

The background of the slide features a vibrant sunset or sunrise over a body of water. The sun is a bright yellow orb on the horizon, casting a long, shimmering reflection across the dark blue water. The sky is filled with wispy clouds, and the overall color palette is dominated by blues, yellows, and oranges.

Air  
Land  
Sea  
Space  
Cyberspace

Innovation. In all domains.

## **Building a Complex Hardware Cost Model for Antennas**

David Bloom and Danny Polidi  
Raytheon Space and Airborne Systems

4/13/2014

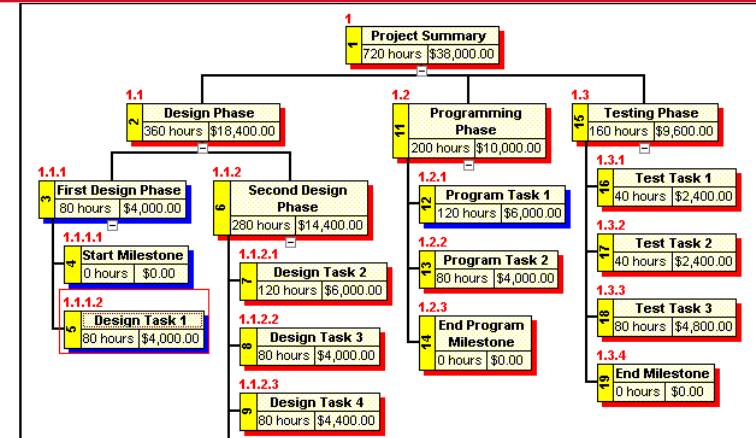
# Introduction: An Erector Set Analogy



# Challenges of Product Level Cost Model Development

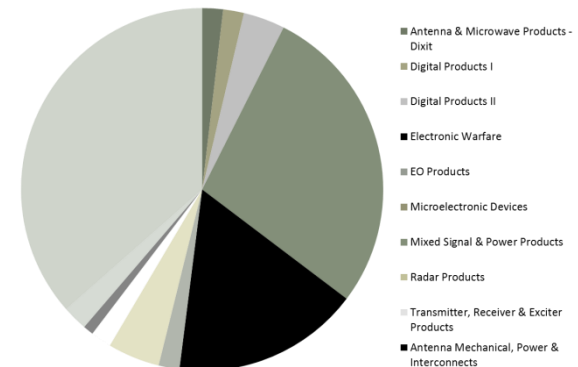
## A. Government DOD Contractor Challenge (Cost)

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

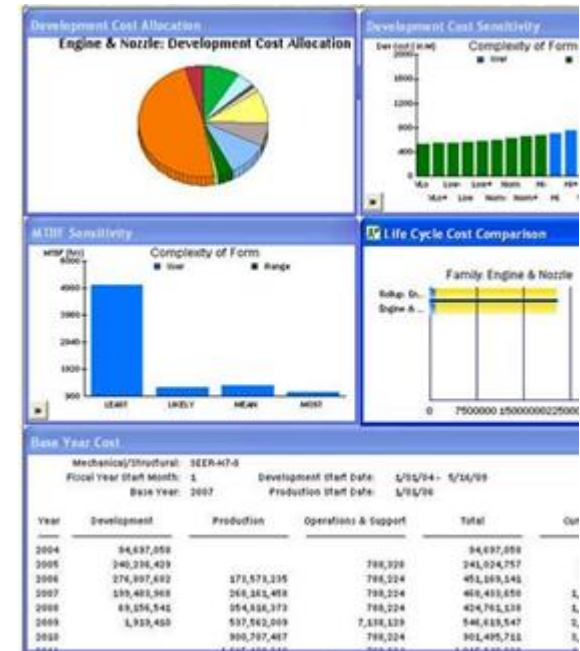
1. Great at getting the bid in the ballpark
2. Great for tops down, reduced cost, bidding
3. Great for organizing bid into PBS
4. Great for remembering the hidden costs that are often forgotten

## 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 ASICs
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

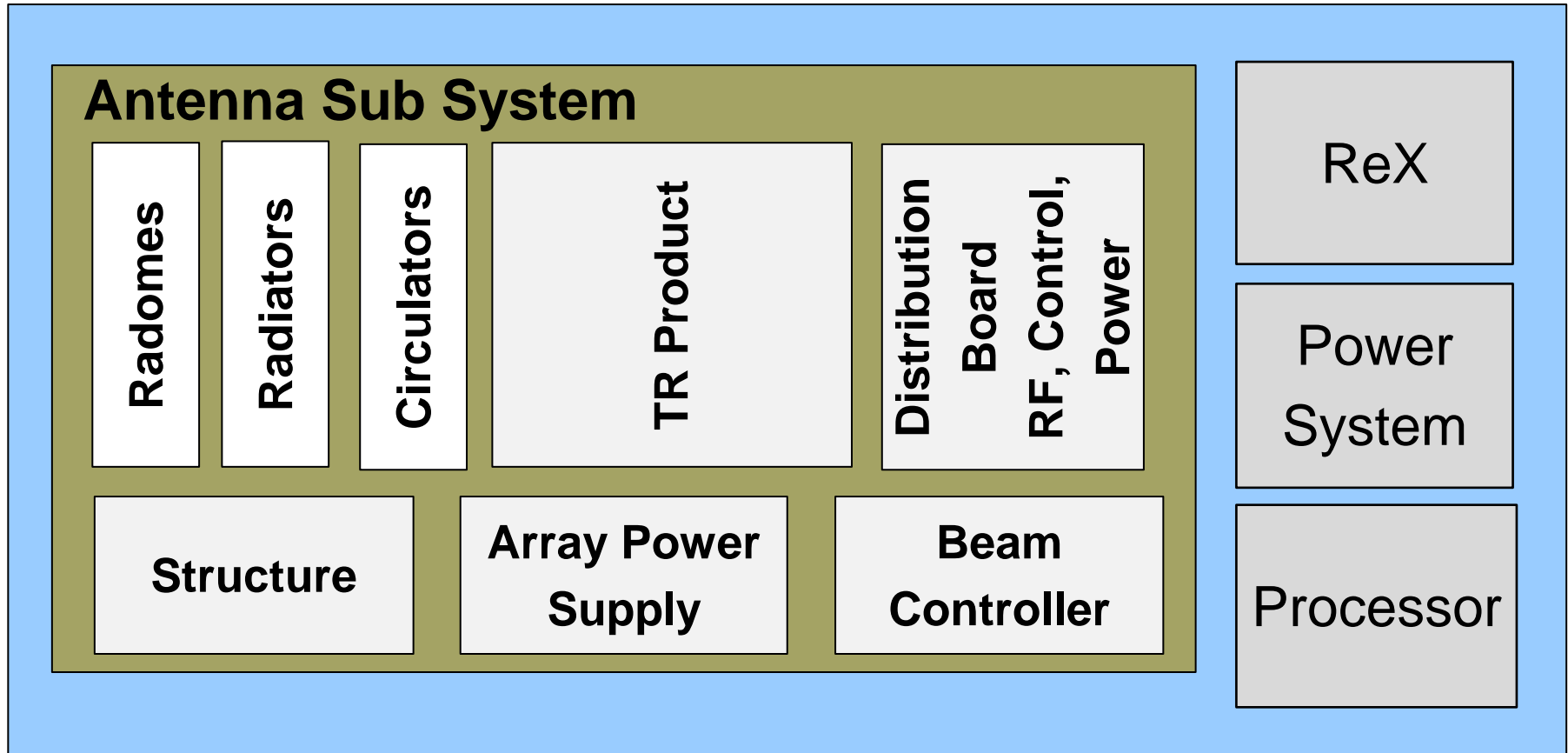
## C. Cost Connecting Gate 5 (plan after win) to Execution

