230 (High)
- 300, 400, 500, 800 (High)
- 1100, 1110, 1150 (Low)
- 1200, 2600 (High)

Outputs

- QOS Analysis Report

References

- T9300-AF-PRO-020 Revision 1
- IEEE 45.3

14surv: Perform Vulnerability and Recoverability Analysis

A

Description

- Demonstrate the electrical power system meets Zonal and Compartment Survivability requirements and the propulsion system meets survivability requirements

Inputs

- R110 (High)
- 200, 300, 400, 500 (High)
- 600, 700, 800, 810 (High)
- 900 (Low)
- 2600 (High)

Outputs

- 1400 Zonal Survivability and Propulsion survivability Analysis Report
- 1410 Compartment Survivability Analysis Report

References

- T9300-AF-PRO-020 Revision 1
- IEEE 45.3

A

15arcf: Perform Arc Flash Analysis

Description

- Demonstrate the electrical power and propulsion system meet arc flash safety requirements
- Performed for switchboards, load centers, and motor control centers
- Performed for equipment with switchgear installed that is rated for more than 1000 amps continuous current

Inputs

- R050 Machinery Arrangements (High)
- 400 Primary Power System Element Design (High)
- 500 Zonal Power System Element Design (High)
- 600 Propulsion System Element Design (High)
- 800 Electrical Power System CONOPS (low)
- 810 Propulsion System CONOPS (low)
- 2600 Configuration Descriptions (High)

Outputs

- 1500 Arc Flash Analysis Report

References

- T9300-AF-PRO-020 Revision 1
- IEEE 1584, IEEE 1584.1

16safe: Perform System Safety Analysis and Hazard Analysis

A

Description

- Complete Elements 2 and 3 of the System Safety Process defined in MIL-STD-882
- Assumes the system safety approach (Element 1) has been defined in a system safety program plan
- The product of this activity is provided to the system risk management program to execute the remaining elements (4 through 8).

Inputs

- R050, R150 (High)
- 400, 500, 600 (High)
- 700 (Low)
- 800, 810, 900, 2600 (High)

Outputs

- 1600 System Safety Analysis and Hazard Analysis Report

References

- T9300-AF-PRO-020 Revision 1
- Mil-STD-882

A

17cybr: Perform Cybersecurity Analysis

Description

- Implement the Navy's cybersecurity Risk Management Framework Assess tasks, for the applicable systems

Inputs

- R160 (High)
- 400, 500, 600 (High)
- 700 (Low)
- 800, 810, 900, 2600 (High)

Outputs

- 1700 Security Assessment Plan and Assessment of Security Controls

References

- T9300-AF-PRO-020 Revision 1
- Cybersecurity Test and Evaluation Guidebook
- Risk Management Framework for Information Systems and Organizations – NIST Special Publication 800-37

A

18ppsa: Perform Product Support Analysis

Description

- Perform product support analysis (PSA of the in accordance with MIL-HDBK-502A and TA-STD-0017
- Ensure that supportability is included as a system performance requirement and to ensure the system is concurrently developed or acquired with the optimal support system and infrastructure
- Includes the integration of various analytical techniques with the objective of designing and developing an effective and efficient Product Support Package.
- The primary techniques used in PSA are:
  - Failure Mode, Effects and Criticality Analysis (FMECA)
  - Fault Tree Analysis (FTA)
  - Reliability Centered Maintenance (RCM) Analysis
  - Level of Repair Analysis (LORA)
  - Maintenance Task Analysis (MTA)
  - Core logistics analysis
  - Source of repair analysis
  - Depot source of repair analysis

Inputs

- R170 (High)
- 400, 500, 600 (High)
- 700 (Low)
- 800, 810, 900, 1200,1900, 2600 (High)

Outputs

- 1800 Product Support Analysis Report and Logistics Product Data

References

- MIL-HDBK-502A
- TA-STD-0017

A

19phea: Perform Human Engineering Analysis

Description

- Perform human engineering analysis of the electrical power system and propulsion system on a surface combatant in accordance with MIL-STD-46855
- MIL-HDBK-1908 defines human engineering:

"The application of knowledge about human capabilities and limitations to system or equipment design and development to achieve efficient, effective, and safe system performance at minimum cost and manpower, skill, and training demands. Human engineering assures that the system or equipment design, required human tasks, and work environment are compatible with the sensory, perceptual, mental, and physical attributes of the personnel who will operate, maintain, control, and support it."

