

Air
Land
Sea
Space
Cyberspace

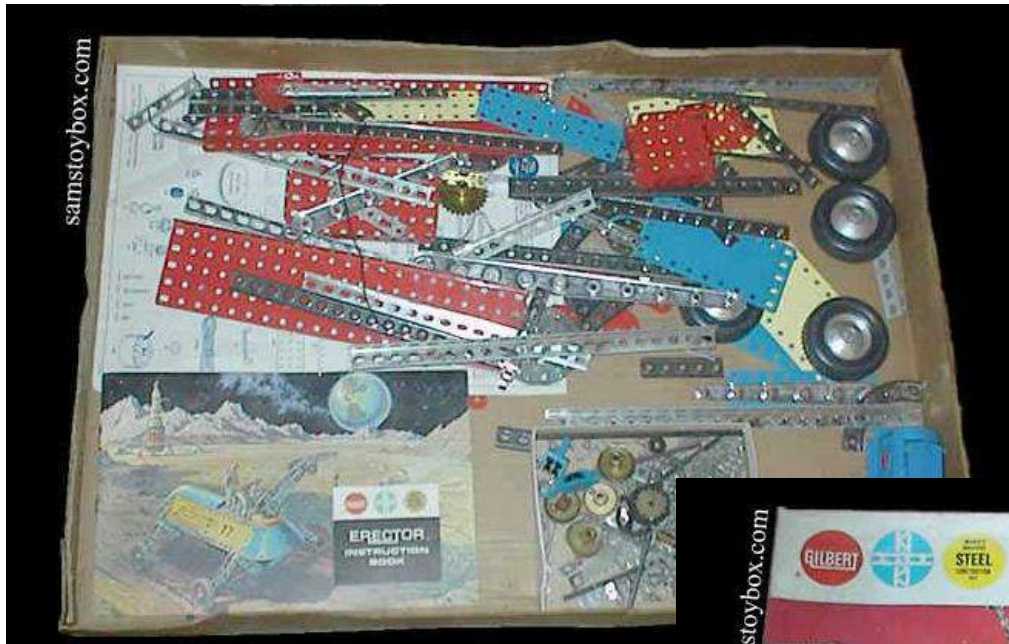
Innovation. In all domains.

Building a Complex Hardware Cost Model for Antennas

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Raytheon Space and Airborne Systems

4/13/2014

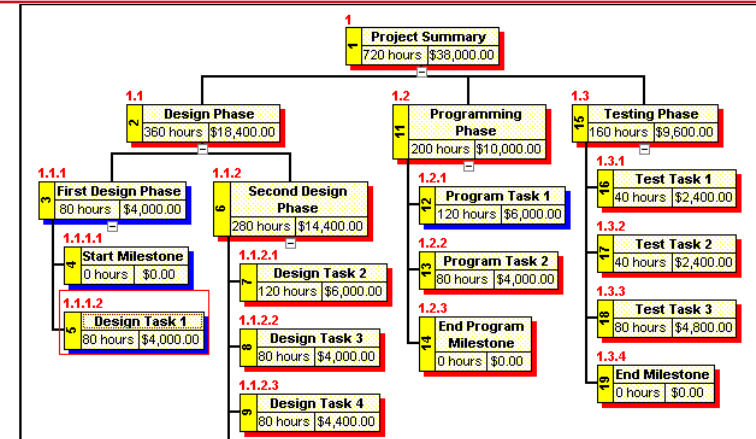
Introduction: An Erector Set Analogy



Challenges of Product Level Cost Model Development

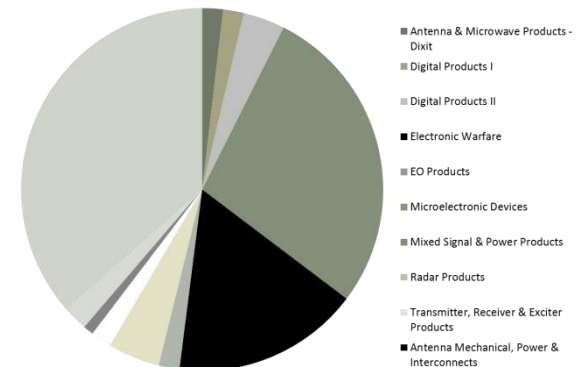
A. Government DOD Contractor Challenge (Cost)

1. Customer expects WBS
2. Engineering works to PBS
3. Must untangle cost relationship between WBS and PBS



B. Internal Organizational Challenge (Cost)

1. Matrix organizations make collecting product level costs problematic
2. Matrix organizations in flux are even more problematic
3. Must unmix organizational data from product data



C. Must Get Agreement on Cost Drivers (Size)

1. Costs are causal
2. Key size and scaling factors are causing factors

Challenge of Bidding Work With Commercial Cost Models

A. Strengths of Commercial Cost Models

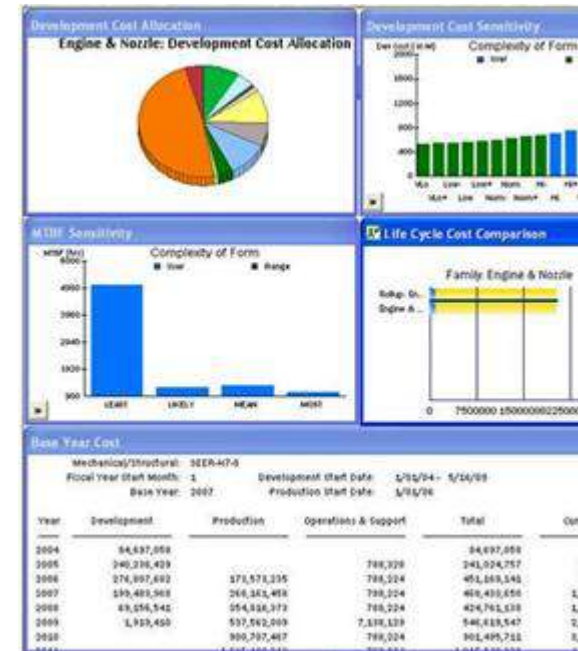
1. Great at getting the bid in the ballpark
2. Great for tops down, reduced cost, bidding
3. Great for organizing bid into PBS
4. Great for remembering the hidden costs that are often forgotten

B. Weaknesses of Commercial Cost Models

1. Strong matrix organizations argue over allotment
2. Tend to not have a good grasp on today's technology (maybe a few years old technology)
3. No flags for items with wide variance in costs tasks such as a performance threshold for ASIC
4. Jobs are performed bottoms up

C. Observations of Commercial Cost Models

1. Great for ROMs!
2. Should be calibrated for actual bids
3. Possible disconnect between bid and performance



Connecting Tops Down With Bottoms Up

A. Cost Model Connecting Gate 3 (ROM) to Gate 4 (actual bid)

1. Gate 3 ROM is organizational independent
2. Gate 4 is organizational and execution dependent
3. Cost Model must bridge this gap
4. Cost Model must also provide flags for high cost variance items that can drive architectural and performance trade offs
5. Cost and size must be based on historical actuals