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



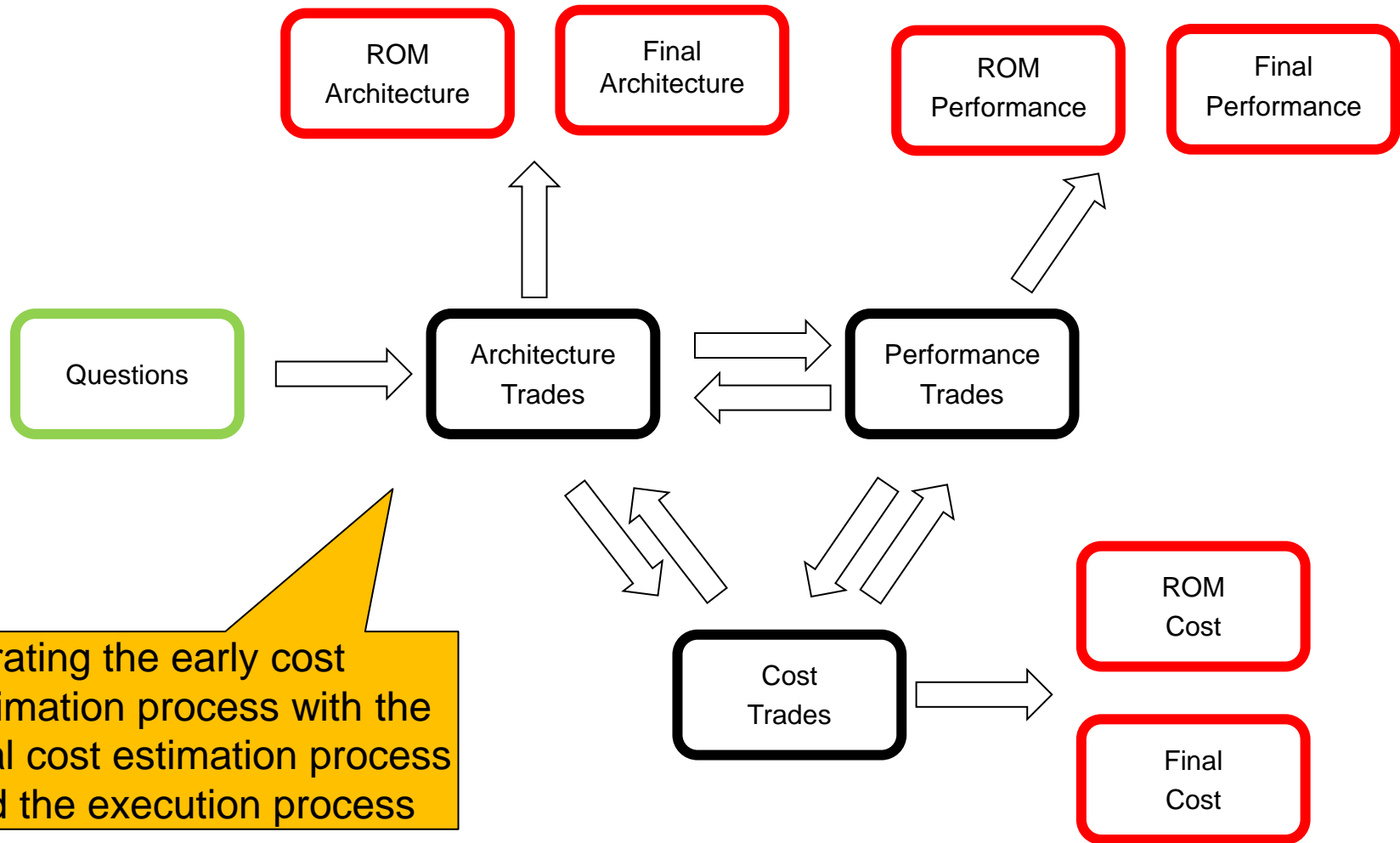
# Beginning With a Standard Reference Architecture

Radar Functional Block Diagram – Generic and applicable to any Program

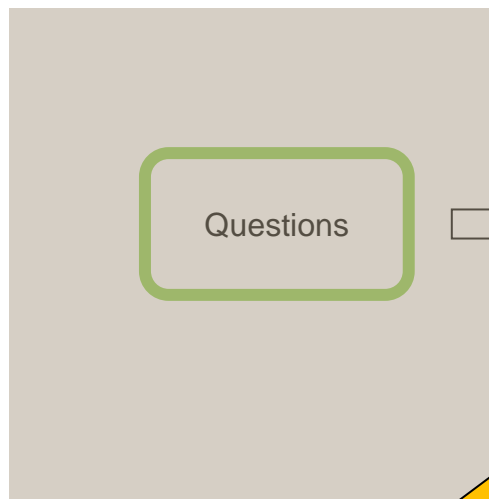


**Consistent Product Structure**

# Overall Antenna Cost Estimation Process



# Getting to a ROM Architecture

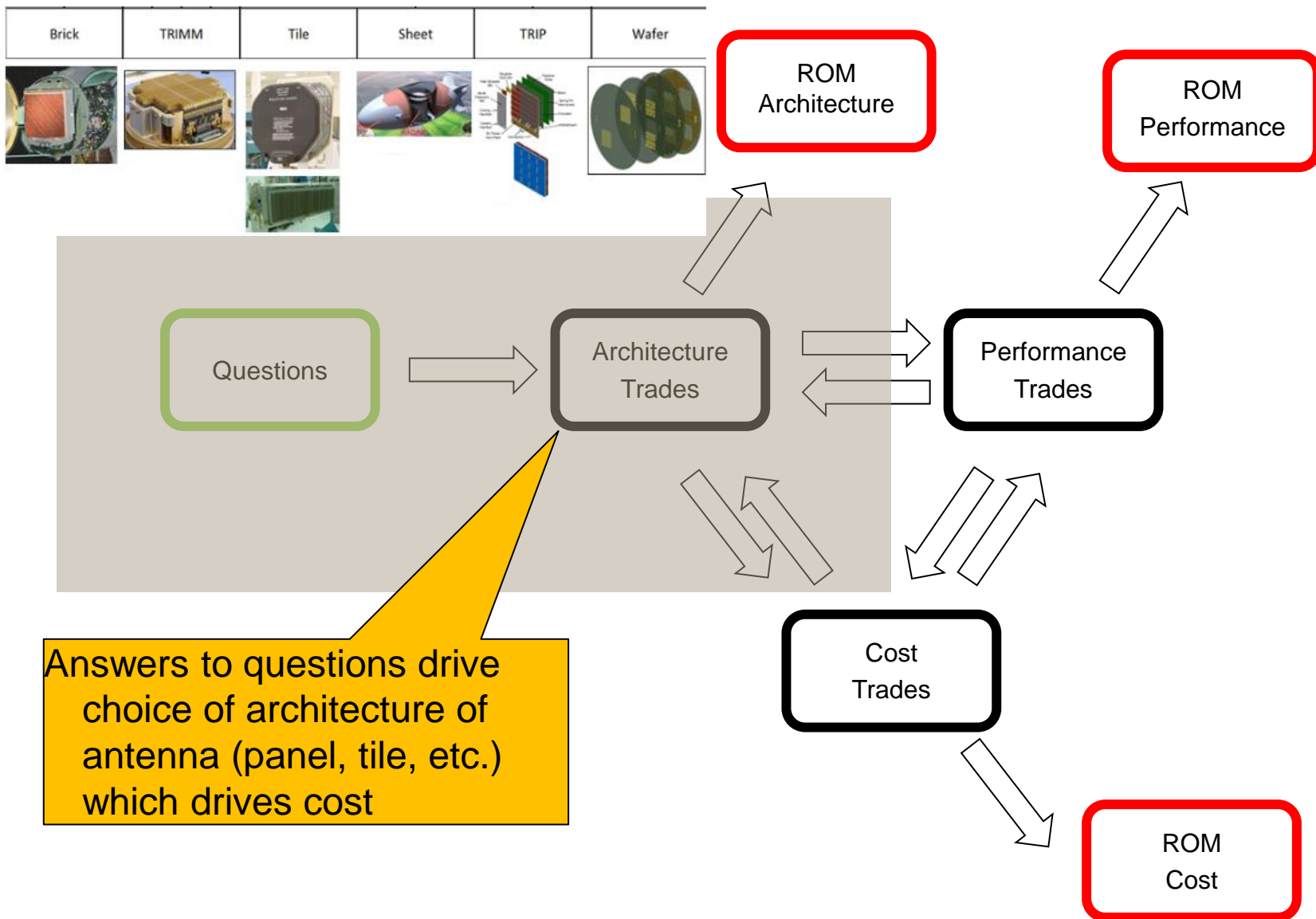


	A	B	C	D
1				
2	<b>Requirements</b>			
3				
4	<b>Bandwidth &amp; Frequency</b>			
5		What is the tunable bandwidth	10-100 MHz	1
6		What is the instantaneous bandwidth	10-100 MHz	2
7		Feed/distribution to the back end	Direct Feeding	3
8	erp			
9		elemental power	100 dBm	4
10		What is the number of elements	4000	5
11	swap			
12		input power (input to PCU)	10 W	6
13		cooling	10 W	7
14		weight	1000 g	8
15		volume (depth)	10 cm	9
16				
17				
18	<b>Electrical Performance</b>			
19		What is the NF of the Receiver	10 dB	10
20		system nf	10 dB	11
21				
22	<b>Architecture</b>			
		Aperture	100 cm	12
		rca (cross section)	100 cm	13
		steerable apertures	100 cm	14
	BSC			
		architecture	100 cm	15

