DEVELOPMENT OF A DESIGN-TO-COST METHOD USING A SENSITIVITY ALGORITHM APPLIED TO A SAMPLE COST MODEL©

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In fulfillment of the requirements
For the Degree of Doctor of Philosophy
Colorado State University
Fort Collins, Colorado
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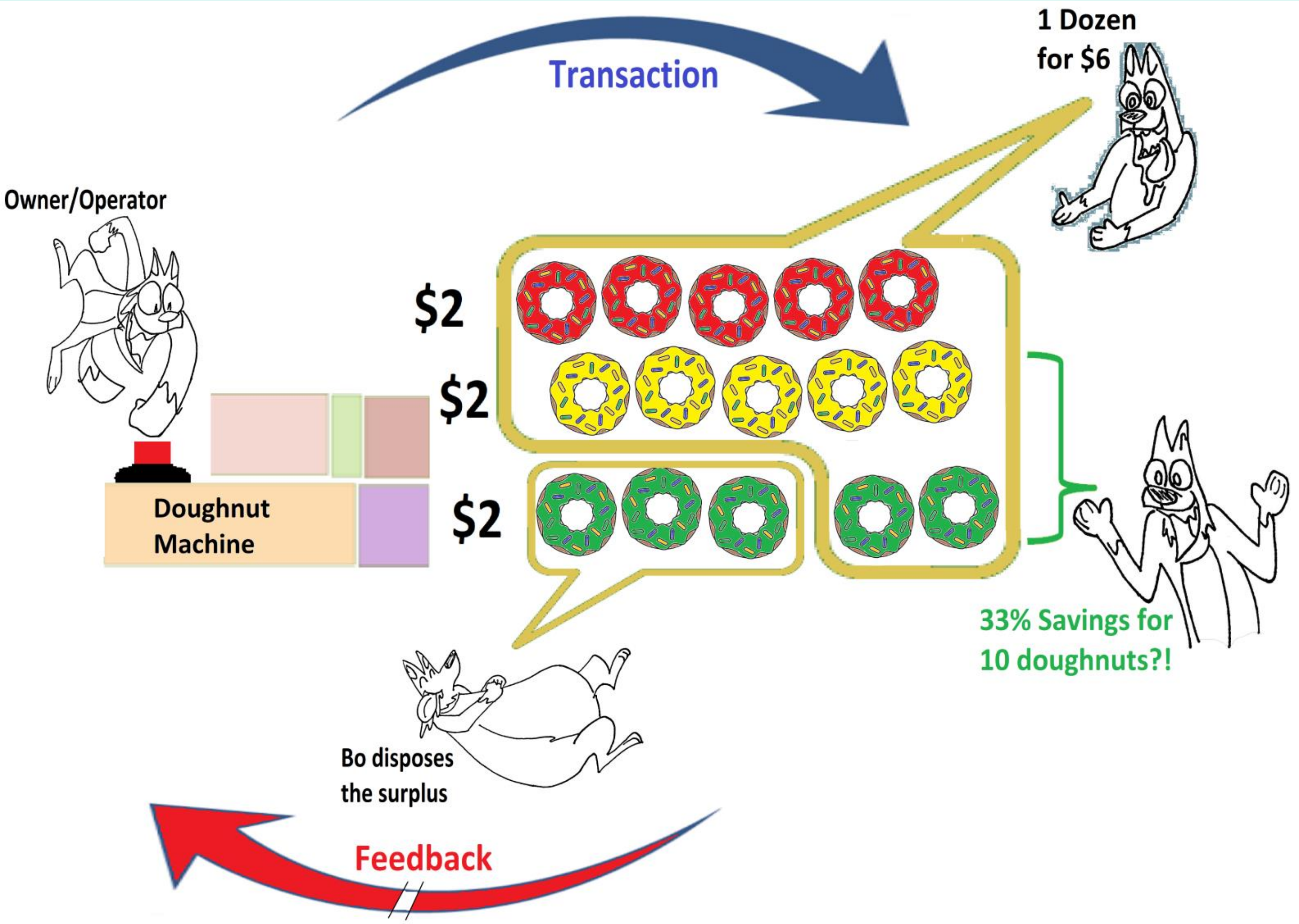
Agenda

- Problem Statement
- Problem Illustrated – Simple Terms
- An Example From The Perspective of a Systems Engineer
- Vision Of A Solution – The “WHAT IF” Scenario
- What industry needs vs. has
- Cost Algorithm Details
- Development Of A Cost Sensitivity Algorithm
  - Path To The Vision
  - Sample Cost Model
  - Development Of Key Size Metrics
  - Application of KSMs On Sample Cost Model
  - Using the Results, Return On Investment Discussion
- Presentation Plans and Publications
- Summary/Questions

Problem Statement

Lack of adequate cost analysis tools early in the design life cycle of a system contributes to non-optimal system design choices both in performance and cost. The goal is to develop algorithms for an automated tool/approach utilizing cost element sensitivity to enable a system designer the ability to understand the relative cost impacts of various decision/choices which affect system design early in the design cycle for an airborne based RADAR system for military aerospace applications.

