

Design Activity Modeling

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Agenda

- 1) What is a Design Activity Model and why do we need it?
- 2) How does the model work?
- 3) Example calculation and model capabilities
- 4) Demonstration



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?
- 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.
- 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.



Design Activity Model (DAM)

- A schedule optimization tool that utilizes the capability of MagicDraw to integrate with MATLAB for parametric simulations
 - Allows for logically complex algorithms to be compressed down to manageable "actions" in MagicDraw



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Defining Important Terms

- Activity Models
 - The digital counterpart of a real design activity that produces a "degree of completion" to represent a physical output through the use of various algorithms
 - Maps physical inputs to appropriately valued parameters



Design Activities Simulated in the Model

- Develop Power System Architectures
- Electric Power Load Analysis (EPLA)
- Load List
- Primary Power System Design
- Zonal Power System Design
- Propulsion System Design
- Casualty Power System Design
- ES Concept of Operations
- Electric Plant and Propulsion Controls
- Endurance and Annual Fuel
- Dynamic Simulation
- Reliability Analysis
- Quality of Service Analysis
- Vulnerability and Recoverability Analysis

- Arc Flash Analysis
- System Safety Analysis and Hazard Analysis
- Cybersecurity Analysis
- Product Support Analysis
- Human Engineering Analysis
- Develop Specifications
- Develop strategy for power system flexibility
- Assess Power System flexibility
- Electrical System and Propulsion System Development Testing
- Develop mission System Power System Interface
- Cost Engineering Analysis
- Develop Configurations
- Set Reduction



Defining Important Terms

Activity Model

- The digital counterpart of a real-life design activity that produces a degree of completion instead of a tangible output through the use of various algorithms
- Maps physical inputs to appropriately valued parameters

Product

- The output of an activity model
- Some activities have several products (EPLA)

Quality

- The degree of completion of the product of a given activity
- Represented as an interval from 0.0 5.0
- Product quality
- Requirement quality
- Interdependent products



Design Structure Matrix





Design Structure Matrix

			Requirement Providing the Input																								
			R-010	R-020	R-030	R-040	R-050	R-060	R-070	R-080	R-090	R-100	R-110	R-120	R-130	R-140	R-150	R-160	R-170	R-180	R-190	R-200	R-210	R-220	R-230	R-240	R-250
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Outputs and Insights From the DAM

- Estimate of duration and cost of conducting Preliminary and Contract Design
 - Ship power and propulsion design only
- Demonstrates Design Activity Interdependence
- Rate of Convergence of Iterative Design Process
- Improved understanding of design
 - Enables the user to model different design processes implementing different design methods to understand schedule and cost trade-offs.
 - Enable continuous process improvement.



What the DAM Does Not Capture

Does not model (need to budget for these items separately)

- Financial Management
- Risk Management
- 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



Important Parameters of Activity Models

- Number of Engineers Assigned to an Activity
 - Senior or junior engineers
 - $n_{FTE} = n_{senior} + n_{junior}$

• Effective Workforce and Efficiency of Junior Engineers

- $L_1 = n_{senior} + L_{factor} n_{junior}$

• Effective Work Accomplished by a Team

For
$$n_{FTE} > 1$$
 $f_{FTE}(n_{FTE}) = \frac{B_0}{n_{FTE}} + B_1 + B_2 n_{FTE} + B_3 n_{FTE}^2$ $B_0 = 0.3631$ For $n_{FTE} \le 1$ $f_{FTE}(n_{FTE}) = 1.0$ $B_1 = 0.6369$ For $n_{FTE} \le 1$ $f_{FTE}(n_{FTE}) = 1.0$ $B_3 = 0.0$

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



Important Parameters of Activity Models

- Setup Work
 - Represents the "initial work" necessary in any design activity
 - Necessary to complete before an activity can begin quality convergence
 - An interval from 0.0 1.0 and must be 1.0 to produce quality

Recurring Work

- Represents the "actual work" performed in any design activity
- An interval from 0.0 1.0 but does not have to be 1.0
- The greater recurring work is, the greater the minimum quality output will be



Important Parameters of Activity Models

Level of Precision

- Low, Moderate, High (x = [1,2,3])
- Can represent different things based on the activity model (phases of execution, precision of tools, depth of analyses, etc.)