B. Cost Model Connecting Gate 4 (actual bid) to Gate 5 (plan after win)

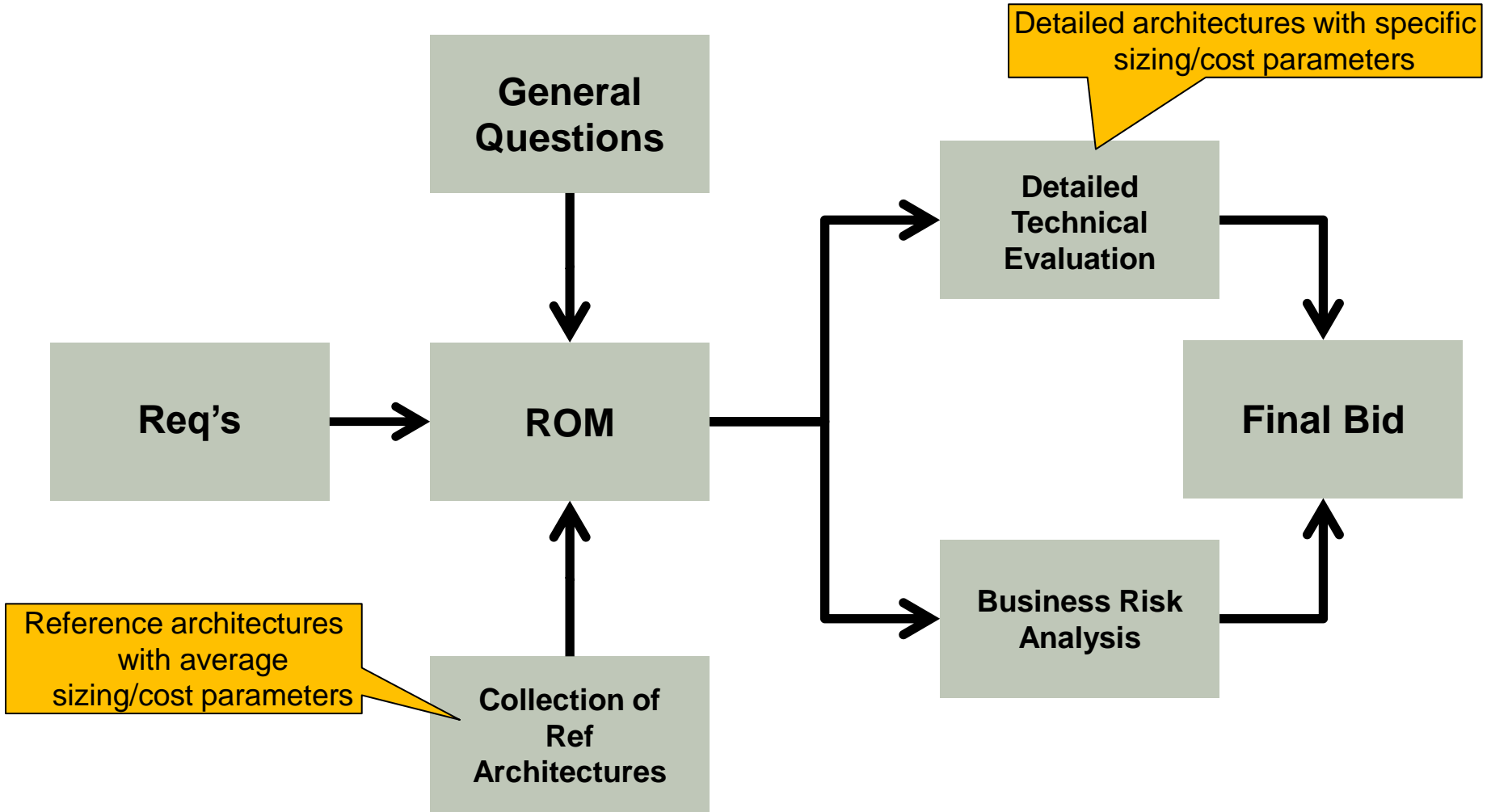
1. Must be detailed enough to provide cost details for execution plan
2. Must be flexible enough to account for organizational changes

C. Cost Connecting Gate 5 (plan after win) to Execution

1. Must apply to EACs also!
2. Must have standardized cost and size collection forms
3. Must be able to rapidly evolve with technology

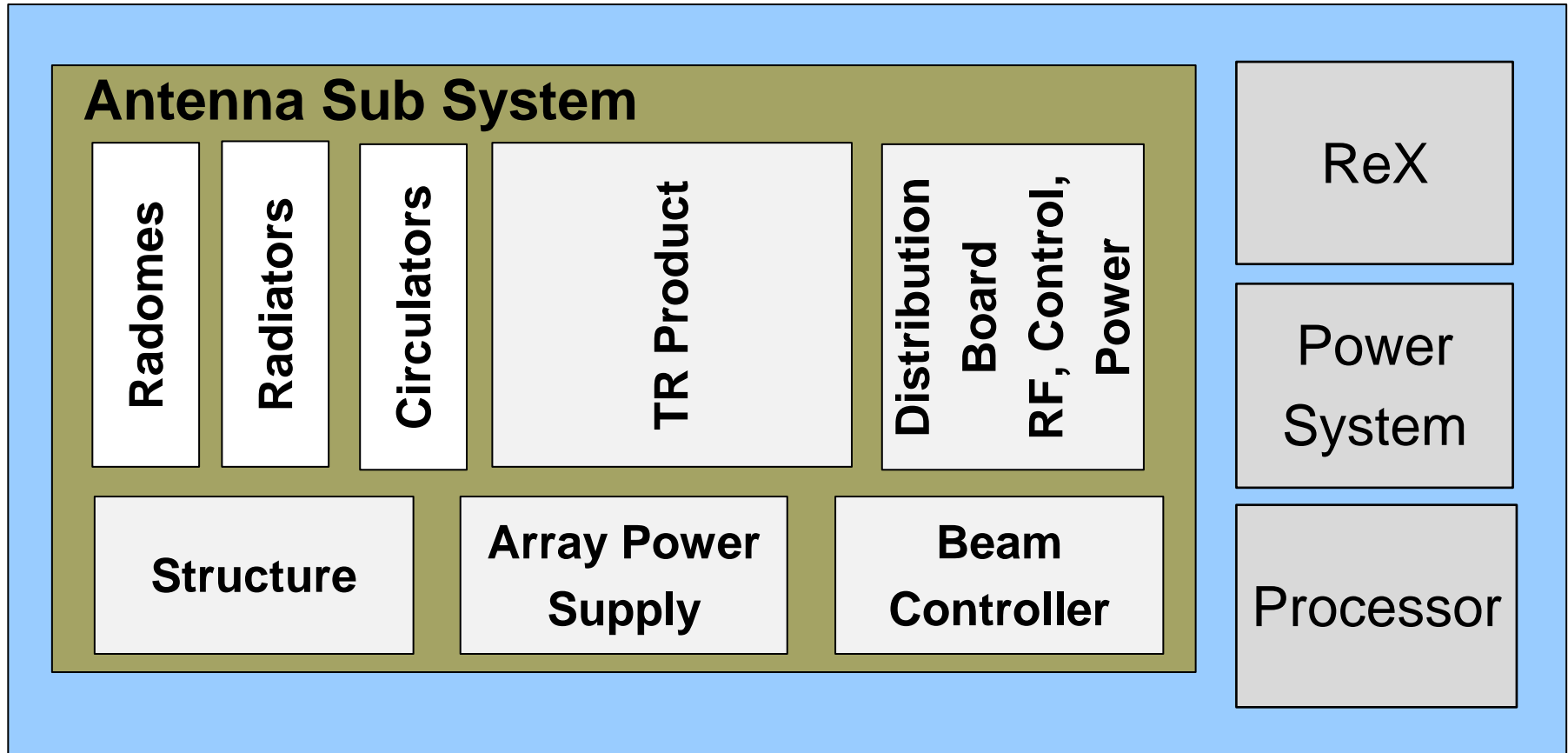


Synergistic “Bottoms Up” Cost Estimation Approach



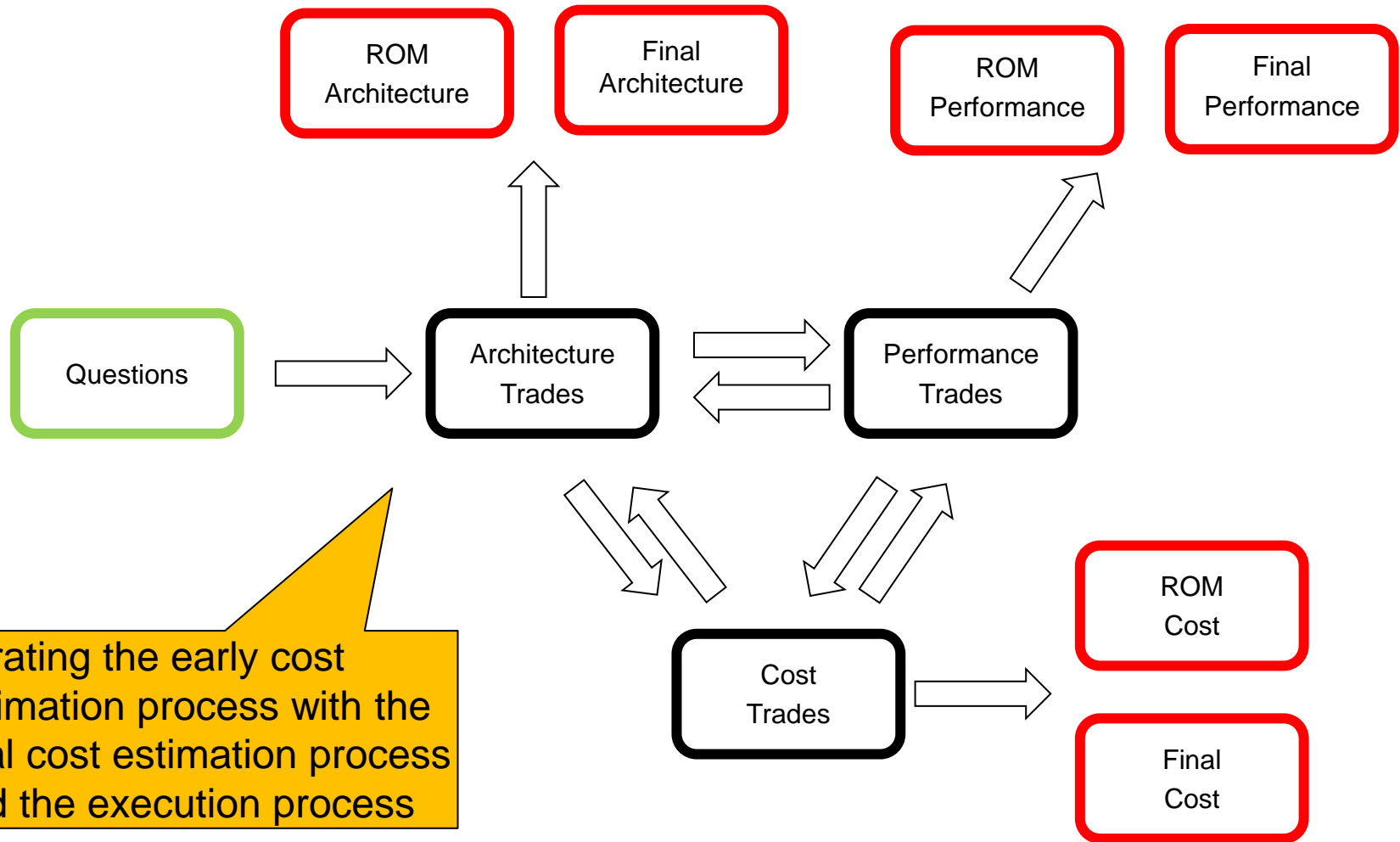
Beginning With a Standard Reference Architecture