Simple set of high level questions answered using rough requirements

ROM  
Cost

# Architectural Trade-offs



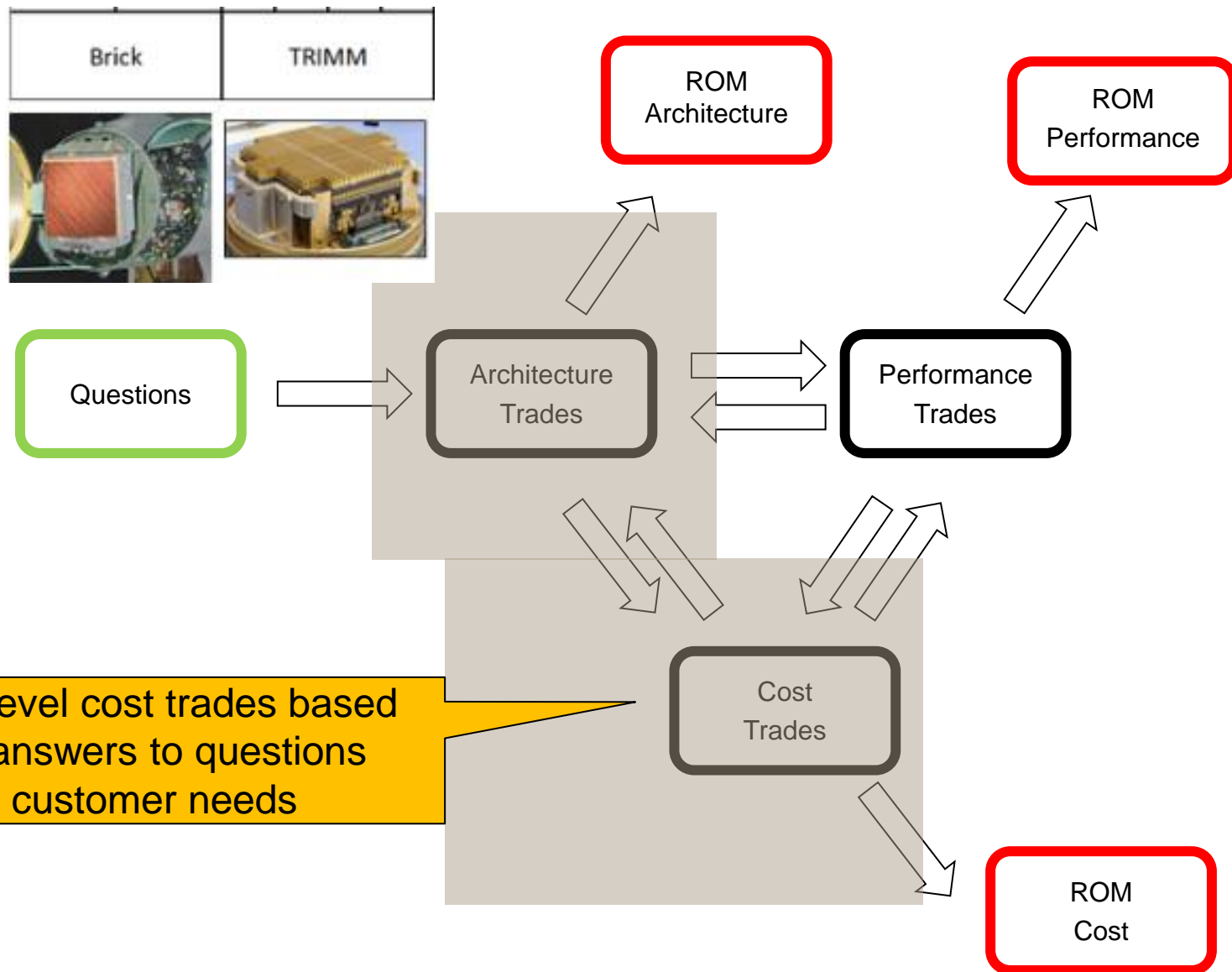
Answers to questions drive choice of architecture of antenna (panel, tile, etc.) which drives cost

# Flexible Reference Architecture Key to Result

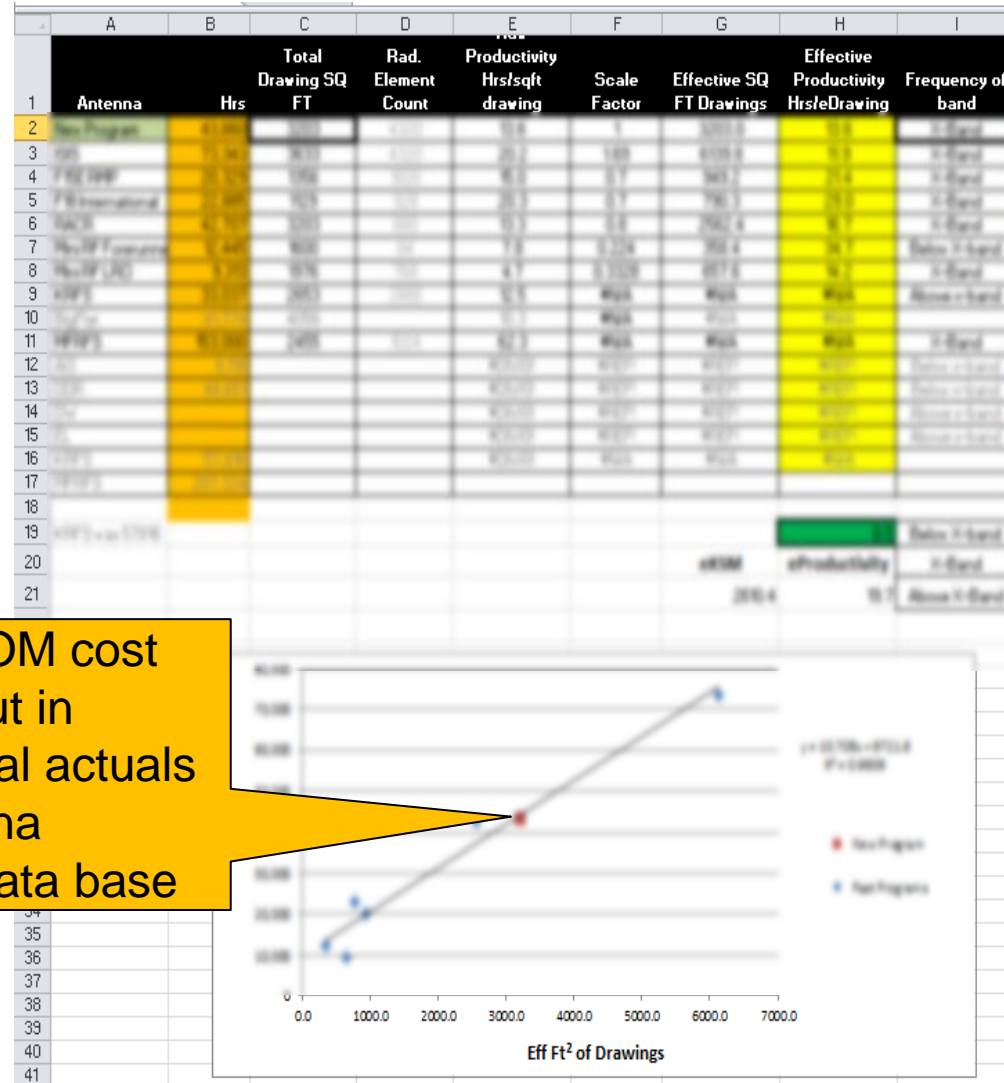
PRODUCT BASED ROM MODEL										
Requirements				Hardware Impact						
				BSC	Radiator	Radome	Array Power Supply	Power & Control Distribution	Array	Feed Network
1	Bandwidth & Frequency			Standard	Standard	Standard	Standard	Standard	Standard	Standard
2	What is the tunable bandwidth	10-20% bandwidth	1							
3	What is the instantaneous bandwidth	10-20% BW	2				Higher efficiency components	Higher efficiency cooling		
4	Feed/distribution to the back end	Standard structure	3	Additional Memory	Standard structure	High Multiplier			Standard Design	Low efficiency design
5	erp						More size, air cooled	More size, air cooled		
6	elemental power	1-10 dBm	4	Phase Shift (PPM) Compensator phase and TD	Multiplier				Standard BCU	Integrated feedthrough
7	What is the number of elements	4000	5							
8	swap									
9	input power (input to PCU)	10-20W	6		efficiency size, heat sink	High Temp Material	Heat cooled	Heat cooled	Standard power components	Regular network
10	cooling	100-200 W	7							
11	weight	Standard Weight	8	Heat or air cooled			Regular weight design	Regular weight design	70%	
12	volume (depth)	Light	9	Regular operation in any situation		Integrated cooling (Water)				Regular design weight
13							High efficiency volume design	High efficiency volume	70% or Phase	
14										More cooling size
15										
16										
17										
18	Electrical Performance									
19	What is the NF of the Receiver	Standard	10	Standard	Standard	Standard	Standard	Standard	Standard	Standard
20	system nf	Low	11		Standard	Standard	Standard	Standard	Standard	Standard
21										
22	Architecture									
23										
24	Aperture	Single slot	12							Standard
25	rcs (cross section)	Low	13							Standard
26	steerable apertures	Low RCS	14							High cost structure
27	BSC									
28	architecture	Standard	15							
29										
30										
31										
32										