Adjustment Factors

- An array whose elements range from 0.0 2.0
- Represent factors such as personnel experience, level of tool support, documentation, etc



Example of Adjustment Factors

Architecture Requirements Volatility	F _{setup_k}	F _k	Process Capability	F _{setup_k}	F _k
Much Less than Normal	0.8	0.8	Much Less than Normal	1	1
Less Than Normal	0.9	0.9	Less Than Normal	1	1
Normal	1	1	Normal	1	1
More than Normal	1.1	1.1	More than Normal	1	1
Much more than normal	1.25	1.25	Much more than normal	1	1
Personnel experience			Documentation		
Very Inexperienced	2	2	Much less than normal	0.5	0.5
Inexperienced	1.5	1.5	Less than normal	0.75	0.75
Normal	1	1	Normal	1	1
Experienced	0.7	0.7	More than normal	1.5	1.5
Very Experienced	0.5	0.5	Much more than normal	2	2
Tool Support					
Stand-alone tools, little data	5	5			
Stand-alone tools, moderate missing data	2	2			
Normal – stand alone, some missing data	1	1			
Integrated with IDE, some missing data	0.7	0.7			
Integrated with IDE – no missing data	0.5	0.5	c		ARITIME 202

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Design Activities in the Model

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26-29 September Houston, TX

Model Description Documents (MDDs)

- Model Description Documents provide understanding of interrelationships between design activities.
 - 1. Introduction / Purpose
 - Describes the activity purpose and identifies outputs
 - 2. Inputs
 - Lists necessary inputs to the given activity that are the output qualities of other activities or just requirement qualities
 - 3. Outputs
 - Lists the output(s) of the activity and what each output would translate to in a physical output



Model Description Documents (MDDs)

- 4. Controls
 - Size function default value(s) (f_size)
 - Default workforce numbers (n_{senior}, n_{junior})
 - Default junior engineer efficiency (L_{factor})
 - What the LoP represents (*x*)
- 5. Mechanisms
 - Effort (what the setup/recurring work translate to)
 - Nominal workloads based on the LoP (A_{setup}, A_1)
 - Adjustment factor tables (F_{setup}, F_1)
 - Labor Categories



Example Calculation





Calculate the *increase* in setup work per model iteration (work week):

 $w_{setup_inc} = \frac{W_{week}}{W_{setup}}$

If the increase in setup work is greater than or equal 1.0, then setup work is finished:

 $w_{setup} = 1.0$

If the increase in setup work is less than 1.0, the effort will continue in week 2 and beyond until:

 $w_{setup} + w_{setup_inc} \ge 1$

Recalculate remaining effective work accomplished after finishing setup work

 $W_{week} = (W_{setup})(w_{setup}) + w_{setup_inc} - 1)$

Use the remaining effective work accomplished for the week and apply it to recurring work:

 $w_{recurring_inc} = \frac{W_{week}}{W_{recurring}}$

Calculate recurring work:

 $w_{recurring} = \min(w_{recurring} + w_{recurring_inc}, 1)$

Calculate also the maximum allowable increase in quality:

 $q_{inc_max} = 0.5(w_{recurring_inc})$



As an example of the calculation of quality, the design activity "Develop Power System Architecture" receives two high-quality inputs (R200, R210):

If one of the high-quality inputs is of a quality less than 4.0:

$$R200 = 3.0$$

$$R210 = 5.0$$

$$q_0 = 3.5 + 0.5w_{recurring} + \frac{1.0}{4.0} \left(\frac{1}{N+M}\right) \sum_{n=1}^{N} \min(q_{hi_n}, 4.0)$$

If all high-quality inputs are of a quality greater than 4.0:

R200 = 4.5R210 = 4.5

 $q_0 = 4.5 + 0.5 w_{recurring}$

A low level of precision (x = 1) may have a better rate of quality increase, but the quality However, we must take intraconsistentiative imagination allowable increase in quality. If Fuglivonally intrest level of precision crease in quality is less than any calculated quality, it must be the maximum allowable increase in quality is less than any calculated quality, it must be allows the design activity in partice sevent precision (quality = 5.0) Likewise, a medium level of prebision (pulled) defay it cause quality to converge slight slower, but is capped at 3.5