Radar Functional Block Diagram – Generic and applicable to any Program



Consistent Product Structure

Overall Antenna Cost Estimation Process



Getting to a ROM Architecture

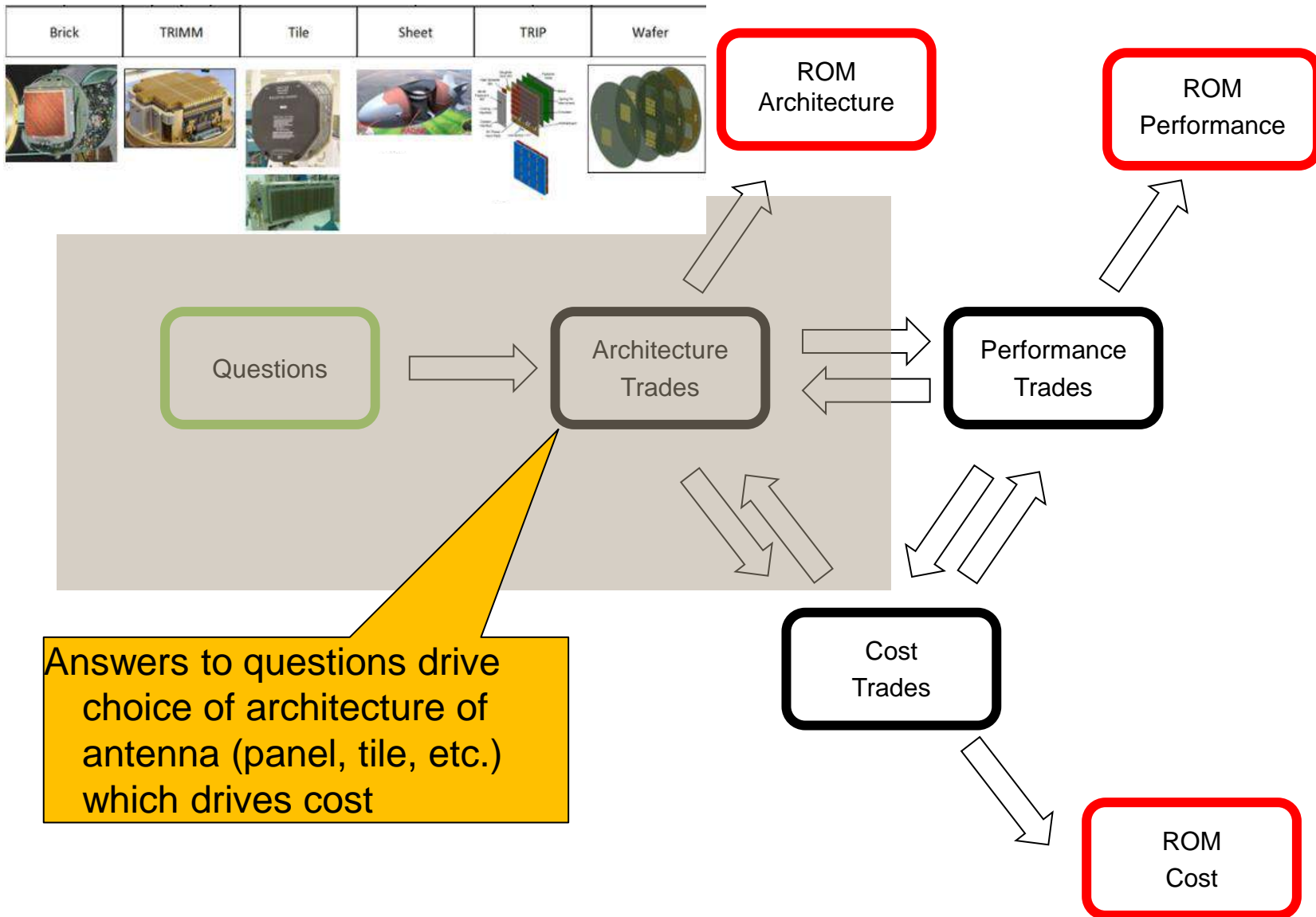


	A	B	C	D
1				
2	Requirements			
3				
4	Bandwidth & Frequency			
5		What is the tunable bandwidth	100 MHz bandwidth	1
6		What is the instantaneous bandwidth	100 MHz	2
7		Feed/distribution to the back end	Direct Feeding	3
8	erp			
9		elemental power	100 dBm	4
10		What is the number of elements	4000	5
11	swap			
12		input power (input to PCU)	100 W	6
13		cooling	100 W	7
14		weight	Normal Weight	8
15		volume (depth)	Light	9
16				
17				
18	Electrical Performance			
19		What is the NF of the Receiver	Medium	10
20		system nf	Low	11
21				
22	Architecture			
		Aperture	Large Aperture	12
		rca (cross section)	Low	13
		steerable apertures	Low	14
	BSC			
		architecture	Standard	15

Simple set of high level questions answered using rough requirements

ROM
Cost

Architectural Trade-offs



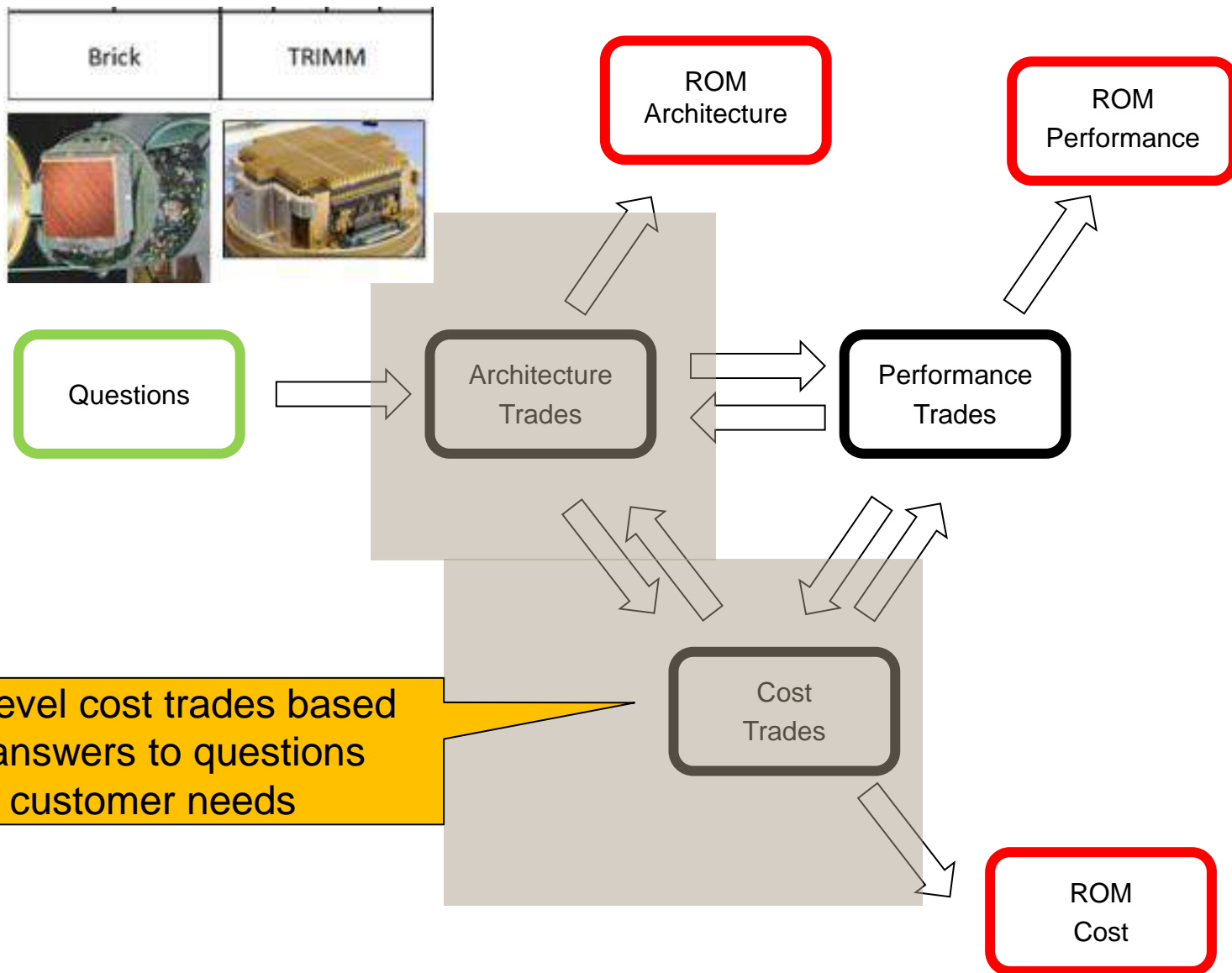
Answers to questions drive choice of architecture of antenna (panel, tile, etc.) which drives cost