Problem - Illustrated

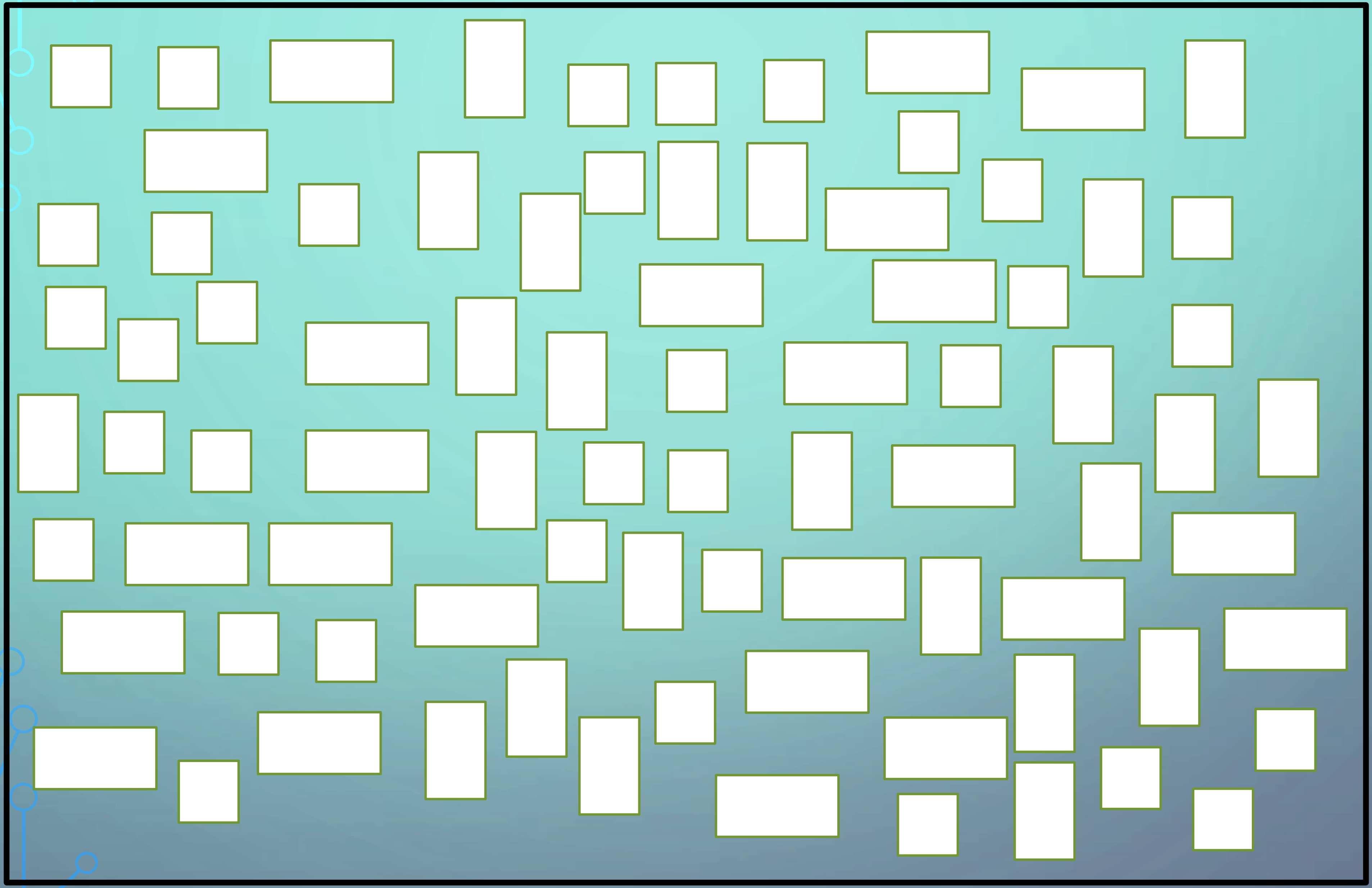


Unidirectional Process which lacks Feedback to Optimize a Solution

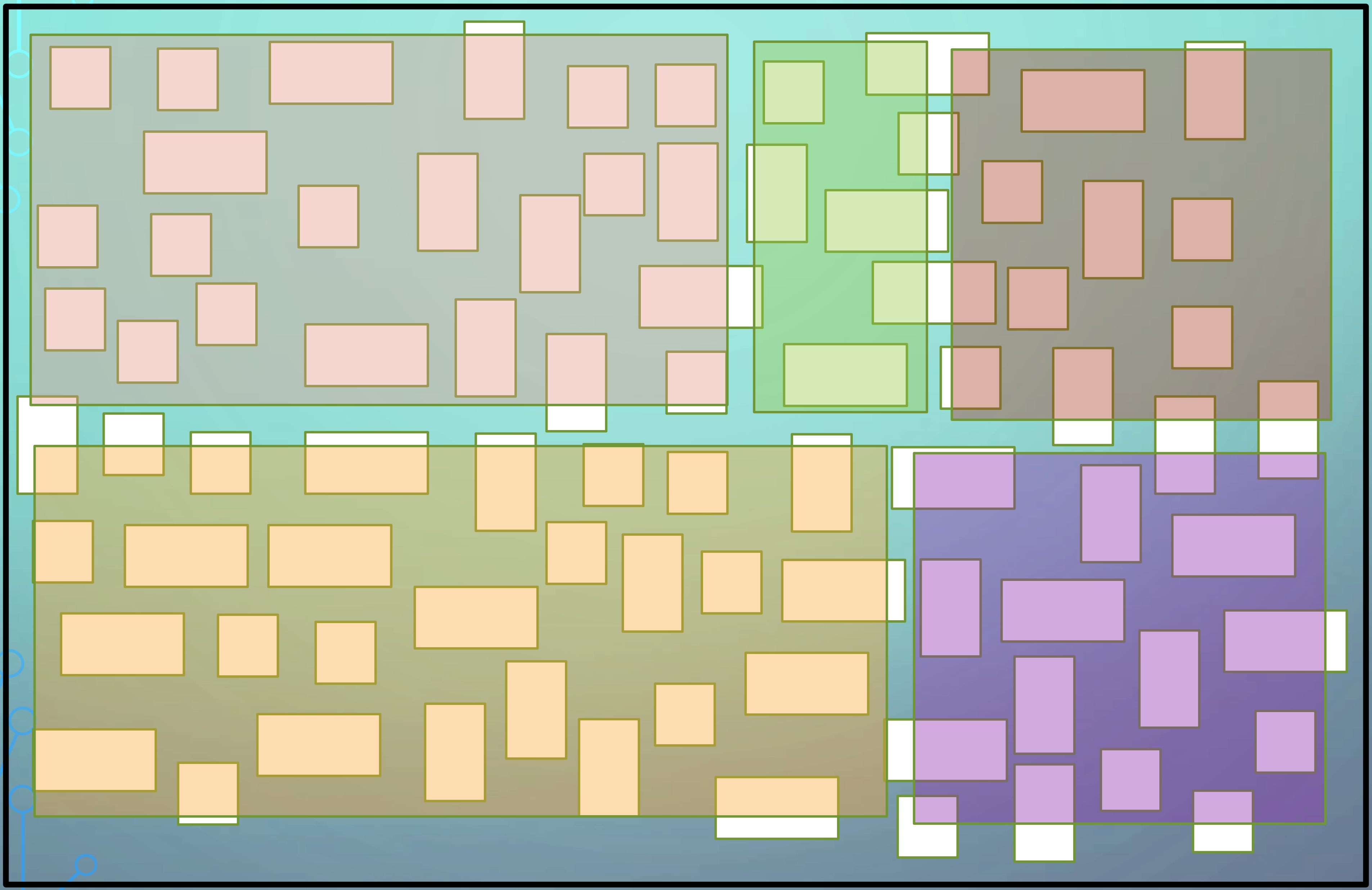
An Illustration From the Perspective of a System Designer

Complex System

Start with a System design



Complex System

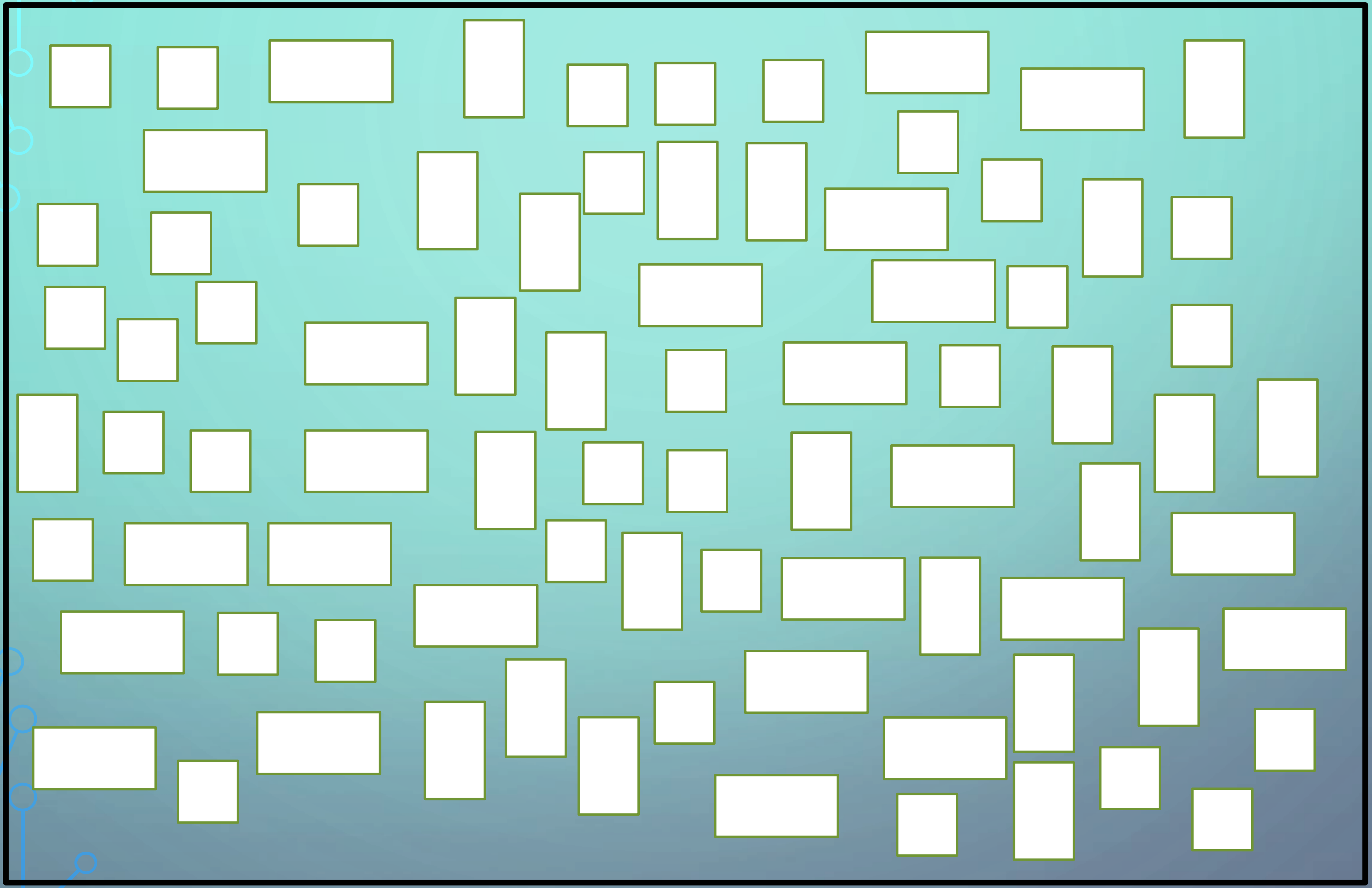


There is:

- A System
- Subsystem Blocks
- Components

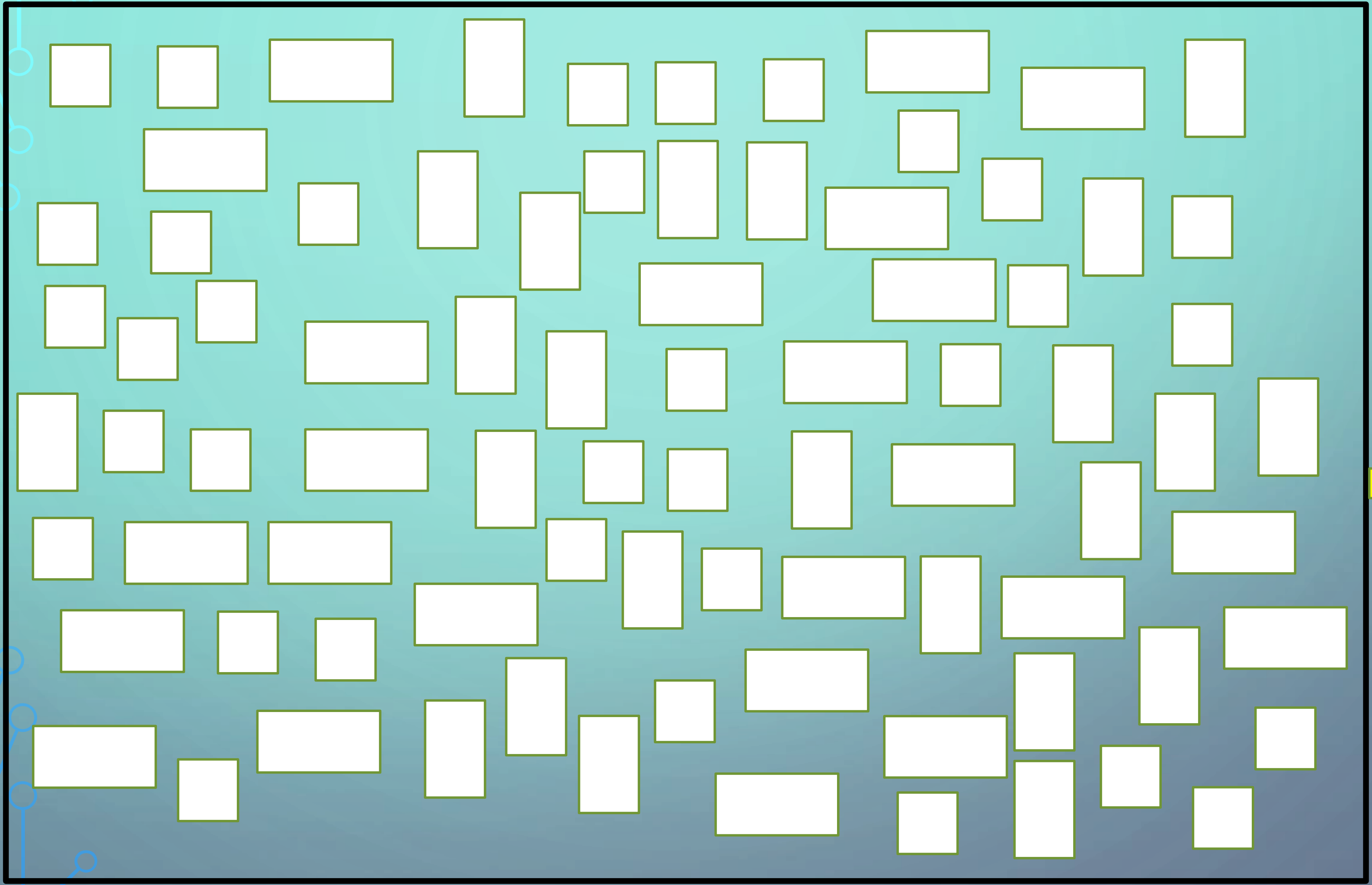
Complex System

Focus on Components



Complex System

Load System into cost model tool.