© DAM Control Element																			
Be	Begin Simulation Months to simulate: 2.00 Selection Complete Number of Products to Automate: 38					We Total De	eek: 8 sign C	3 ost (\$): 4	832000	Automation - Weeks Complete: 8 / 8 Automatic Execution - Activities: 1 Automatic Execution - Requirements: 1					Plot Quality Data Plot Product Impact Metrics				
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2	8	64000	1.25	Product 700 (Dev	elop and Maintain Pro	sualty Power System	Design)		1.80	Requirement	060 (General A	rrangements)				System Arch: 1	Cost Eng:	1	
2	8	64000	1.29	Product 800 (Electrical Power System CONOPS)						Requirement	070 (Master Eq	upment List)				EPLA: 23 Power System Eng: 17	Lest Eng: Reliability Eng:	6 5	
2	8	64000	1.88	Product 810 (Propulsion System CONOPS) Product 900 (Devolution System ConOPS)						Requirement	080 (Combat Sy	stems Design)				Power System Sim: 11	Safety Eng.	1	
2	8	64000	1.38	Product 1000 (Perform Endurance Fuel and Annual Fuel Calculations)						Requirement	090 (Other Dist	ibuted System D	Designs)	Prop. System Eng: 4 Logistician: 2					
1	8	64000	0.11 Product 1100 (Transient Analysis) 0.15 Product 1110 (Stability Applysis)						1.80	Requirement	100 (Speed Pov	ver Curve)				Surv. Elig. 5	Control Eng.	1	
	8	112000	0.16	Product 1110 (Sta Product 1120 (Dv	ibility Analysis) namic Response Ana	ilvs			3.30	Requirement	110 (Survivabili	y Requirements	;)						
1	8	64000	0.11	Product 1130 (Con	mmon Mode Current /	Analysis)			3.30	Requirement	120 (QOS Requ	irements)		Senior En	g. Junior Eng		Senior Eng.	Junior En	g.
	8	64000	0.11	Product 1140 (Fault Current Analysis and Protective Device Coordination Study) Product 1150 (Harmonic and Non-Fundamental Frequency Analysis)				3.30 Requirement 130 (Endurance Requirements)				1	0	Product 100	1	1	Product 1160		
	8	112000	0.16	Product 1160 (Thermal Analysis)					1.80	Requirement	140 (Operational	I Profiles)		1	0	Product 200	1	4	Product 1200
1	8	256000	1.38	Product 1200 (Perform Reliability Analysis)					1.80	Requirement	150 (Safety Sys	stem Plan)		4	3	Product 210	1	2	Product 1300
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3	8	64000	3.00	Product 2100 (De	velop Strategy for Po	wer System Flexibilit	y)		1.80	Requirement	220 (Maneuveri	ng Analysis)		1	0	Product 600	1	1	Product 1800
3	8	64000	1.90	Product 2200 (As	sess Power System	Flexibility)			1.70	Requirement	230 (Thermal S	(stem Design)		1	0	Product 700	1	1	Product 1900
2	8	64000	0.12	Product 2300 (Per Product 2400 (Der	velop Mission System	m and Propulsion System Inte	stem DT) erface)		3.20	Requirement	240 (Design Re	ference Mission)	1	0	Product 800	1	1	Product 2000 (pow
2	8	64000	1.20	Product 2500 (Per	form Cost Engineerin	ig Analysis)	,		1.70	Requirement	250 (Program R	eliabilitv Data)		1	0	Product 810	1	1	Product 2000 (prop)
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	0			Product 2100 (36)	Reduction				IL	J				1	0	Product 1000	1	0	Product 2100
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F	Product 400	Product 500	Product 600	Product 700	Product 800	Product 810			Req 060	Req 070	Req 080	Req 090	Req 100	1	1	Product 1120	1	0	Product 2400
									Reg 110	Reg 120	Reg 130	Reg 140	Reg 150	1	0	Product 1130	1	0	Product 2500
F	Product 900	Product 1000	Product 1100	Product 1110	Product 1120	Product 1130								1	0	Product 1140	1	0	Product 2600
P	roduct 1140	Product 1150	Product 1160	Product 1200	Product 1300	Product 1400			Reg 160	Reg 170	Req 180	Req 190	Req 200	1	1	Product 1150	1	0	Product 2700
P	roduct 1410	Product 1500	Product 1600	Product 1700	Product 1800	Product 1900			Req 210	Req 220	Req 230	Req 240	Req 250						
P	roduct 2000	Product 2100	Product 2200	Product 2300	Product 2400	Product 2500													
Product 2600 Product 2700																			



Metrics

Workforce Metrics – [0, 0, 0]

- 0 Not the active precision level
- 1 Setup limited (active precision level)
- 2 Recurring limited (active precision level)
- 3 Quality increment limit (active precision level)
- 4 Limited by level of precision or input quality
- Input Quality Metrics [0, 0, 0]
 - 0 Output quality not limited by inputs, or not the active precision level
 - 1 Output quality limited by at least one input



Metrics

- Impact Metrics- [0, 0, 0, ...,0]
 - An array of 0's and 1's that indicates what activities the quality of the product that owns the impact metric affects
 - 0 Not hindering the production of another product quality
 - 1 Hindering the production of another product quality



Current Capabilities of the DAM

• Direct Outputs

- Degree of completion of any given design activity model
- Estimated cost and duration of individual design activities
- Estimated total cost and duration of the whole design schedule
- Additional Information
 - Graphic User Interface (GUI)
 - Various metrics to identify obstacles for convergence
 - MATLAB plots of above metrics and activity output product degree of completion over time





27

26-29 September Houston, TX



P100 P200 P210 P220 P230 P300 P400 P500 P600 P700 P800 P810 P900 P100P1100P1100P1100P1140P1150P1160P1200P1300P1400P1410P1500P1600P1700P1800P1900P2100P2200P2300P2400P2500P2600P2700

Product Providing the Input



28

Product Receiving the Input



Requirement Providing the Input



29

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Thank you for your attention. This concludes the presentation.

Questions?