Flexible Reference Architecture Key to Result

PRODUCT BASED ROM MODEL															
Requirements					Hardware Impact										
					BSC	Radiator	Radome	Array Power Supply	Power & Control Distribution	Array	Feed Network				
1															
2	Requirements					Hardware Impact									
3						BSC	Radiator	Radome	Array Power Supply	Power & Control Distribution	Array	Feed Network			
4	Bandwidth & Frequency					Standard base	Standard base	Standard base	Standard base	Standard base	Standard base	Standard base			
5		What is the tunable bandwidth	100% (100-1000)	1											
6		What is the instantaneous bandwidth	100% (100-1000)	2											
7		Feed/distribution to the back end	Standard structure	3	Additional Memory	Standard structure	High efficiency	Higher efficiency components	Higher efficiency cooling	Standard design	High efficiency filter				
8	erp	elemental power	100 dBm	4	Phase 10 PPSM 2 amplifier phase and TC	High efficiency		More eff. air cooled	More eff. air cooled	Standard filter	High efficiency filter				
10		What is the number of elements	4000	5											
11	swap	input power (input to PCU)	100 kW	6	Power 100W										
12		cooling	100 kW	7											
14		weight	Standard weight	8											
15		volume (depth)	Light	9											
18	Electrical Performance														
19		What is the NF of the Receiver	Standard	10											
20		system nf	Standard	11											
22	Architecture														
24		Aperture	Standard	12											
25		rcs (cross section)	Standard	13											
26		steerable apertures	Standard	14											
27	BSC	architecture	Standard	15											

Specific antenna architecture with specific sub products related to that architecture with average cost driving parameters

Still Top Down Cost Estimation

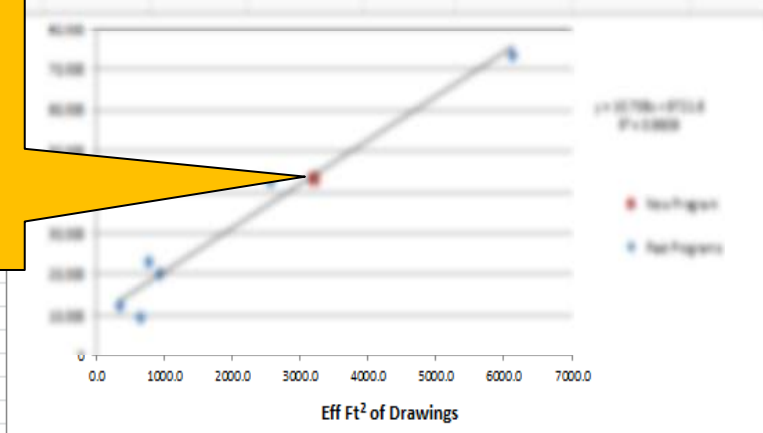


High level cost trades based on answers to questions and customer needs

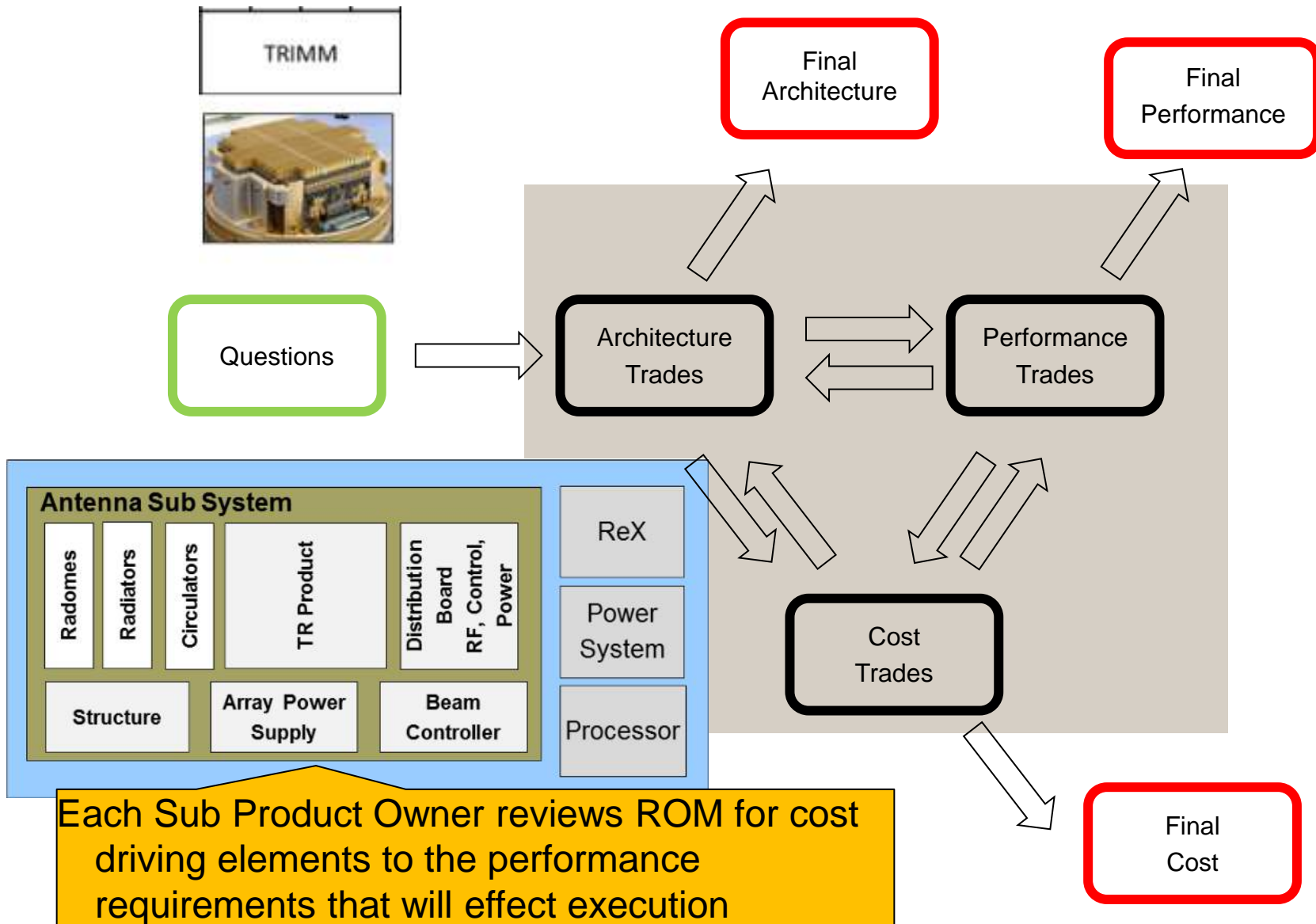
Result of the ROM Bidding Process

	A	B	C	D	E	F	G	H	I
	Antenna	Hrs	Total Drawing SQ FT	Rad. Element Count	Productivity Hrs/sqft drawing	Scale Factor	Effective SQ FT Drawings	Effective Productivity Hrs/eDrawing	Frequency of band
2	Antenna Program	1000	1000	100	100	1	1000	1000	1 Band
3	Antenna	2000	2000	200	200	1	2000	2000	1 Band
4	Antenna	3000	3000	300	300	1	3000	3000	1 Band
5	Antenna	4000	4000	400	400	1	4000	4000	1 Band
6	Antenna	5000	5000	500	500	1	5000	5000	1 Band
7	Antenna	6000	6000	600	600	1	6000	6000	1 Band
8	Antenna	7000	7000	700	700	1	7000	7000	1 Band
9	Antenna	8000	8000	800	800	1	8000	8000	1 Band
10	Antenna	9000	9000	900	900	1	9000	9000	1 Band
11	Antenna	10000	10000	1000	1000	1	10000	10000	1 Band
12	Antenna	11000	11000	1100	1100	1	11000	11000	1 Band
13	Antenna	12000	12000	1200	1200	1	12000	12000	1 Band
14	Antenna	13000	13000	1300	1300	1	13000	13000	1 Band
15	Antenna	14000	14000	1400	1400	1	14000	14000	1 Band
16	Antenna	15000	15000	1500	1500	1	15000	15000	1 Band
17	Antenna	16000	16000	1600	1600	1	16000	16000	1 Band
18	Antenna	17000	17000	1700	1700	1	17000	17000	1 Band
19	Antenna	18000	18000	1800	1800	1	18000	18000	1 Band
20	Antenna	19000	19000	1900	1900	1	19000	19000	1 Band
21	Antenna	20000	20000	2000	2000	1	20000	20000	1 Band