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

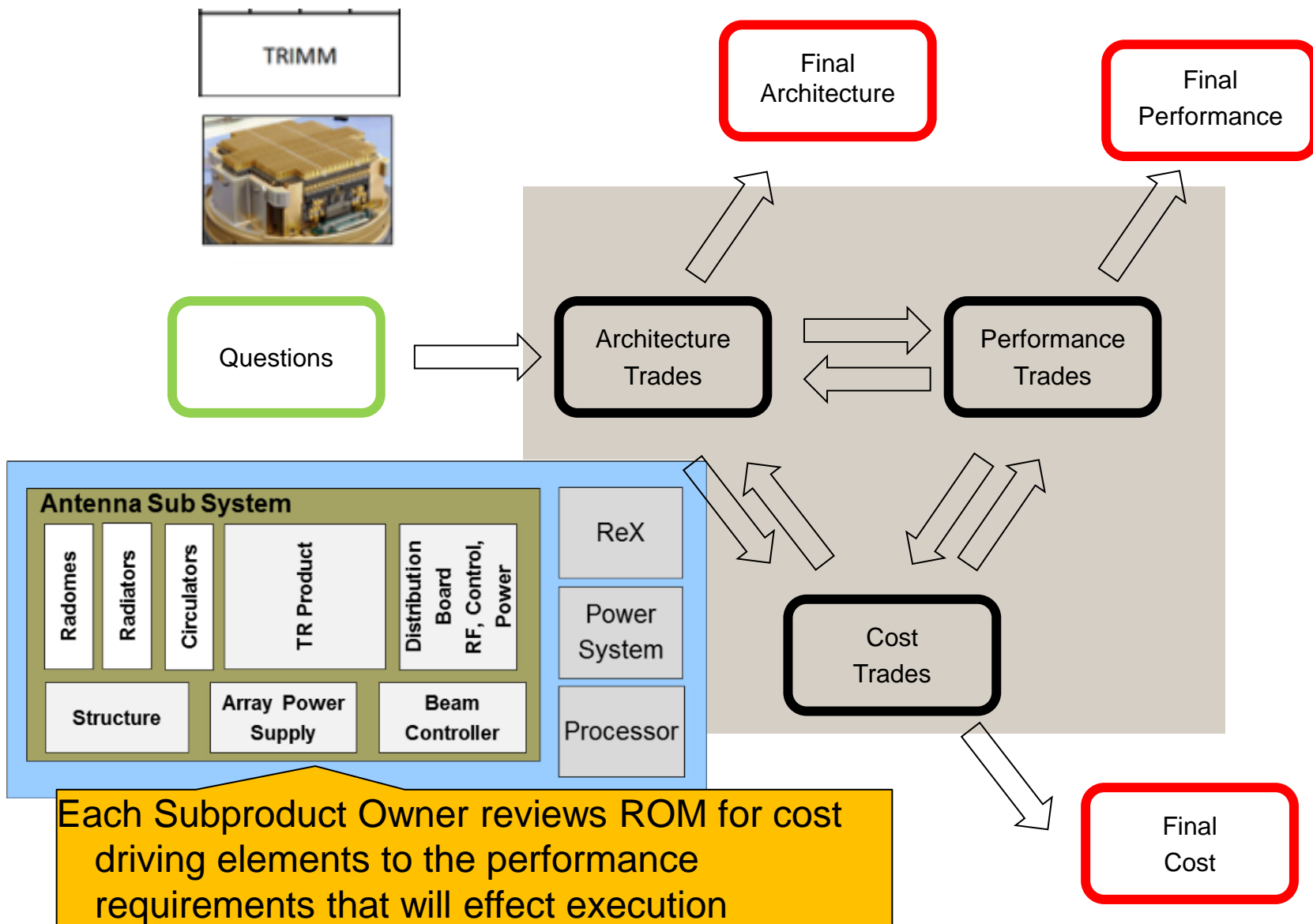
# ROM Still Top Down Cost Estimation



# Result of the ROM Bidding Process

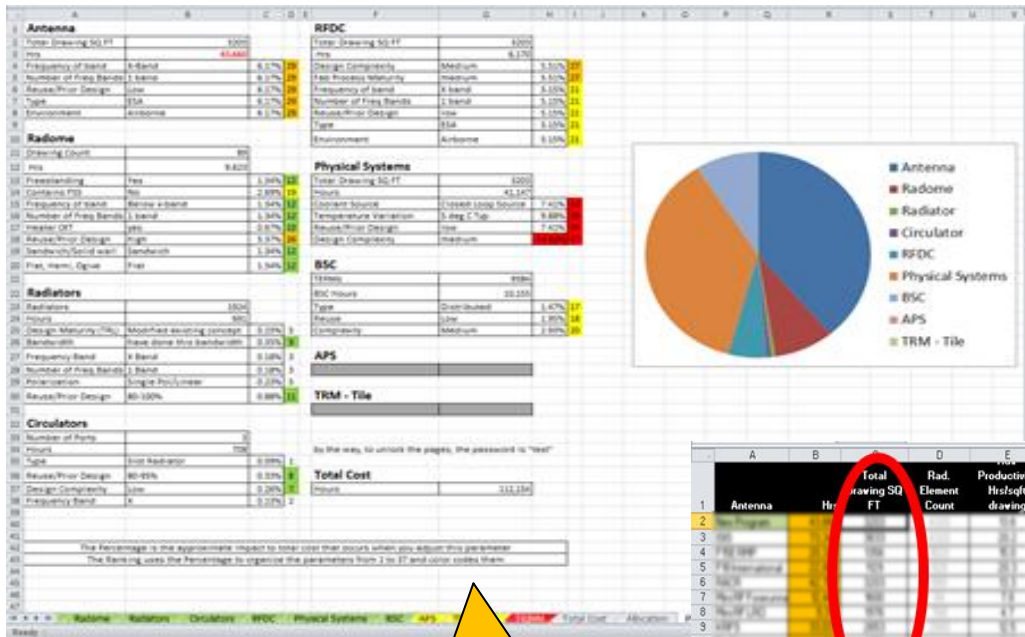


# Moving to the Final Cost Estimate

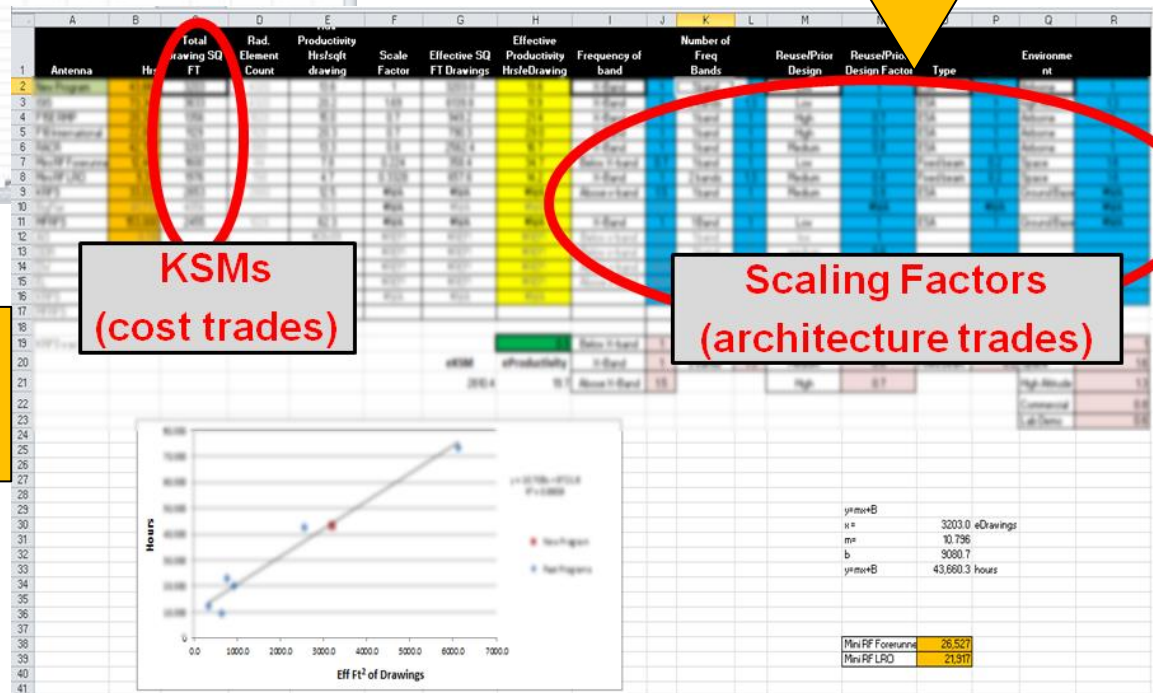


Each Subproduct Owner reviews ROM for cost driving elements to the performance requirements that will effect execution