Inputs

- 400 Primary Power System Element Design (High)
- 500 Zonal Power System Element Design (High)
- 600 Propulsion System Element Design (High)
- 700 Casualty Power System Design (Low)
- 800 Electrical Power System CONOPS (High)
- 810 Propulsion System CONOPS (High)
- 900 Electric Plan ant Propulsion Control system Design (High)
- 2600 Configuration Descriptions (High)

Outputs

- 1900 Human Engineering Analysis Report

References

- MIL-STD-46855
- MIL-STD-1472
- MIL-HDBK-1908

D

20spec: Develop Specification Sections

Description

- Develop draft shipbuilding specification sections, identify knowledge gaps, perform work to fill knowledge gaps, and produce final draft specification sections for integration into the overall shipbuilding specification

Inputs

- All requirements and products
- High Impact
  - R010, R020, R030, R050, R070
  - R110, R120, R180
  - 200, 210, 220, 230, 400, 500, 600
  - 700, 800, 810, 900
  - 2400, 2600, 2700

Outputs

- 2000 Specification Sections

References

- NAVSEA T9300-AF-PRO-020 Revision 1
- Preliminary Electrical Systems DPC MVDC Supplement

21flxs: Develop Power System Flexibility Strategy

D

Description

- Define the strategy for meeting ship flexibility requirements in the design of the power system
- The strategy includes the process for assessing whether the flexibility requirements have been met.

Inputs

- R030 Margin and Service Life Allowance Policy (High)
- R180 Flexibility Requirements (High)
- 100 List and description of power and propulsion conceptual architectures (High)

Outputs

- 2100 Flexibility Strategy

References

- NAVSEA T9300-AF-PRO-020 Revision 1
- Preliminary Electrical Systems DPC MVDC Supplement
- *Flexibility in Engineering Design* by Richard de Neufville and Stefan Scholtes

22flxa: Assess Power System Flexibility

Description

- Implement the assessment process defined in the Power System Flexibility Strategy

Inputs

- R030 (High)
- 100, 200, 400, 500, 600 (High)
- 900, 2100, 2600 (High)

Outputs

- 2200 Power System Flexibility Assessment

References

- NAVSEA T9300-AF-PRO-020 Revision 1
- Preliminary Electrical Systems DPC MVDC Supplement
- *Flexibility in Engineering Design* by Richard de Neufville and Stefan Scholtes

23test: Perform Electrical System and Propulsion System Development Test & Evaluation

A

Description

- Perform development test and evaluation of the electrical power system and propulsion system
- Developmental Test & Evaluation (DT&E) is conducted throughout the acquisition process to assist in engineering design and development, to verify that technical performance specifications have been met or in Set-Based Design, to develop the knowledge needed for a set-reduction.
- DT&E includes the T&E of components, subsystems, Preplanned Product Improvement (P3I) changes, hardware/software integration, and production qualification testing.
- DT&E encompasses the use of models, simulations, test beds, and prototypes or full-scale engineering development models of the system.

Inputs

- 400, 500, 600 (High)
- 700 (Low)
- 900 (High)
- 1100, 1110 1120, 1130 (Low)
- 1140, 1150, 1160 (Low)
- 2600 (High)

Outputs

- 2300 DT&E Test Plan, Procedures, and Reports

References

- NAVSEA T9300-AF-PRO-020 Revision 1
- IEEE 45.3

24msps: Develop Mission System – Power System Control Interface

D

Description

- Document the control signals exchanged between selected mission systems and the power system, as well as the expected behavior of the mission systems and electrical power system in response to the control signals
- This interface is expected to be used with high power mission systems and selected pulsed loads.
- Once this interface has been codified into a standard interface (perhaps as part of MIL-STD-1399 or equivalent), then this activity may no longer be required.