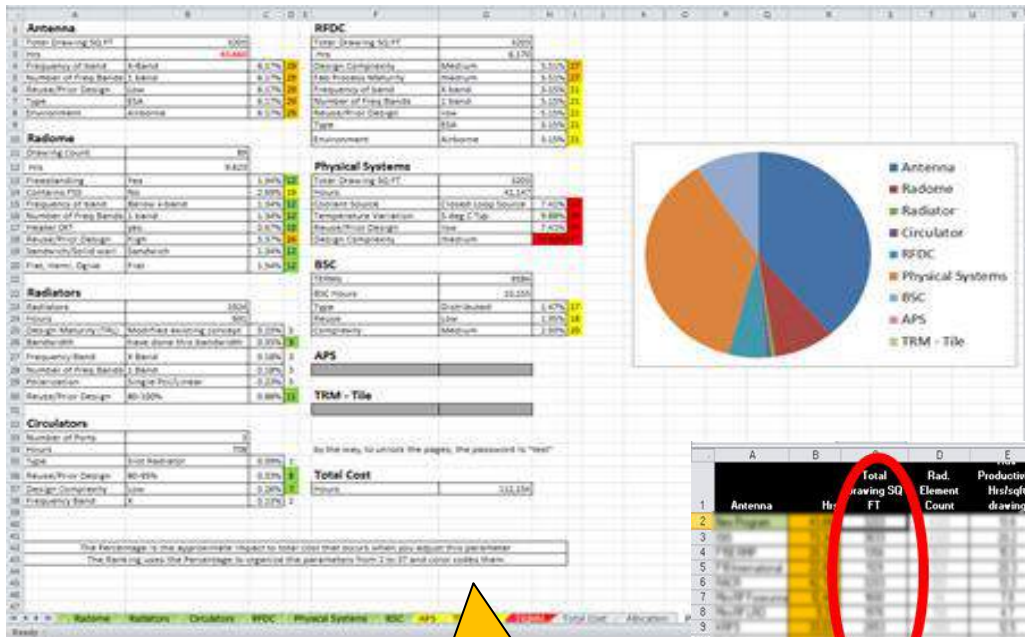
Effort results in a ROM cost estimate that is put in context of historical actuals of previous antenna programs in the data base