# Expert Review of the ROM Cost Estimate



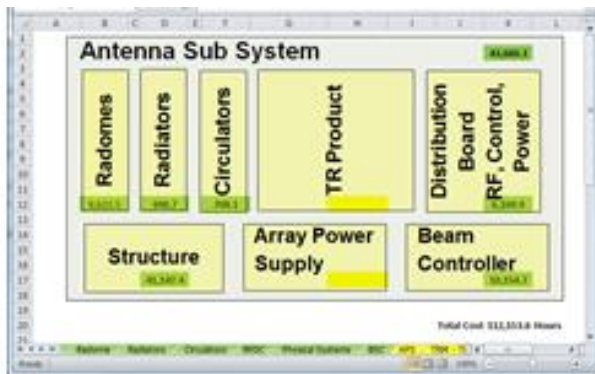
Pre-populated size factors of each subproduct from the ROM is now reviewed in detail for applicability to the final bid



Cost Model maintains running bid total of updated subproduct cost information

# Final Basis Of Estimate is Based on Historical Actuals

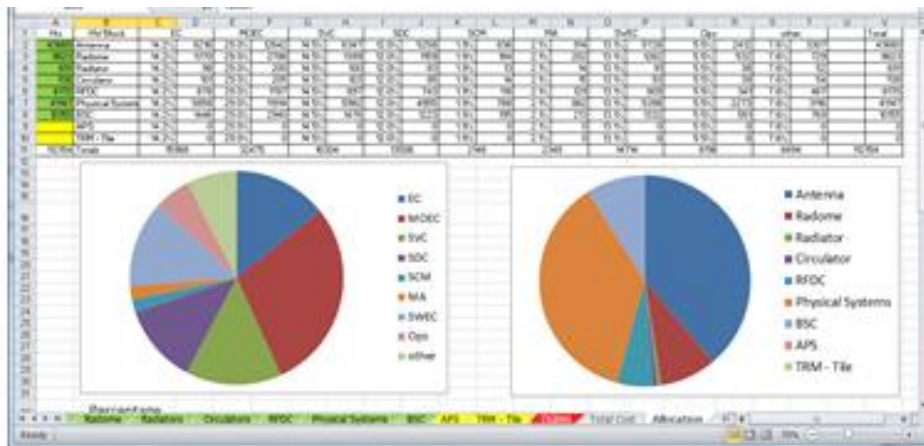
## Final Cost Totals



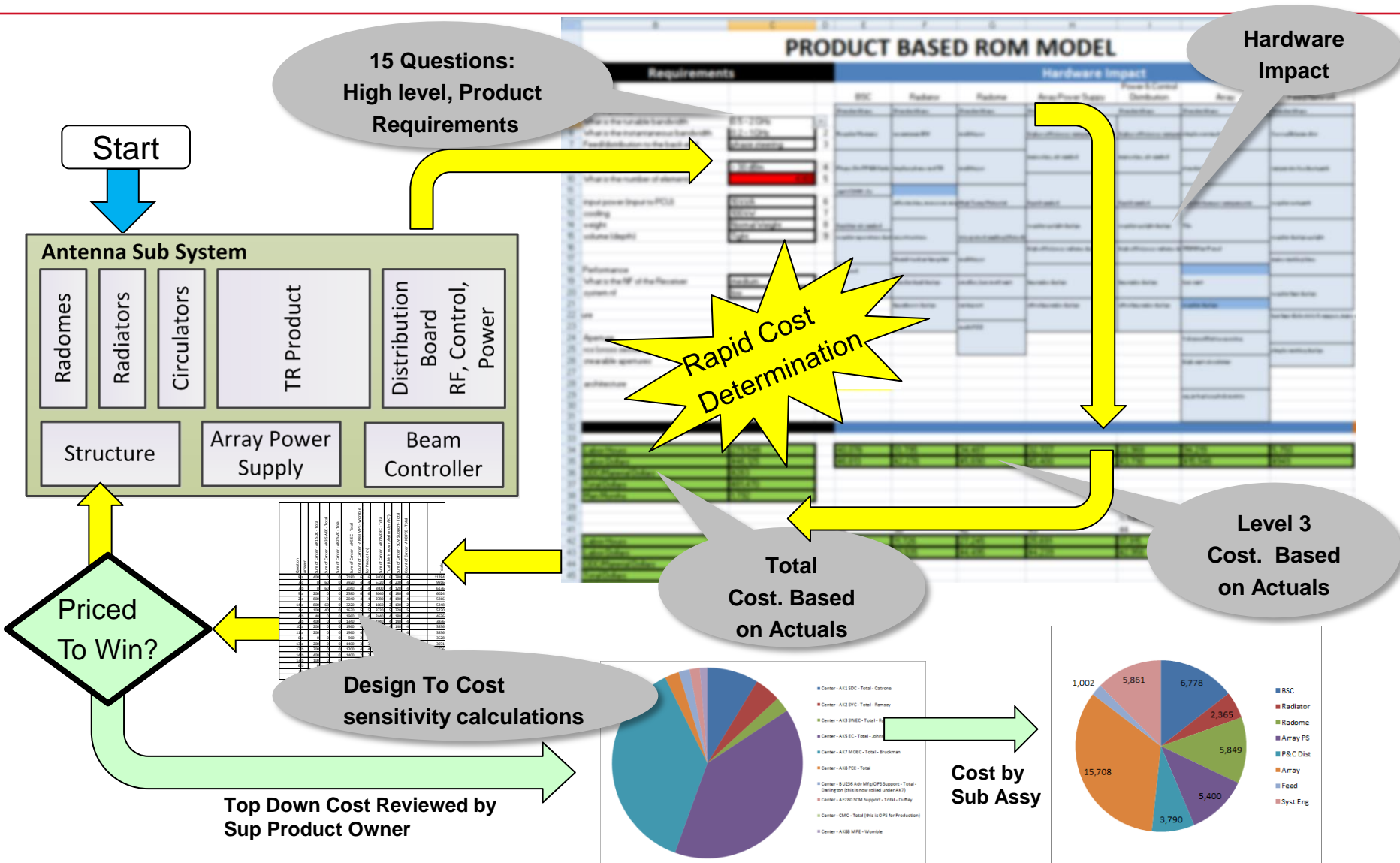
## Final Architecture With Sizing Parameters