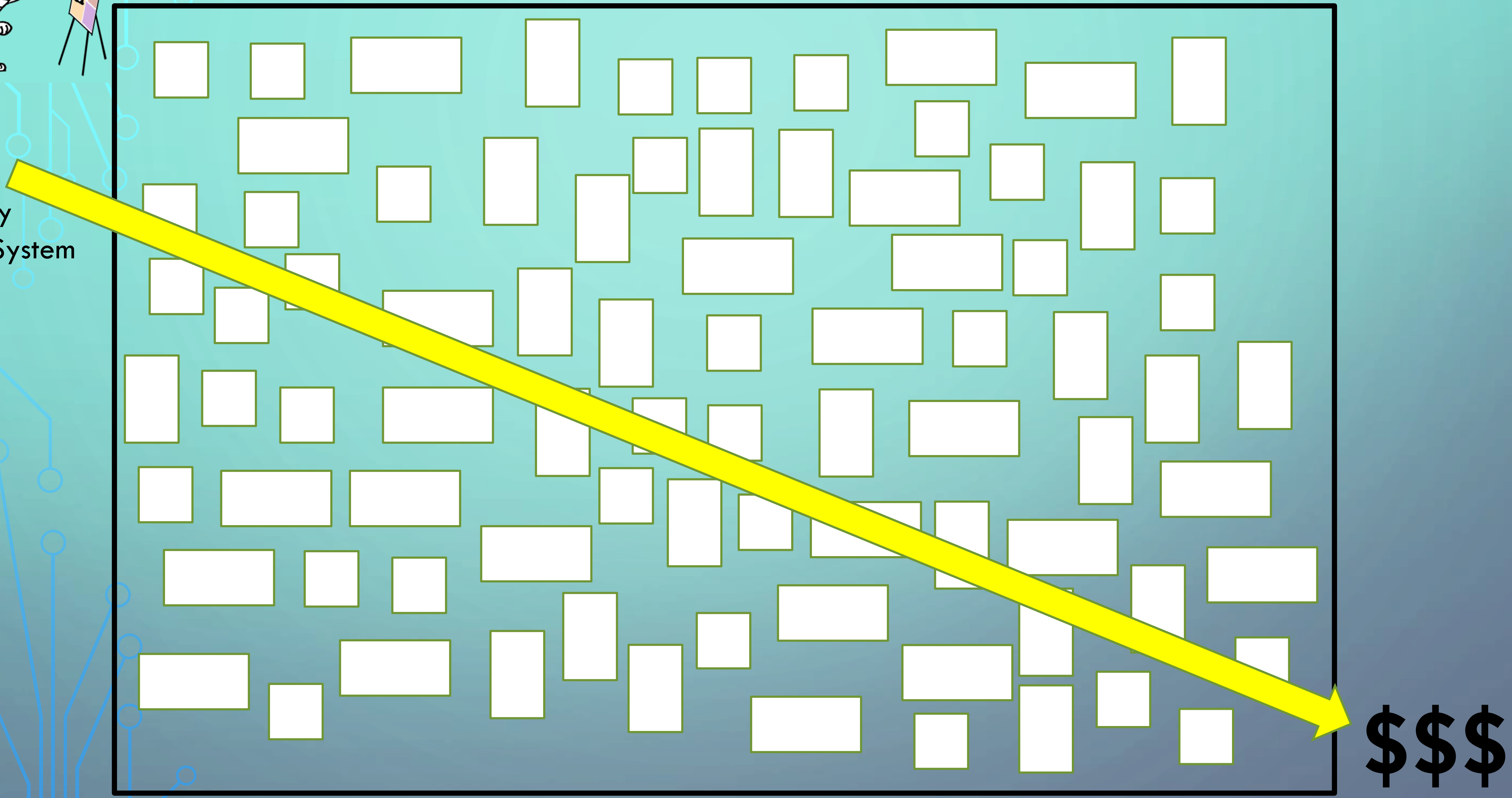


Calculate System Cost

$$$

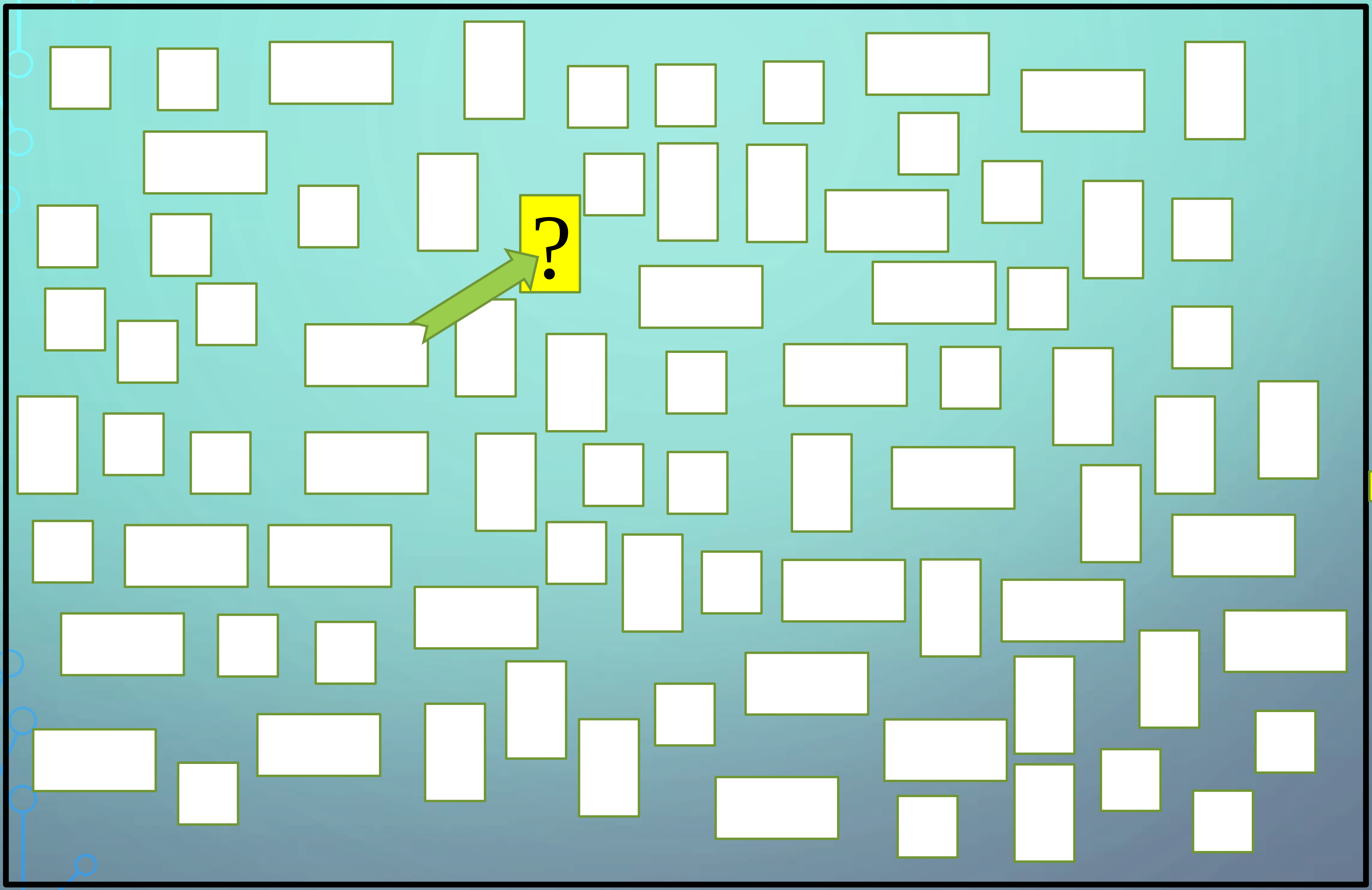
Complex System

Goal:
Positively
Impact System
Cost



Complex System

Determine cost if there is improvements on this ONE Component

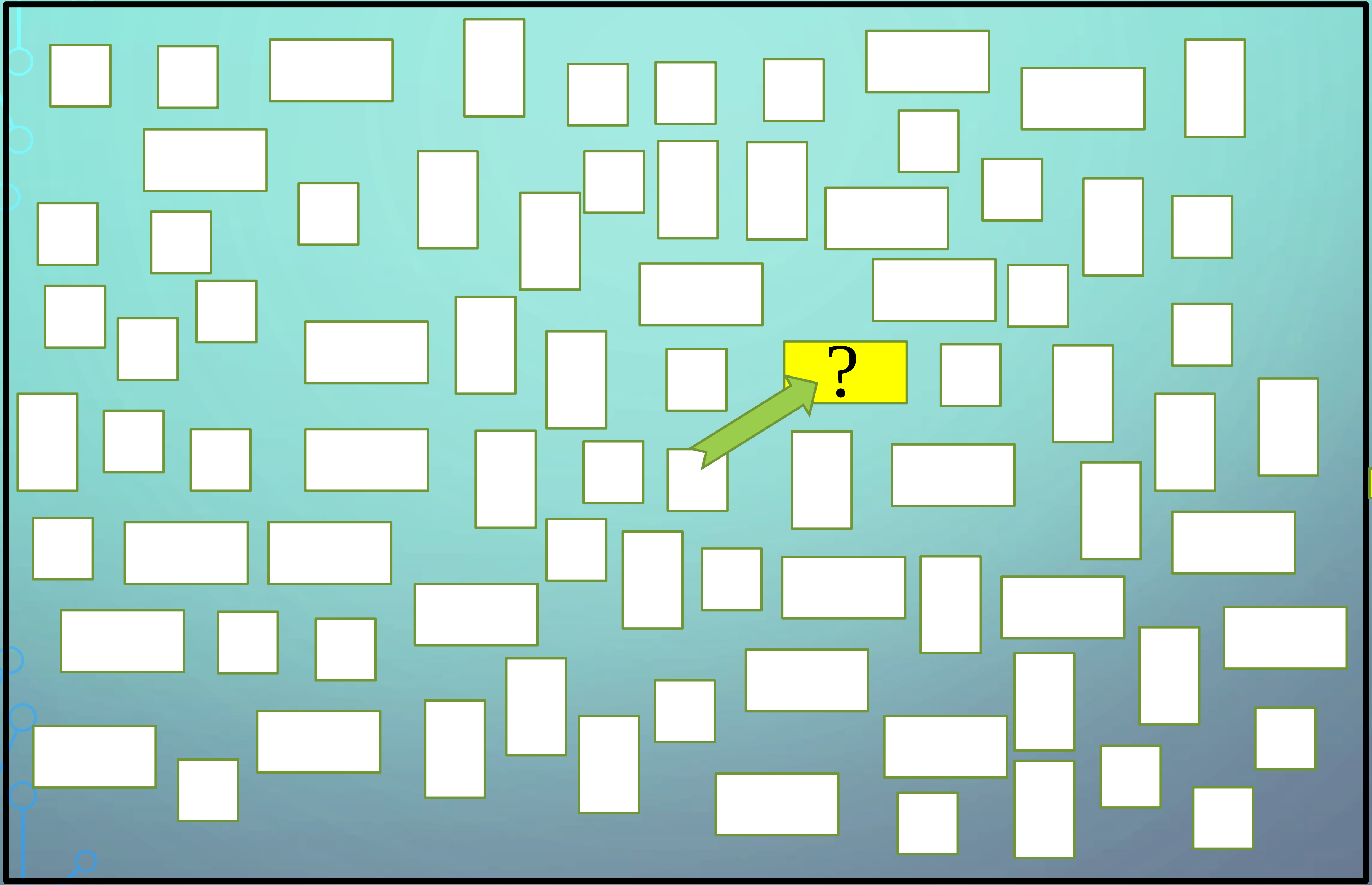


Calculate System Cost

$$$

Complex System

<u>Try again.</u> Determine cost if there is improvements on this ONE Component



Calculate System Cost

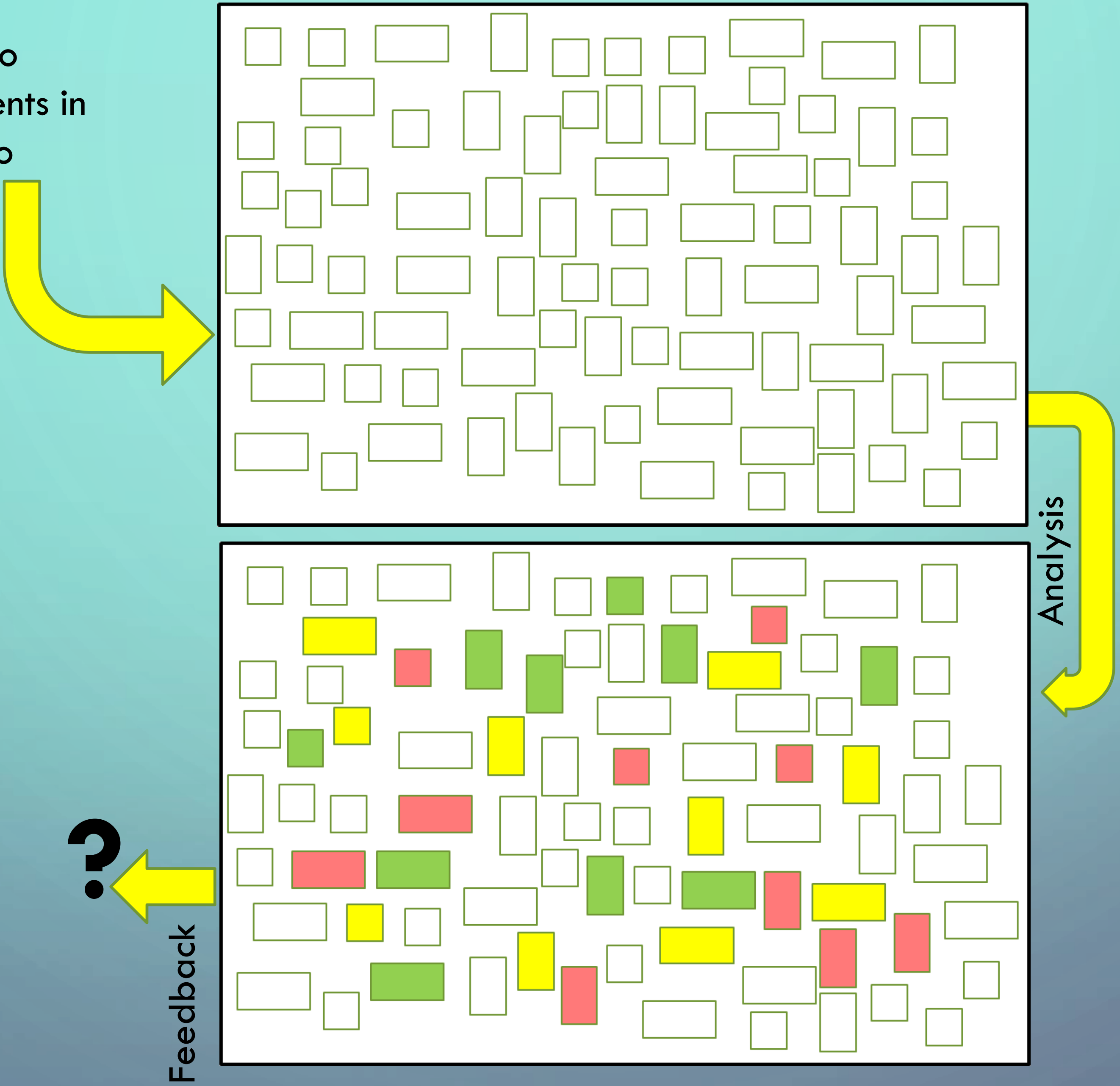
$$$

Vision Of A Solution

The “WHAT IF” scenario

Complex System

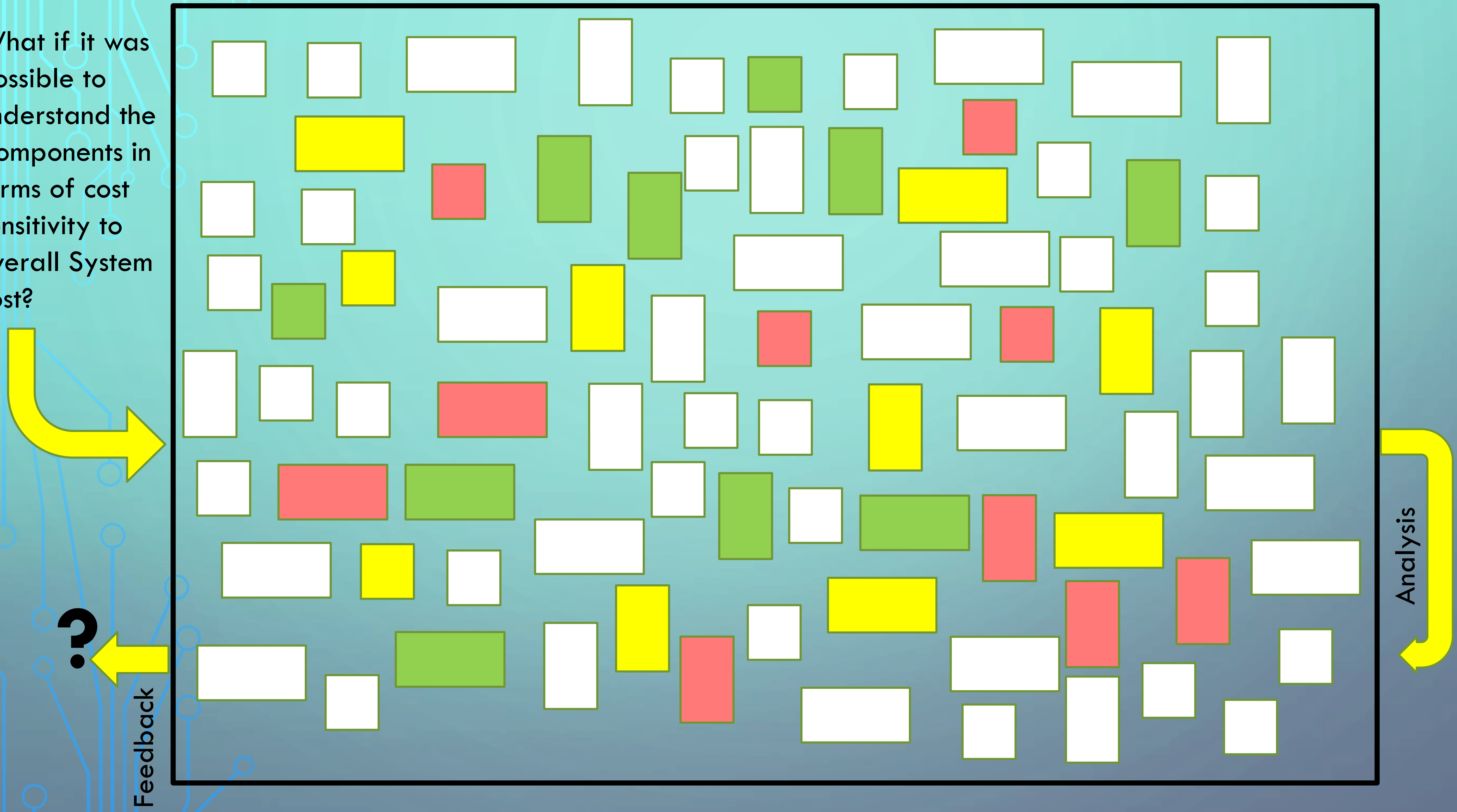