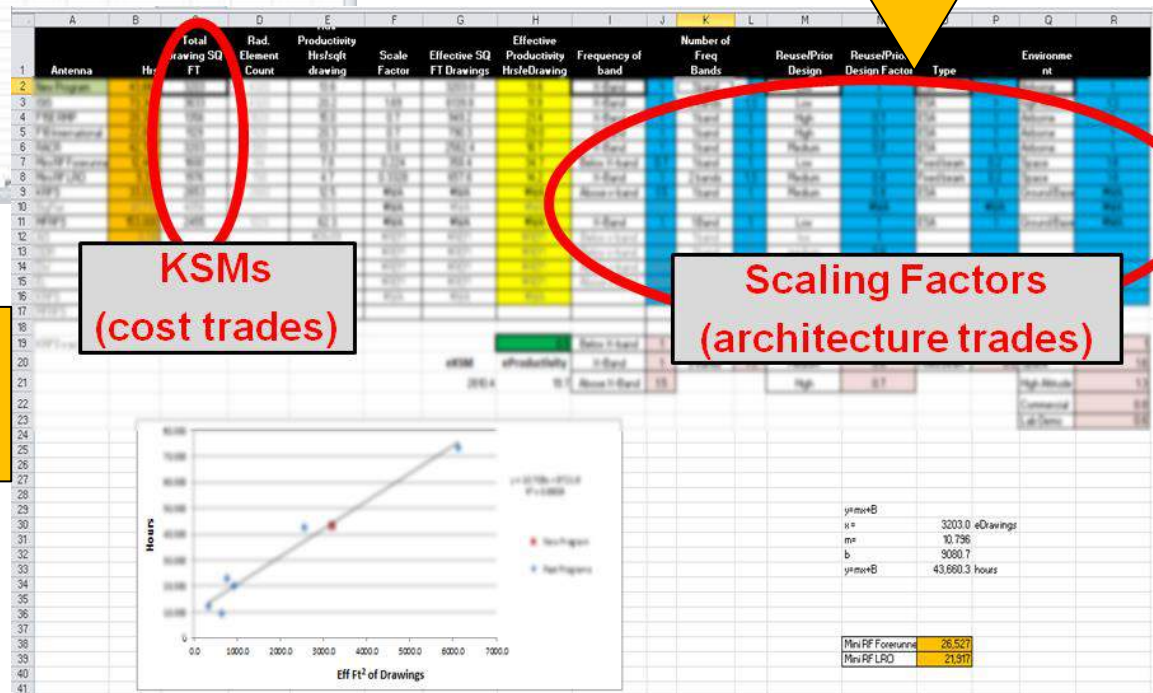
Moving to the Final Cost Estimate



Expert Review of the ROM Cost Estimate

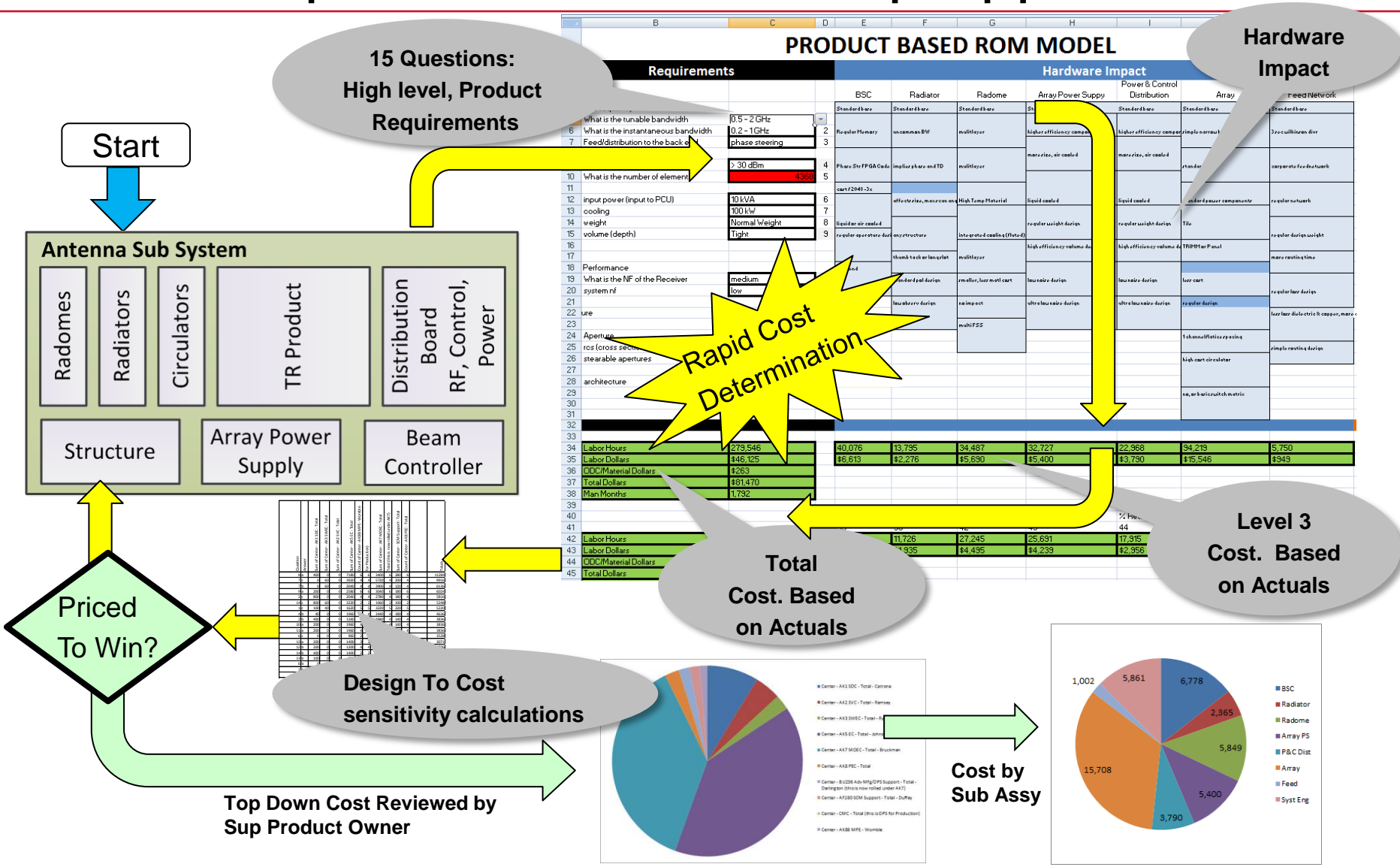


Pre-populated size factors of each subproduct from the ROM is now reviewed in detail for applicability to the final bid



Cost Model maintains running bid total of updated subproduct cost information

Review Tops Down, Bottoms Up Approach

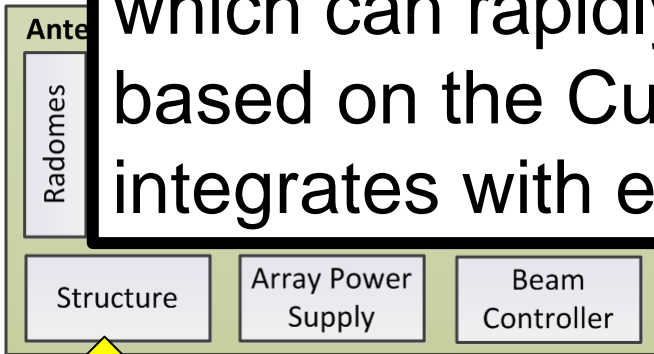


Cost Models – Tops Down, Model Based bidding

15 Questions:
High level, Product Requirements

Hardware Impact

The Cost Model tool is an interactive tool which can rapidly determine cost of hardware based on the Customer's requirements and integrates with execution team



PRODUCT BASED ROM MODEL

Requirements	Hardware Impact					
	BSC	Radiator	Radome	Array Power Supply	Power & Control Distribution	Array
Standardize	Standardize	Standardize	Standardize	Standardize	Standardize	Standardize
Labor Hours	40,076	13,795	34,487	32,727	22,968	34,219
Labor Dollars	\$6,613	\$2,276	\$5,690	\$5,400	\$3,790	\$15,546
ODC/Material Dollars	\$263					
Total Dollars	\$6,876	\$2,276	\$5,690	\$5,400	\$3,790	\$15,546
Man Months	1,732					
Labor Hours	11,726	27,245	25,691	17,915		
Labor Dollars	\$3,935	\$4,495	\$4,239	\$2,356		
ODC/Material Dollars						
Total Dollars	\$3,935	\$4,495	\$4,239	\$2,356		

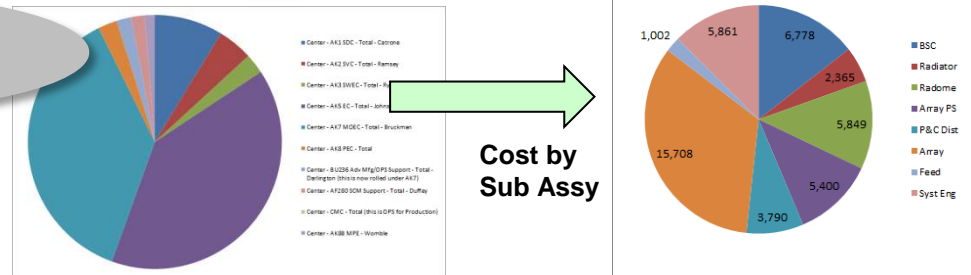


Design To Cost sensitivity calculations

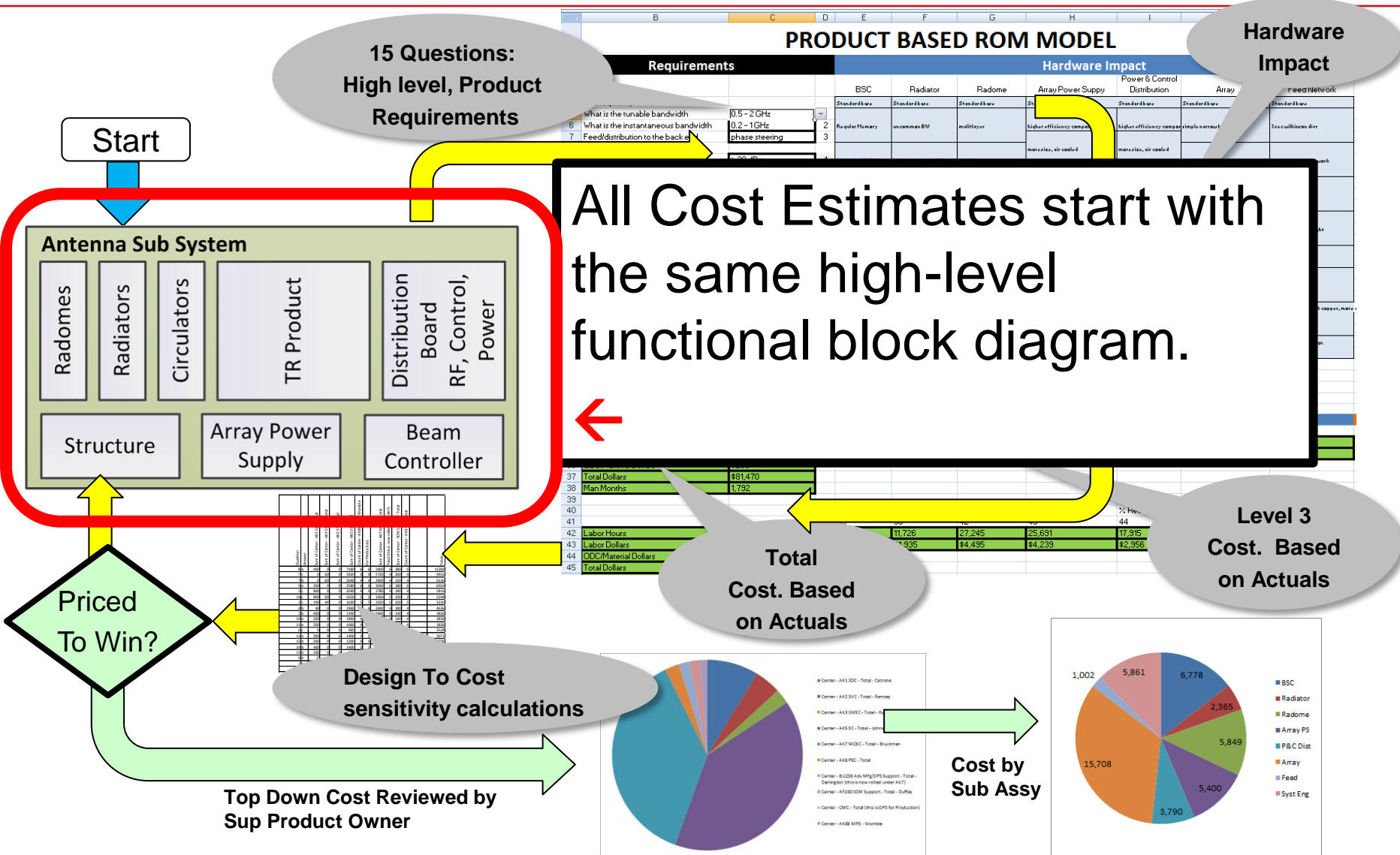
Total Cost. Based on Actuals

Level 3 Cost. Based on Actuals

Top Down Cost Reviewed by Sup Product Owner



Cost Models – Tops Down, Model Based bidding



Cost Models – Tops Down, Model Based bidding

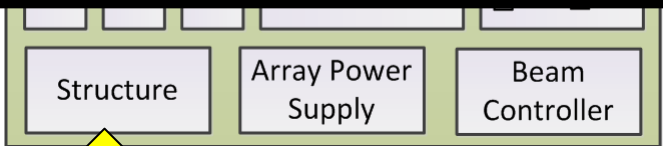
The User answers 15 simple high-level questions regarding Requirements. →