Item	Value	Unit	Rate	Cost
<b>Antenna</b>				
Total Drawing SQ.FT	5000			5000
hrs	6,170			6,170
Frequency of Band	0-Band		0.0%	
Number of Freq Bands	1-Band		0.0%	
Reuse/Prior Design	Low		0.0%	
Type	ESA		0.0%	
Environment	Airborne		0.0%	
<b>RFDC</b>				
Total Drawing SQ.FT	5000			5000
hrs	6,170			6,170
Design Complexity	Medium		1.0%	
Ass Process Maturity	Medium		1.0%	
Frequency of Band	0-Band		0.0%	
Number of Freq Bands	1-Band		0.0%	
Reuse/Prior Design	Low		0.0%	
Type	ESA		0.0%	
Environment	Airborne		0.0%	
<b>Radome</b>				
Drawing Count	0			0
hrs	0,000			0,000
Preassembly	Yes		1.0%	
Contains TR	No		2.0%	
Frequency of Band	Reuse 0-Band		1.0%	
Number of Freq Bands	1-Band		1.0%	
Heater On	Yes		0.0%	
Reuse/Prior Design	High		0.0%	
Bandwidth/Spit width	Bandwidth		1.0%	
Pass, Trans, Optic	Pass		1.0%	
<b>Radiators</b>				
Radiators	2000			2000
hrs	800			800
Design Maturity (TR)	Most/Full drawing concepts		0.0%	
Bandwidth	Reuse some Mhz bandwidth		0.0%	
Frequency Band	0-Band		0.0%	
Number of Freq Bands	1-Band		0.0%	
Environment	Single Freq/Linear		0.0%	
Reuse/Prior Design	80-100%		0.0%	
<b>Circulators</b>				
Number of Parts	0			0
hrs	700			700
Type	Spot Radiator		0.0%	
Reuse/Prior Design	80-95%		0.0%	
Design Complexity	Low		0.0%	
Frequency Band	0		0.0%	
<b>Physical Systems</b>				
Total Drawing SQ.FT	5000			5000
hrs	6,170			6,170
Coastal Source	Coastal Long Source		7.0%	
Temperature Variation	5 deg C Top		0.0%	
Reuse/Prior Design	Low		7.0%	
Design Complexity	Medium		0.0%	
<b>BSC</b>				
Items	998			998
BSC Hours	32,155			32,155
Type	Distributed		1.0%	
Reuse	Low		1.0%	
Complexity	Medium		1.0%	
<b>APS</b>				
<b>TRM - Tile</b>				
By the way, to unlock the pages, the password is "test"				
<b>Total Cost</b>				
Hours	311,155			311,155