What if it was possible to understand the Components in terms of cost sensitivity to overall System cost?



Sensitivity Analysis Results
Component 1
Component 2
Component 3
Component 4
Component 5
Component 6
Component 7
Component 8
Component 9
Component 10
Component 11
Component 12
Component 13
Component 14
Component 15
Component 16
Component 17
Component 18
Component 19
Component 20
Component 21
Component 22
Component 23
Component 24
Component 25
Component 26
Component 27
Component 28
Component 29
Component 30

Complex System

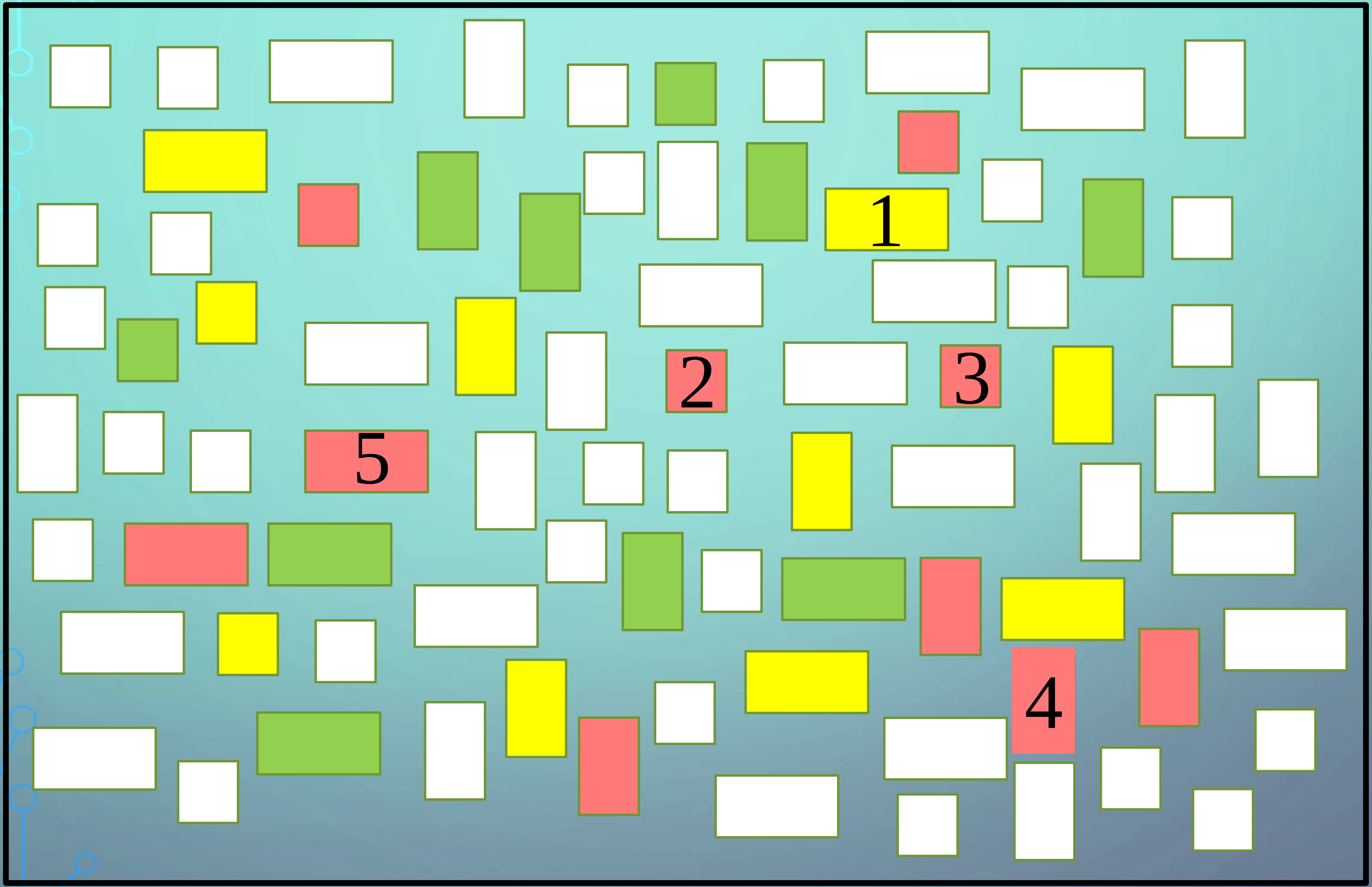
What if it was possible to understand the Components in terms of cost sensitivity to overall System cost?