PRODUCT BASED ROM MODEL

Requirements	BSC	Radiator	Radome	Array Power Supply	Power & Control Distribution	Array	Feed Network
What is the tunable bandwidth	0.5 - 2 GHz						
What is the instantaneous bandwidth	0.2 - 1 GHz						
Feed/distribution to the back	phase steering						
What is the number of elements	> 30 dBm	4388					
input power (input to PCU)	10 kVA						
cooling	100 kW						
weight	Normal Weight						
volume (depth)	Tight						
Performance							
What is the NF of the Receiver system	medium						
Aperture	low						
res losses							
steerable apertures							
architecture							

Hardware Impact

Rapid Cost Determination



Labor Hours	279,546	40,076	13,795	34,487	32,727	22,968	34,219	5,750
Labor Dollars	\$46,125	\$6,613	\$2,276	\$5,690	\$5,400	\$3,790	\$15,546	\$349
ODC/Material Dollars	\$263							
Total Dollars	\$81,470							
Man Months	1,732							

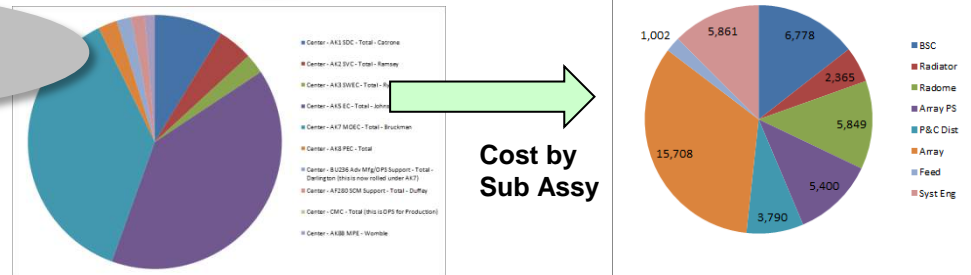
Total Cost. Based on Actuals

Level 3 Cost. Based on Actuals



Design To Cost sensitivity calculations

Top Down Cost Reviewed by Sup Product Owner



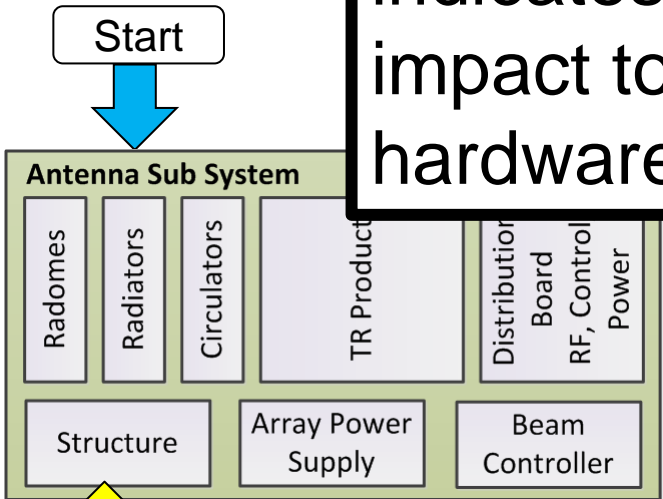
Cost Model From the answers, Model Based bidding

From the answers, the Cost Model tool indicates the impact to the hardware.

PRODUCT BASED ROM MODEL

Hardware Impact

	BSC	Radiator	Radome	Array Power Supply	Power & Control Distribution	Array	Feed Network
Standard Part	Standard Part	Standard Part	Standard Part	Standard Part	Standard Part	Standard Part	Standard Part
2	Regular Memory	uncommon BW	multilayer	higher efficiency compo	higher efficiency compo	simple network	3000mil/len dur
3	Phase Shif FPGA Coe	impiler phase an dTD	multilayer	micro size, air cooled	micro size, air cooled	rtander	corporate feed network
4	cont Z248 -2u	affictrix, micro con	High Temp Material	liquid cooled	liquid cooled	under power componen	regular network
5	liquid air cooled	regular operation dur	integrated cooling (Phase)	regular weight dur	regular weight dur	Title	regular dur
6	regular operation dur	any structure	integrated cooling (Phase)	regular weight dur	regular weight dur	Title	regular dur
7	regular operation dur	any structure	integrated cooling (Phase)	regular weight dur	regular weight dur	Title	regular dur
8	regular operation dur	any structure	integrated cooling (Phase)	regular weight dur	regular weight dur	Title	regular dur
9	regular operation dur	any structure	integrated cooling (Phase)	regular weight dur	regular weight dur	Title	regular dur



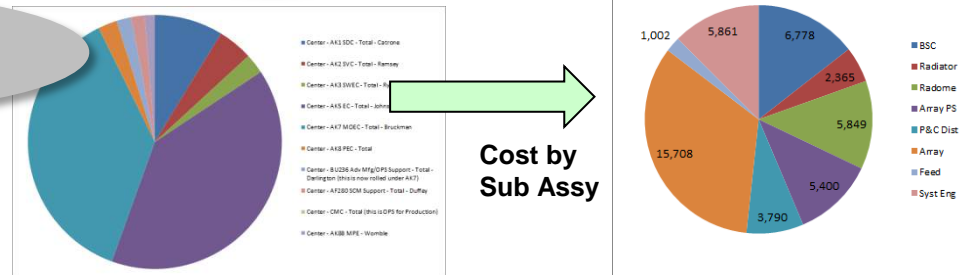
Rapid Cost Determination

20	system inf	low					
21	ure						
22							
23							
24	Aperture						
25	ros (loss spec)						
26	steerable apertures						
27							
28	architecture						
29							
30							
31							
32							
33							
34	Labor Hours	279,546	40,076	13,795	34,487	32,727	22,968
35	Labor Dollars	\$46,125	\$6,613	\$2,276	\$5,690	\$5,400	\$3,790
36	ODC/Material Dollars	\$263					
37	Total Dollars	\$81,470					
38	Man Months	1,732					
39							
40							
41							
42	Labor Hours		11,726	27,245	25,691	17,915	
43	Labor Dollars		\$3,935	\$4,495	\$4,239	\$2,956	
44	ODC/Material Dollars						
45	Total Dollars						

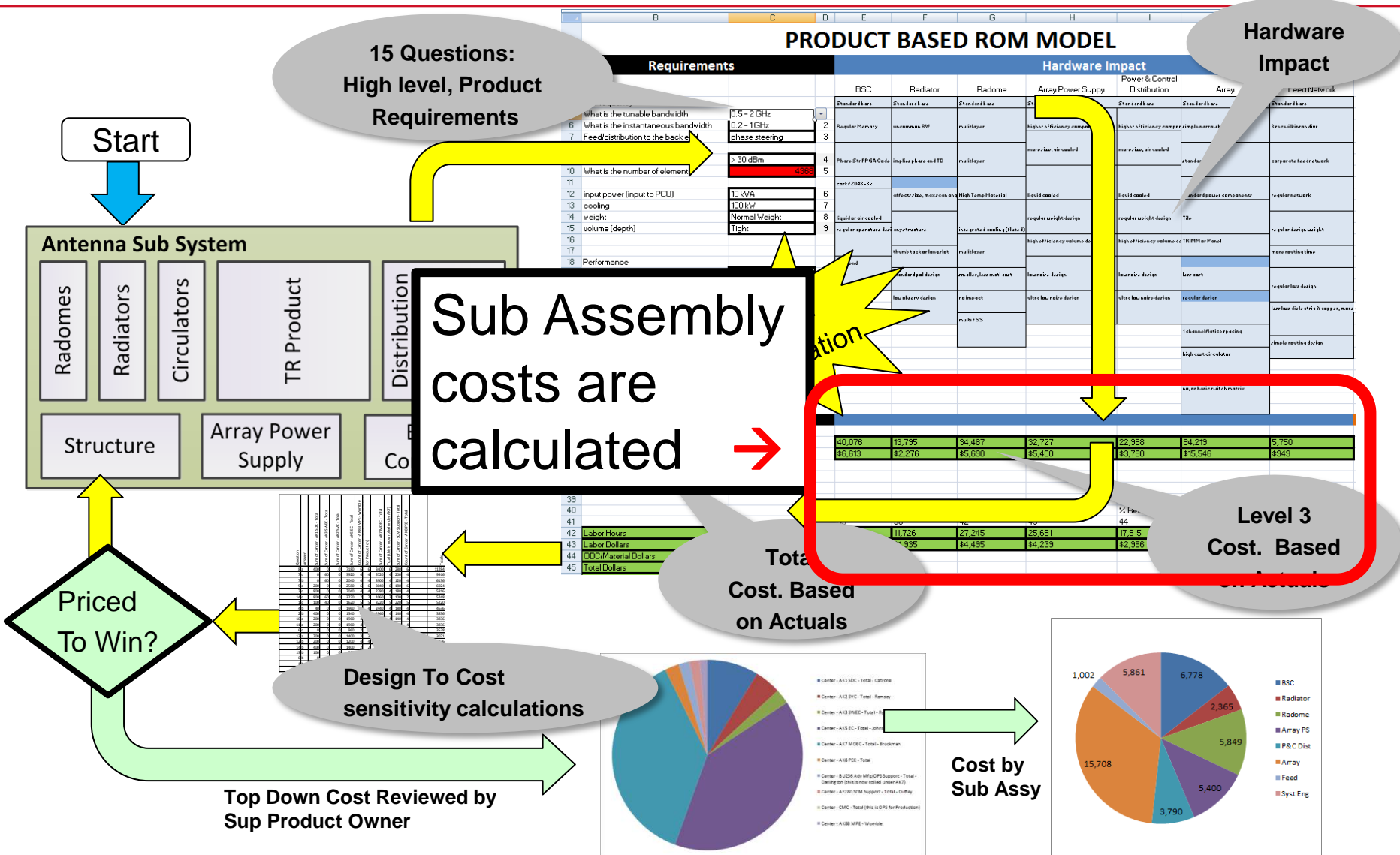
Priced To Win?