Inputs

- 100 List and description of power and propulsion conceptual architectures (Low)
- 300 Load List (Low)
- 400 Primary Power System element design (Low)
- 500 Zonal Power System element design (Low)
- 800 Electrical Power System CONCOPS (Low)
- 900 Electrical and Propulsion Control System Design (Low)

Outputs

- 2400 Project Peculiar Document: Mission System – Power System Control Interface

References

- NAVSEA T9300-AF-PRO-020 Revision 1
- IEEE 45.3

A

25cost: Perform Cost Engineering Analysis

Description

- Perform cost engineering analysis of the electrical power system and propulsion system
- Identify cost drivers in the material costs, non-recurring labor costs, recurring labor costs, and operations and maintenance costs of the electrical power system and propulsion system for the purpose of optimizing design
- The results of the cost engineering analysis are also used in part to develop cost estimates for the total ship.

Inputs

- R050, R060 (Low)
- R190 (High)
- 400, 500, 600 (High)
- 700 (Low)
- 900, 1200, 1800, 2600 (High)

Outputs

- 2500 Cost Engineering Analysis Report

References

D

26cnfg: Develop Configurations

Description

- Develop electrical power system and propulsion system configurations
- The configurations are created by integrating the products from the definition activities – (activities 200 through 900) and in conformance to the architectures from activity 100.
- Typically, multiple configurations are initially developed to explore the design space.
- Later configurations are created to better define the uncertain design space.
- Configurations may also evolve as the fidelity is increased for the definition activities.
- Configurations developed by this activity are analyzed by the analysis activities to determine their feasibility in preparation for set reduction (activity 2700).

Inputs

- R050 (High)
- R060, R190 (Low)
- 100, 200 (High)
- 300 (Low)
- 400, 500, 600 (High)
- 700, 900 (Low)
- 2700 (High)

Outputs

- 2600 Configuration Descriptions

References

- NAVSEA T9300-AF-PRO-020 Revision 1
- Preliminary Electrical Systems DPC MVDC Supplement

d

27strd: Set Reduction

Description

- Perform Set Reduction within a Set-Based Design (SBD) environment for the electrical power system and propulsion system
- Examine the results of analyses on the configurations defined in the "Develop Configurations" activity and categorizes the configurations as:
  a. Feasible (Green)
  b. Not Feasible (Red)
  c. Highly Dominated (Orange or Red)
  d. Uncertain (Yellow)
- The Set-Reduction activity keeps track of the analyses performed on the design space and the classification of configurations within the design space. Once all of the analyses have been performed at least once, this activity examines the uncertain region of the design space and seeks to create sufficient knowledge to further reduce this uncertain region. Options include:
  i. Increasing fidelity of the definition activities
  ii. Creating additional configurations within the yellow region
  iii. Increasing fidelity of the analyses (which may require increasing fidelity of the definition activities)

Inputs

- 200, 210, 220, 230 (High)
- 1100, 1110, 1120, 1130 (High)
- 1140, 1150, 1160, 1200 (High)
- 1300, 1400, 1410, 1500 (High)
- 1600, 1700, 1800, 1900 (High)
- 2200, 2300, 2500, 2600 (High)