Sensitivity Analysis Results
Component 1
Component 2
Component 3
Component 4
Component 5
Component 6
Component 7
Component 8
Component 9
Component 10
Component 11
Component 12
Component 13
Component 14
Component 15
Component 16
Component 17
Component 18
Component 19
Component 20
Component 21
Component 22
Component 23
Component 24
Component 25
Component 26
Component 27
Component 28
Component 29
Component 30

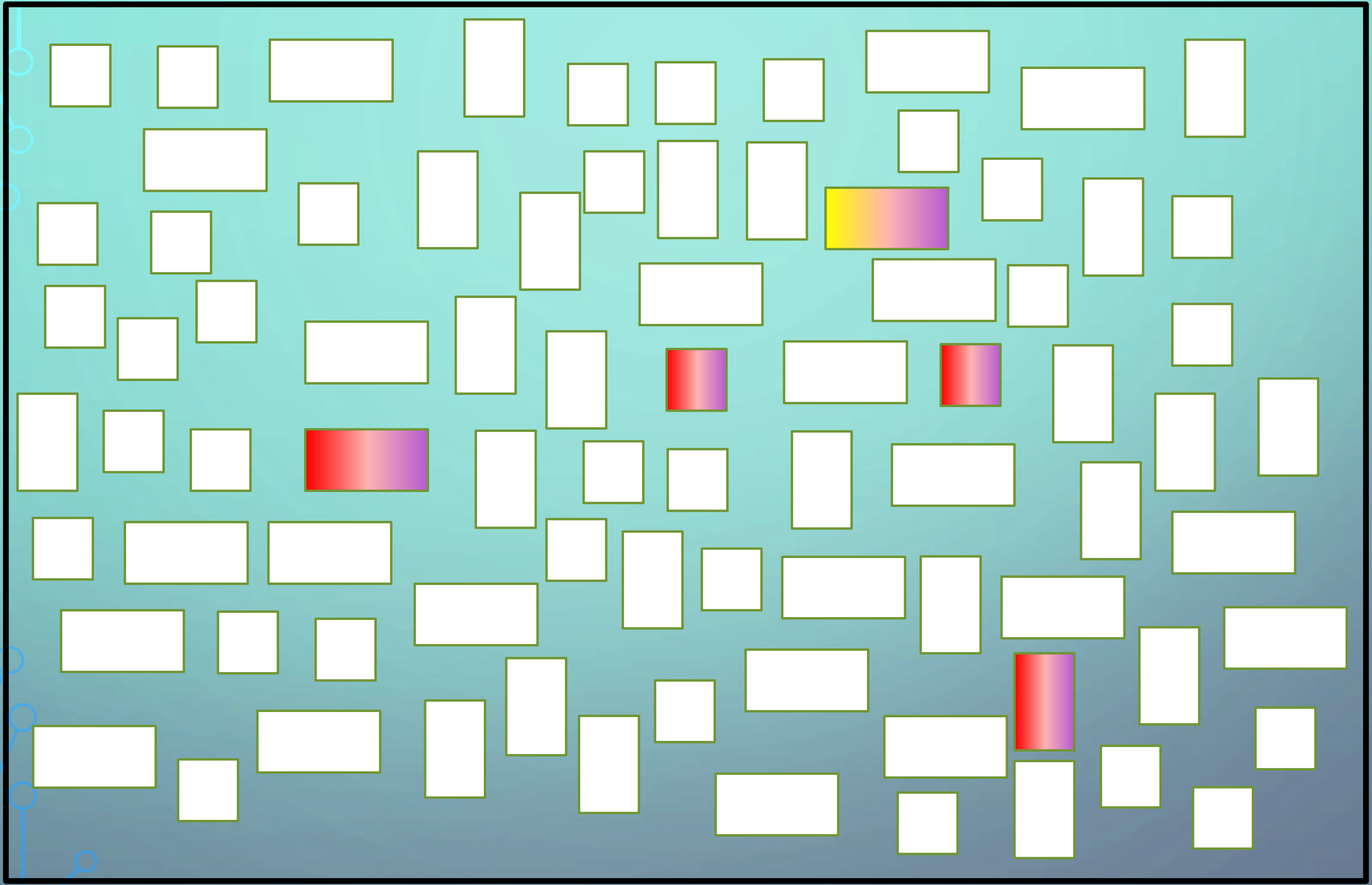
Complex System

Select a few Components, using knowledge of the System, for reasonable improvement goals.



Complex System

Determine impact of simultaneous improvements on these Components

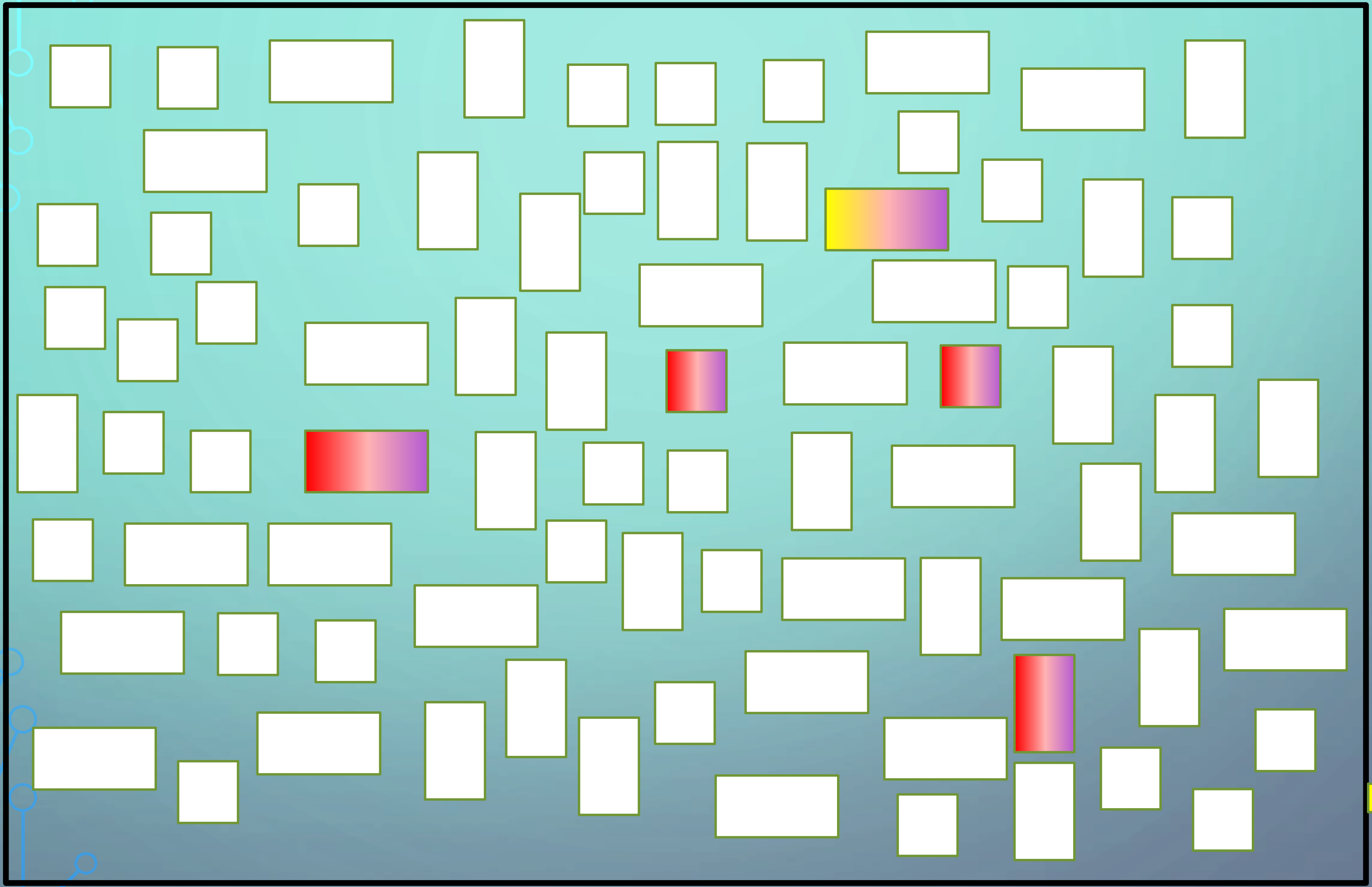


???

Calculate Cost Impact

Complex System

Determine impact of simultaneous improvements on these Components



21%!!