## Final Cost Subproduct Allocations



# Review Tops Down, Bottoms Up Approach

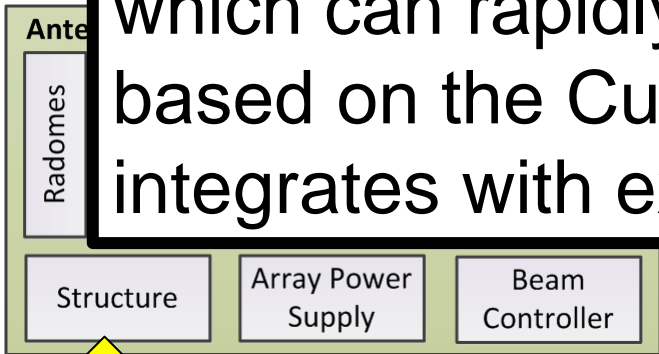


# Cost Models – Tops Down, Model Based bidding

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



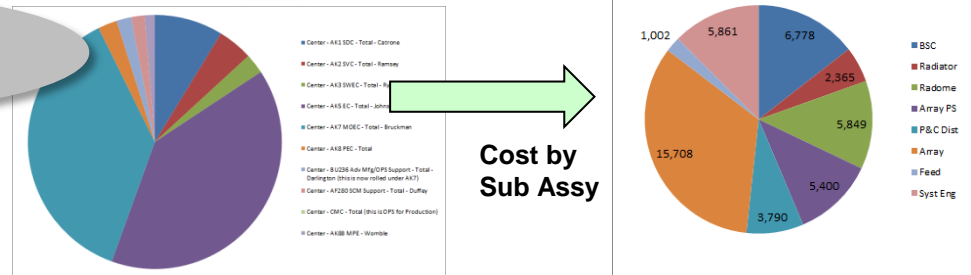
Total Cost. Based on Actuals

Level 3 Cost. Based on Actuals

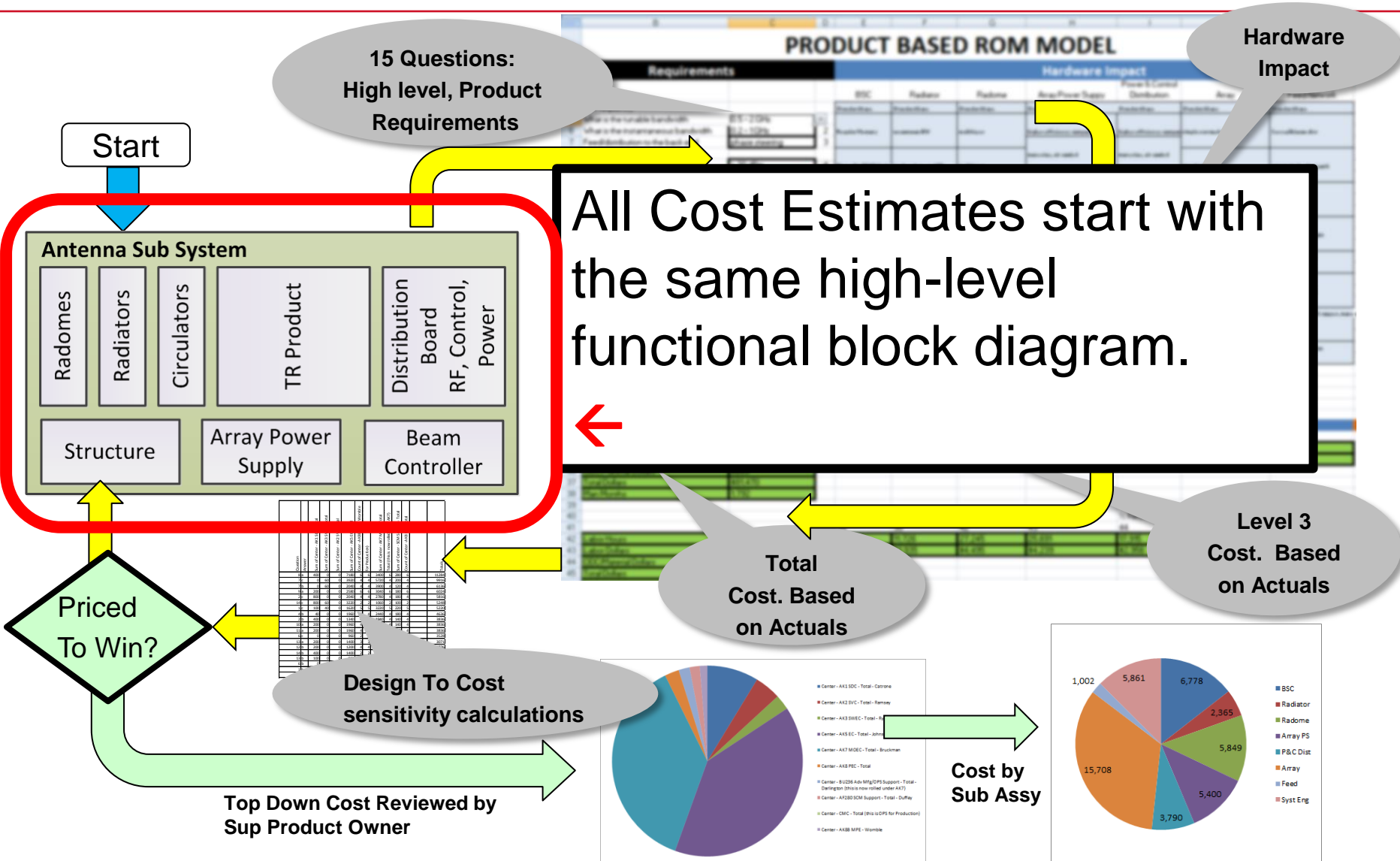


Design To Cost sensitivity calculations

Top Down Cost Reviewed by Sup Product Owner



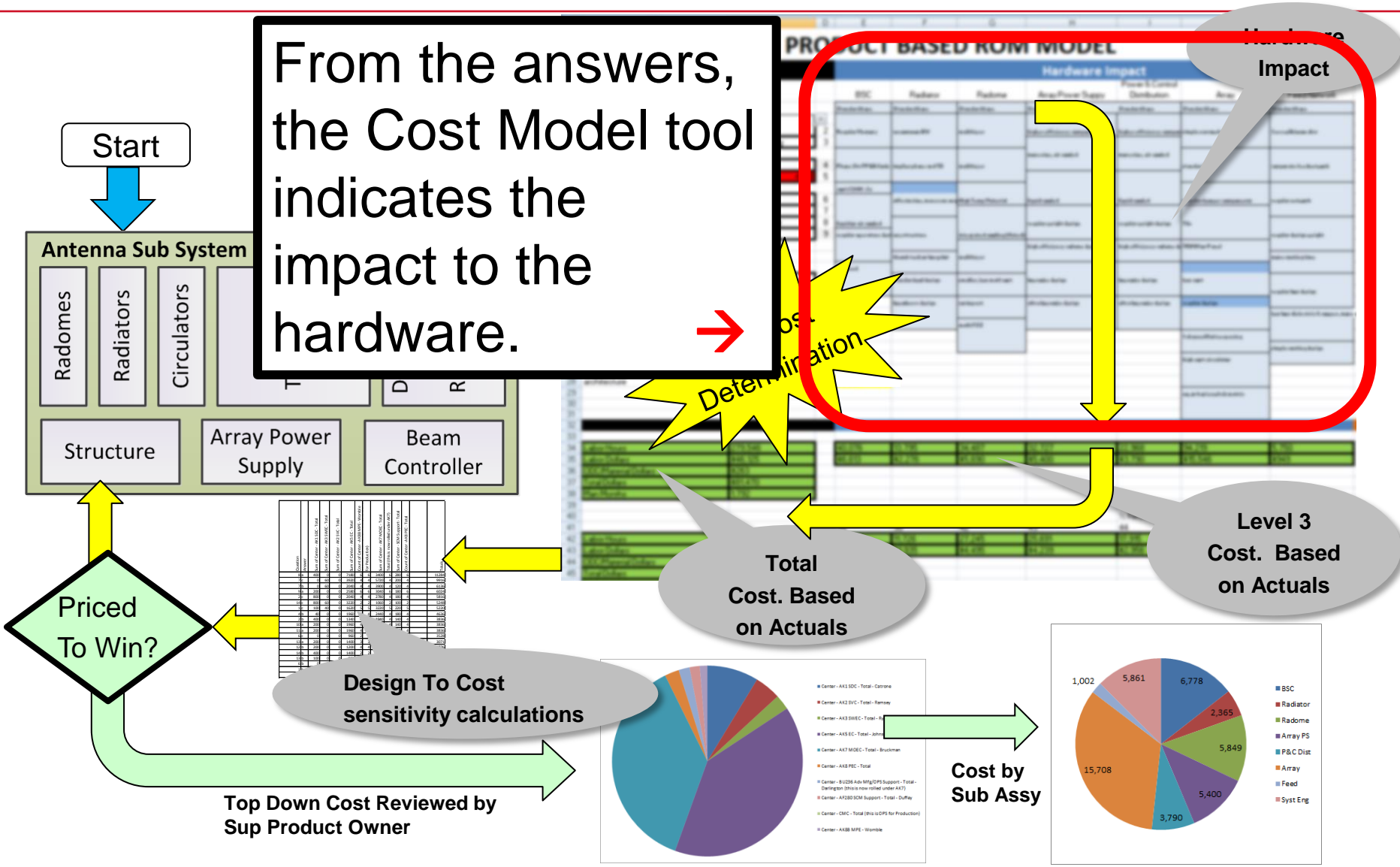
# Cost Models – Tops Down, Model Based bidding