Design To Cost sensitivity calculations

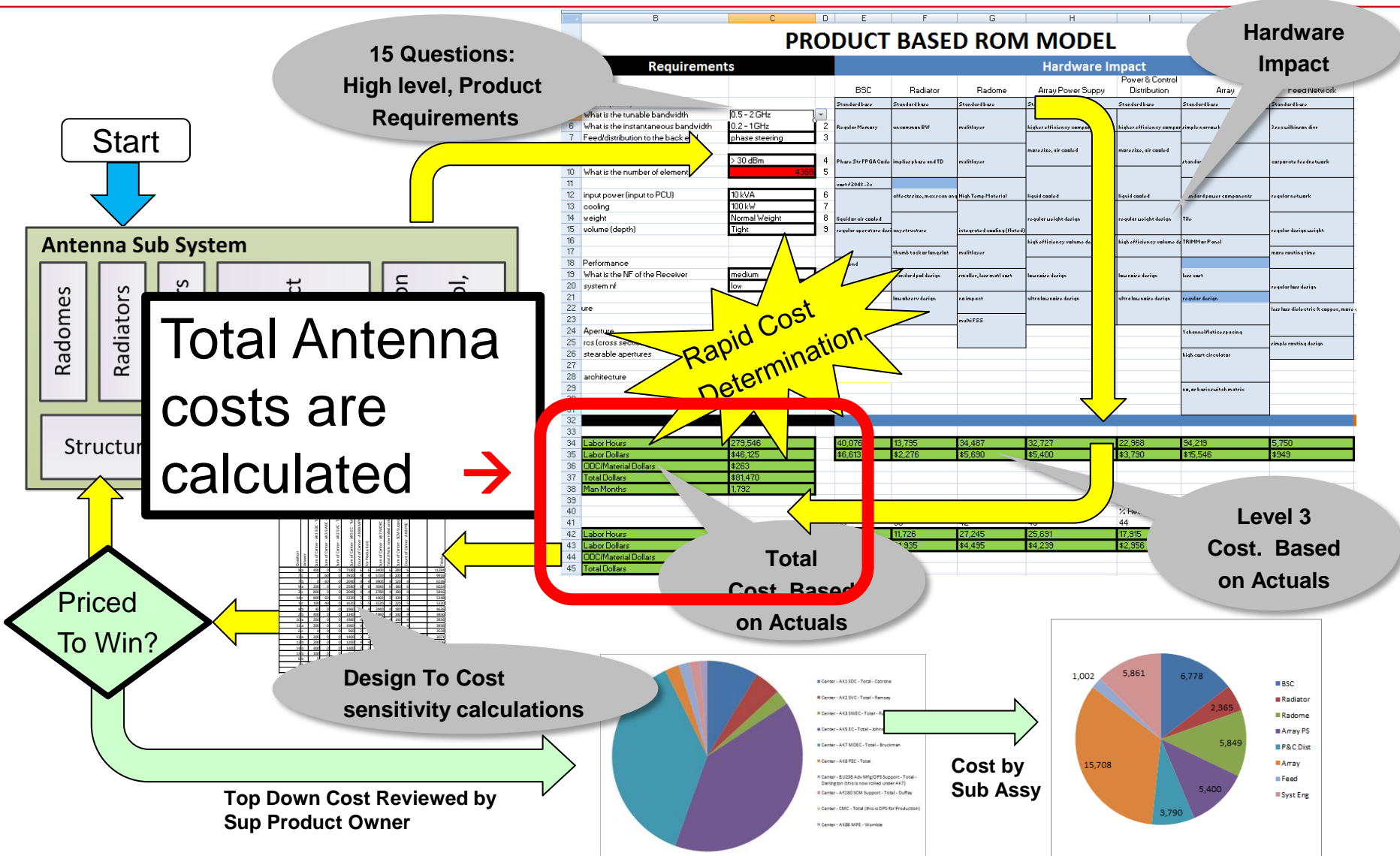
Top Down Cost Reviewed by Sup Product Owner



Cost Models – Tops Down, Model Based bidding



Cost Models – Tops Down, Model Based bidding



Cost Models – Tops Down, Model Based bidding

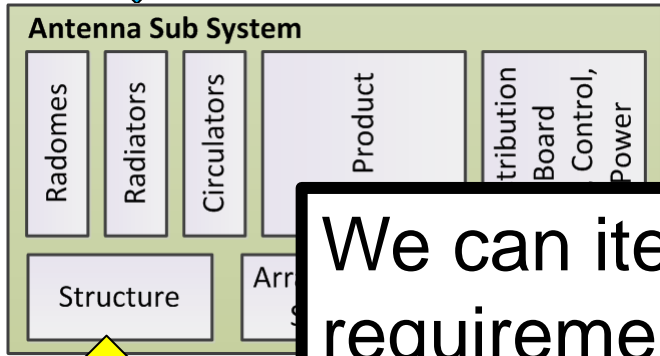
15 Questions:
High level, Product
Requirements

Hardware
Impact

PRODUCT BASED ROM MODEL

Requirements	Hardware Impact					
	BSC	Radiator	Radome	Array Power Supply	Power & Control Distribution	Array
1 What is the tunable bandwidth	Standard	Standard	Standard	Standard	Standard	Standard
2 What is the instantaneous bandwidth	Standard	Standard	Standard	Standard	Standard	Standard
3 Feed/distribution to the back	Standard	Standard	Standard	Standard	Standard	Standard
4 What is the number of elements	Standard	Standard	Standard	Standard	Standard	Standard
5 input power (input to PCU)	Standard	Standard	Standard	Standard	Standard	Standard
6 cooling	Standard	Standard	Standard	Standard	Standard	Standard
7 weight	Standard	Standard	Standard	Standard	Standard	Standard
8 volume (depth)	Standard	Standard	Standard	Standard	Standard	Standard
9 Performance	Standard	Standard	Standard	Standard	Standard	Standard
10 What is the NF of the Receiver system	Standard	Standard	Standard	Standard	Standard	Standard
11 structure	Standard	Standard	Standard	Standard	Standard	Standard
12 Aperture	Standard	Standard	Standard	Standard	Standard	Standard
13 cross section	Standard	Standard	Standard	Standard	Standard	Standard
14 steerable apertures	Standard	Standard	Standard	Standard	Standard	Standard

Start



We can iterate the requirements until we are Priced To Win

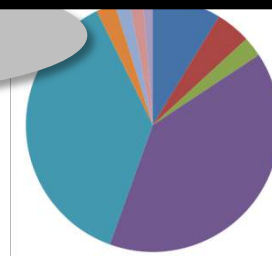
Rapid Cost Iteration

Level 3
Cost. Based
on Actuals

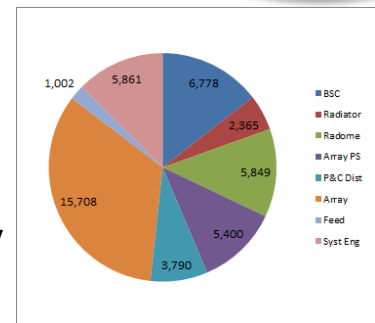
Priced To Win?

Design To Cost
sensitivity calculations

Top Down Cost Reviewed by
Sup Product Owner



Cost by
Sub Assy



Concluding Comments

■ Strengths

- Integrated ROM/Final Bid/Execution planning
- Historical Actuals based
- Organizational roles accounted
- Quantitative complexity factors
- Very fast
- Accuracy

■ Weaknesses

- Data collection burdensome
- What is easy to use is also easy to abuse

Backup and alternative slides