Calculated Cost Impact

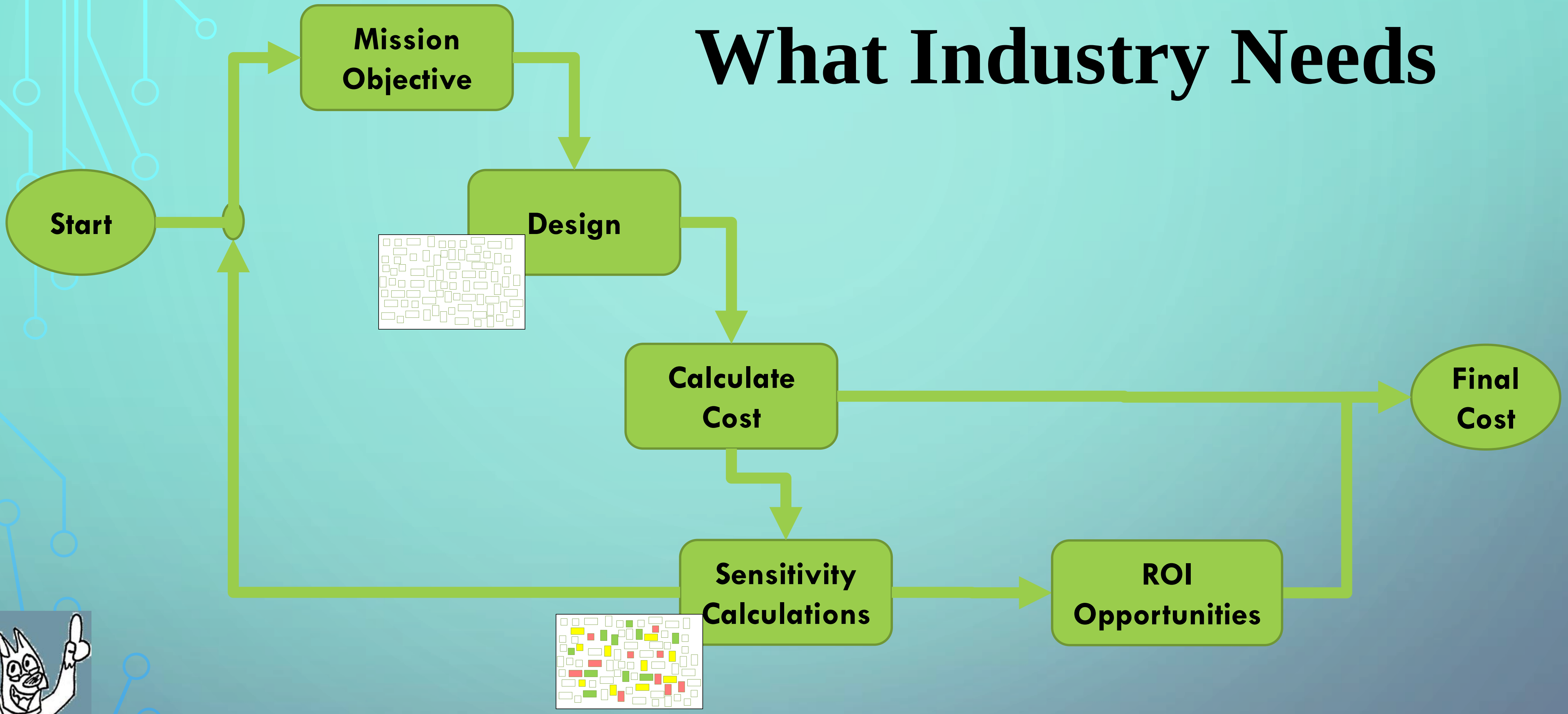
In order to realize a potential component improvement, there needs to be some amount of investment of resources. If there is a potential improvement of $1.78M in system cost, any investment up to that value would yield a profit.

So, the cost algorithm yields an upper limit for a Return On Investment.

$8,464,002.22	<-- Baseline System Cost
$6,682,902.18	<-- New Improved System Cost
$1,781,100.04	<-- Savings
21%	<-- % Improvement