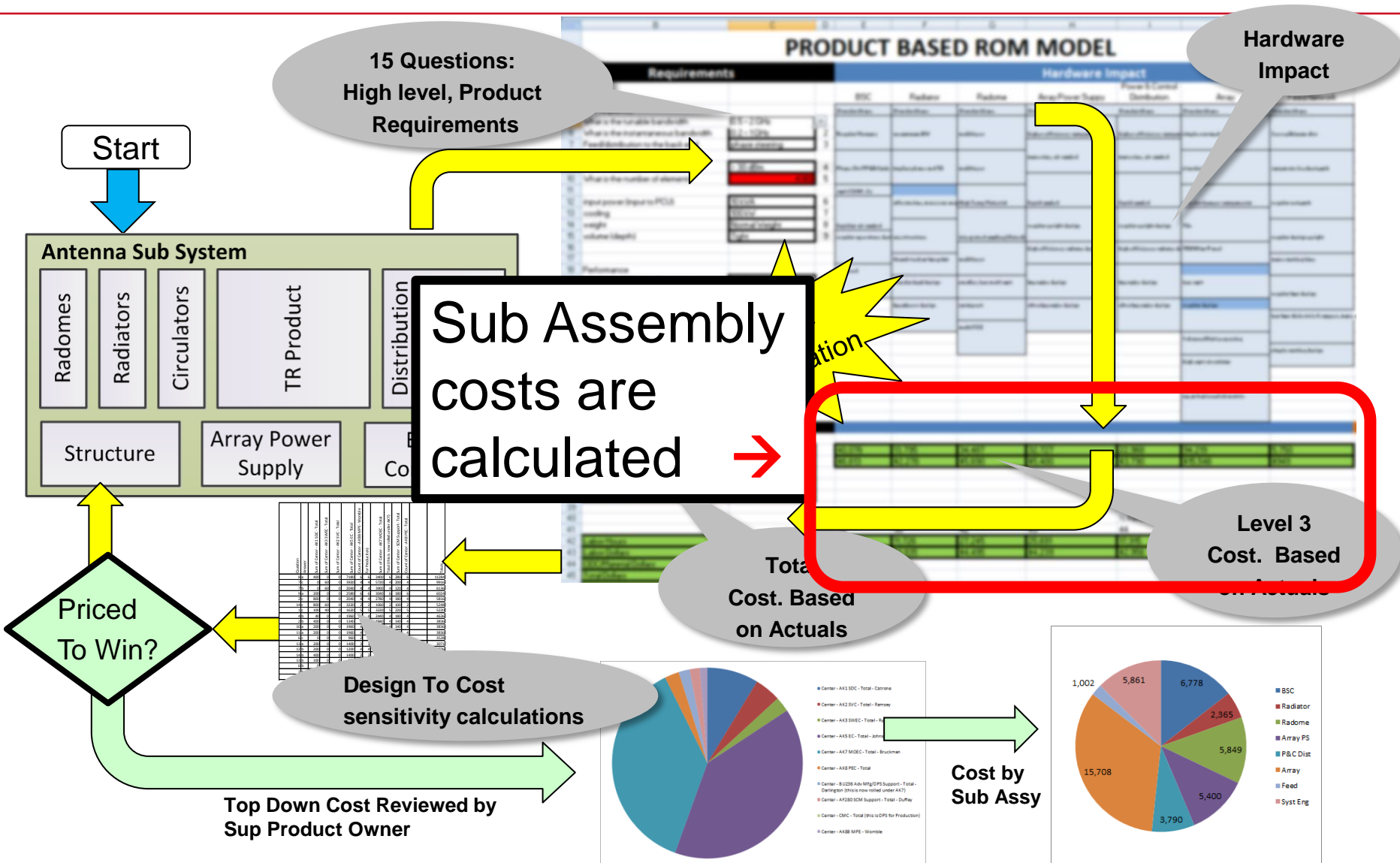


# Cost Models – Tops Down, Model Based bidding

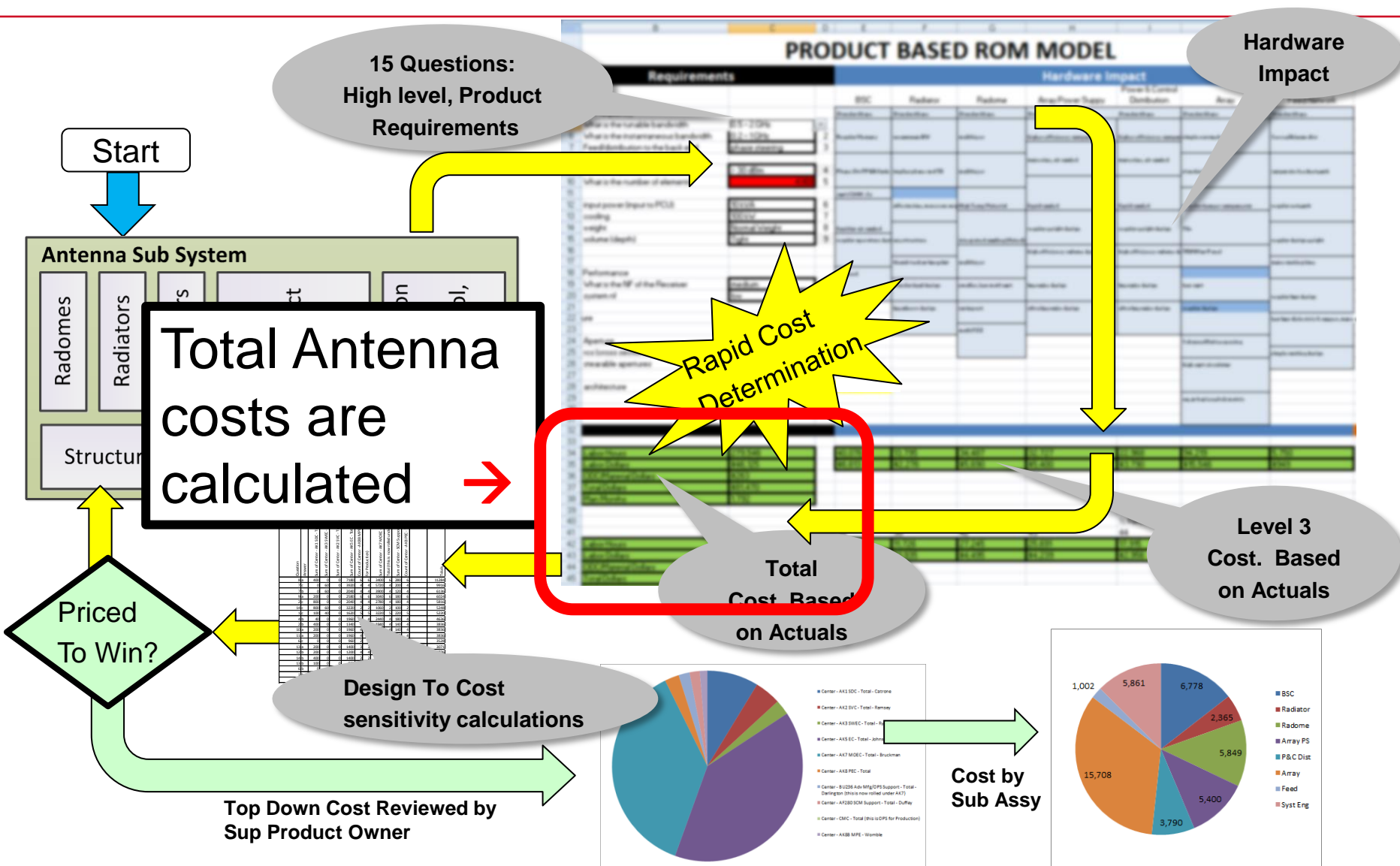
From the answers, the Cost Model tool indicates the impact to the hardware.



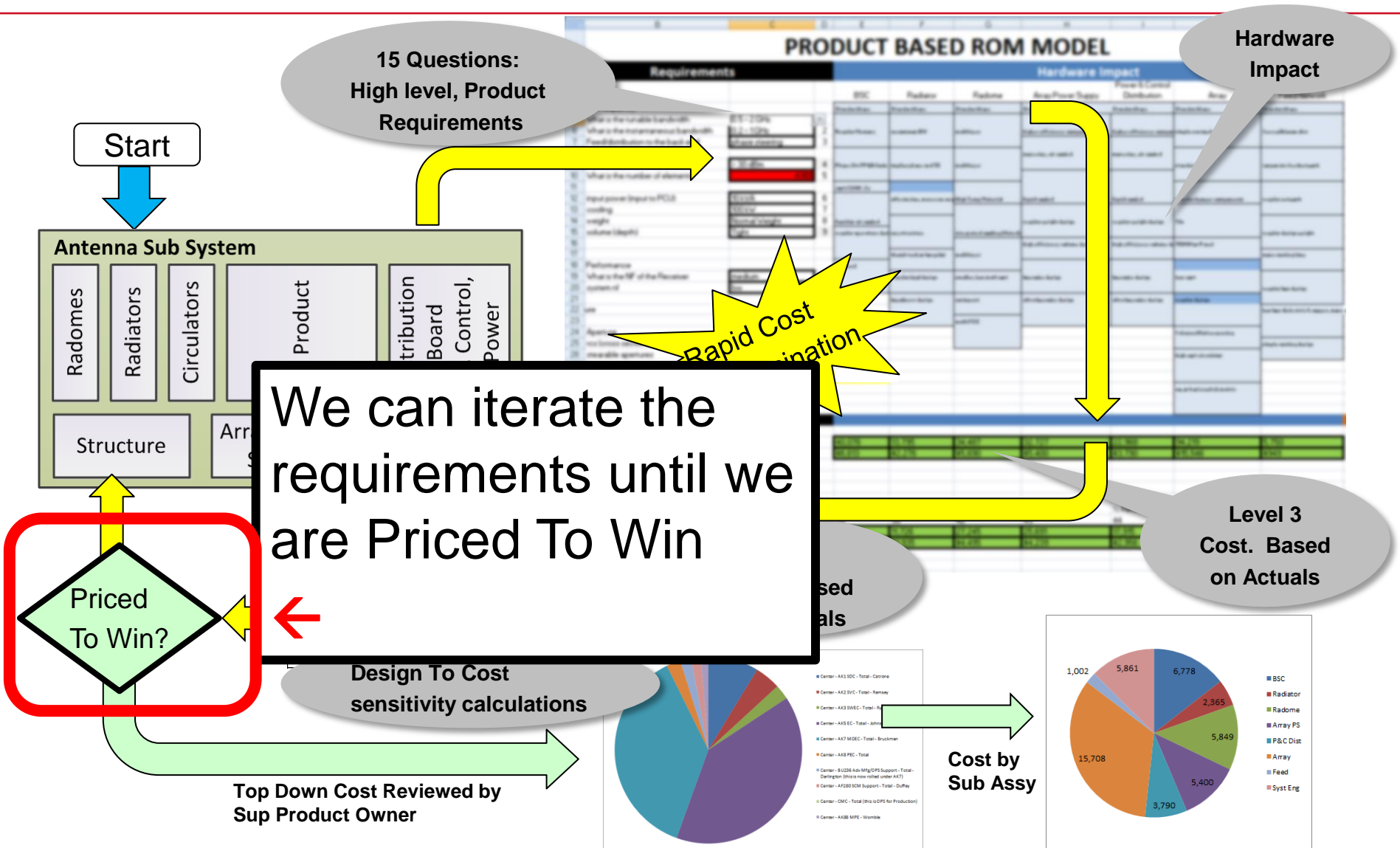
# Cost Models – Tops Down, Model Based bidding



# Cost Models – Tops Down, Model Based bidding



# Cost Models – Tops Down, Model Based bidding



# 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