Outputs

- 2700 Design Space Classification Report

References

Design Activities strongly interrelated

Design data	Block Number	Subblock Number	Predecessor Block Number	100	300	400	500	2100	200	210	220	600	700	800	810	900	1000	1100	1110	1120	1130	1140	1150	1160	1200	1300	1400	1410	1500	1600	1700	1800	1900	230	2200	2300	2400	2500	2600	2700
100	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
300	2	1	1	S	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	W	0
400	2	2	1	S	0	2	0	W	W	0	0	0	W	W	W	0	W	W	W	W	W	W	W	W	W	W	W	0	W	W	W	W	W	0	W	W	0	W	W	0
500	2	3	1	S	W	0	3	W	W	0	0	0	W	W	0	0	0	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	0	W	W	0	W	W	0
2100	2	4	1	S	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
200	3	0	2	S	S	0	0	0	5	0	0	0	0	W	W	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	S	0
210	3	0	2	S	S	0	0	0	0	6	0	0	0	W	W	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	S	0
220	3	0	2	S	S	0	0	0	0	0	7	0	0	W	W	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	S	0
600	3	0	2	S	0	W	0	0	0	0	0	8	0	0	S	0	W	0	0	S	S	0	S	S	W	W	0	0	0	W	W	W	W	0	0	W	0	W	0	0
700	3	0	2	0	S	S	S	0	S	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	W	W	0	0	0	0	0	0	0	0	0	0	S	0
800	3	0	2	S	0	S	S	0	0	0	0	S	0	10	0	S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	S	0
810	3	0	2	S	0	S	0	0	0	0	0	S	0	0	11	S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	S	0
900	3	0	2	S	S	S	S	S	0	0	0	S	W	S	S	12	0	S	0	S	S	S	S	S	S	S	W	W	0	0	S	0	W	0	W	W	S	W	S	0
1000	3	0	2	0	0	S	W	0	S	0	0	S	0	S	S	0	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	S	0
1100	3	0	2	0	S	S	S	0	0	0	0	S	0	S	S	S	0	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	W	0	0	S	0
1110	3	0	2	0	S	S	S	0	0	0	0	S	0	S	S	S	0	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	W	0	0	S	0
1120	3	0	2	0	S	S	S	0	0	0	0	S	0	S	S	S	0	0	0	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	W	0	0	S	0
1130	3	0	2	0	S	S	S	0	0	0	0	S	0	S	S	S	0	0	0	0	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	W	0	0	S	0
1140	3	0	2	0	S	S	S	0	0	0	0	S	0	S	S	S	0	0	0	0	0	18	0	0	0	0	0	0	0	0	0	0	0	0	0	W	0	0	S	0
1150	3	0	2	0	S	S	S	0	0	0	0	S	0	S	S	S	0	0	0	0	0	0	19	0	0	0	0	0	0	0	0	0	0	0	0	W	0	0	S	0
1160	3	0	2	0	S	S	S	0	0	0	0	S	0	S	S	S	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	W	0	0	S	0
1200	3	0	2	0	0	S	S	0	0	0	0	S	W	S	S	S	0	0	0	0	0	0	0	0	21	0	0	0	0	0	0	0	0	0	0	0	0	0	S	0
1300	3	0	2	0	S	S	W	0	S	S	S	0	0	S	0	0	0	W	W	0	0	0	W	0	S	22	0	0	0	0	0	0	0	S	0	0	0	0	S	0
1400	3	0	2	0	S	S	S	0	S	0	0	S	S	S	S	W	0	0	0	0	0	0	0	0	0	0	23	0	0	0	0	0	0	0	0	0	0	0	S	0
1410	3	0	2	0	S	S	S	0	S	0	0	S	S	S	S	W	0	0	0	0	0	0	0	0	0	0	0	24	0	0	0	0	0	0	0	0	0	0	S	0
1500	3	0	2	0	0	S	S	0	0	0	0	S	0	S	S	0	0	0	0	0	0	0	0	0	0	0	0	0	25	0	0	0	0	0	0	0	0	0	S	0
1600	3	0	2	0	0	S	S	0	0	0	0	S	W	S	S	S	0	0	0	0	0	0	0	0	0	0	0	0	0	26	0	0	0	0	0	0	0	0	S	0
1700	3	0	2	0	0	S	S	0	0	0	0	S	W	S	S	S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27	0	0	0	0	0	0	0	S	0
1800	3	0	2	0	0	S	S	0	0	0	0	S	W	S	S	S	0	0	0	0	0	0	0	0	S	0	0	0	0	0	0	28	S	0	0	0	0	0	S	0
1900	3	0	2	0	0	S	S	0	0	0	0	S	W	S	S	S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29	0	0	0	0	0	S	0
230	3	0	2	S	S	0	0	0	0	0	0	0	0	W	W	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	0	0	0	0	S	0
2200	3	0	2	S	0	S	S	S	S	0	0	S	0	0	0	S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	31	0	0	0	S	0
2300	3	0	2	0	0	S	S	0	0	0	0	S	W	0	0	W	0	W	W	W	W	W	W	W	0	0	0	0	0	0	0	0	0	0	0	32	0	0	S	0
2400	3	0	2	W	W	W	W	0	0	0	0	0	0	S	0	S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33	0	0	0
2500	3	0	2	0	0	S	S	0	0	0	0	S	W	0	0	S	0	0	0	0	0	0	0	0	S	0	0	0	0	0	0	S	0	0	0	0	0	34	S	0
2600	3	0	2	S	W	S	S	0	S	0	0	S	W	0	0	W	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	35	S
2700	3	0	2	0	0	0	0	0	S	S	S	0	0	0	0	0	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	0	S	S	36

Iteration is required

Questions?