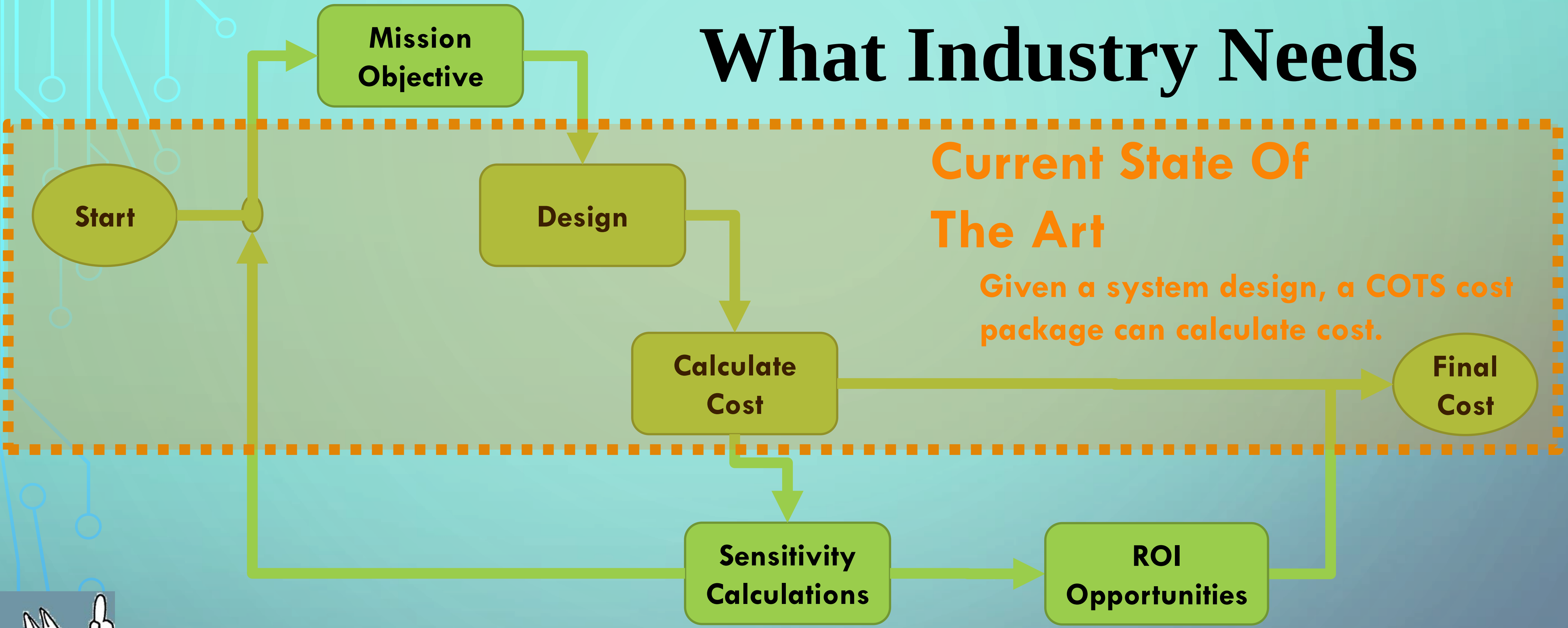
Potential Component Improvements

What Industry Needs



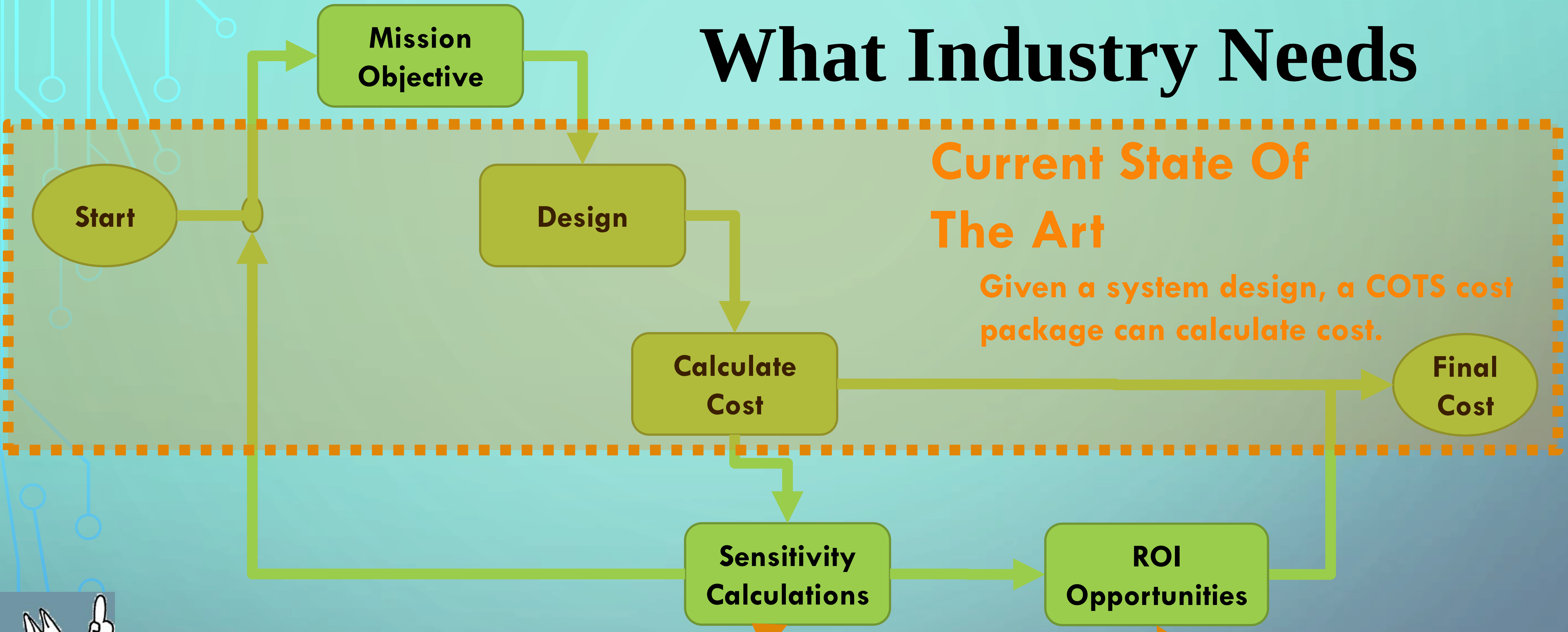
Process for an optimized solution

What Industry Needs

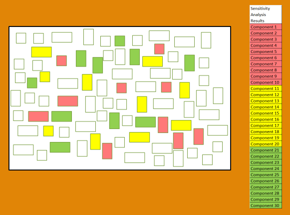


Process for an optimized solution

What Industry Needs



This is possible!

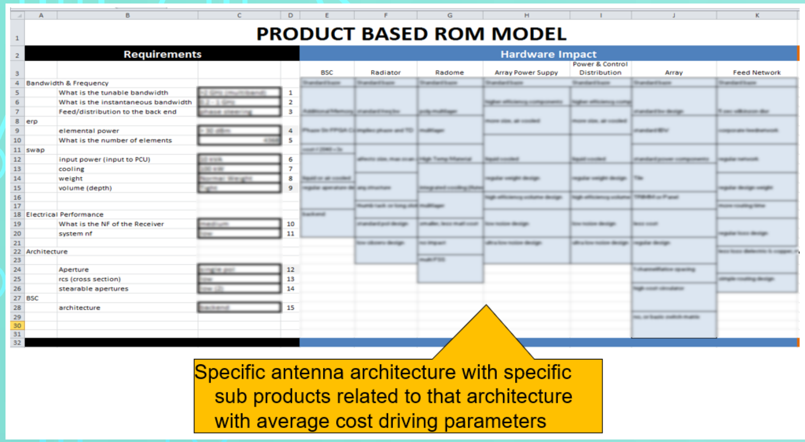


Process for an optimized solution

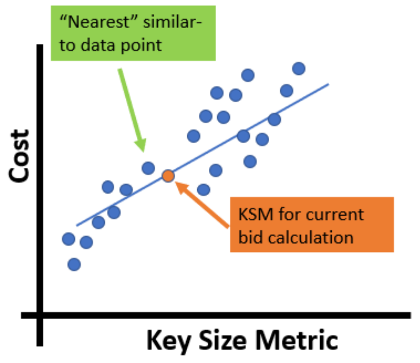
This is a bonus!

$16,975,050.27	<-- Baseline System Cost
$13,080,098.88	<-- New Improved System Cost
$3,894,951.39	<-- Savings
23%	<-- % Improvement

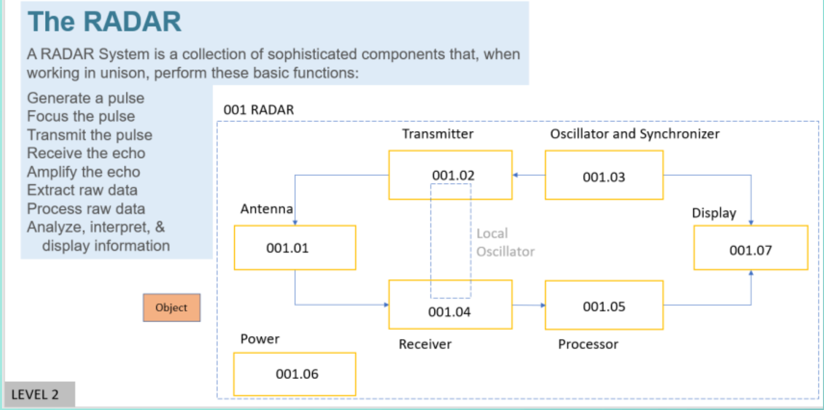
Cost Algorithm Details



Early Excel based cost model work - 2014

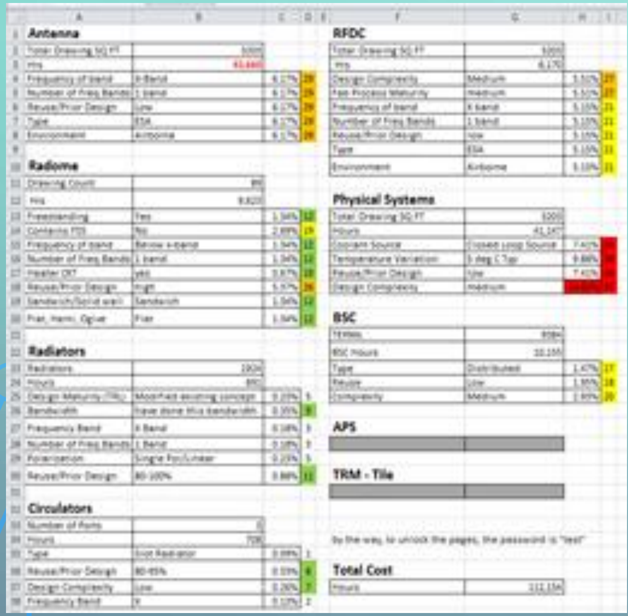


Solving the BOE conundrum - 2015

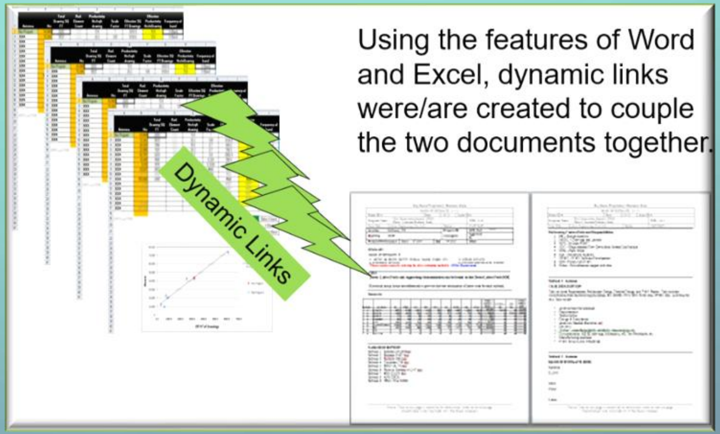


Standardized Block Diagrams - 2018

Path to the Cost Sensitivity Algorithm has been developing over many years



Early Cost Sensitivity Discoveries - 2014



Dynamic BOE Linkages - 2015

Level 1	Level 2	Level 3	Block Name
001			Radar
	001.01		Antenna
		001.01.01	Radiator
		001.01.02	TR Product
		001.01.03	Duplexer
	001.02		Transmitter
		001.02.01	Power Amplifier
		001.02.02	Up Converter
		001.02.03	Local Oscillator
	001.03		Synchronizer
		001.03.01	Synchronizer
	001.04		Receiver
		001.04.01	Low Noise Amplifier
		001.04.02	Down Converter
		001.04.03	Local Oscillator
		001.04.04	IF Amplifier
		001.04.05	Filters
		001.04.06	2nd Down Converter
		001.04.07	2nd Local Oscillator
		001.04.08	Detector
		001.04.09	Analog to Digital Converter
	001.05		Processor
		001.05.01	Processor
	001.06		Power
		001.06.01	Transformer
		001.06.02	Rectifier
		001.06.03	Filter
		001.06.04	Regulator
	001.07		Display
		001.07.01	Video Amplifier
		001.07.02	Display

Standardized WBS - 2018

Developing the Cost Algorithm

Sample Cost Model

Work Elements

- Σ 1: NewGen Listening Station
  - Σ 1.1: Equipment Configuration
    - Σ 1.1.1: Receiver Module
      - 1.1.1.1: Receiver
      - 1.1.1.2: RF Module
      - 1.1.1.3: RF Machined Housing
      - 1.1.1.4: Rcv Chassis
    - Σ 1.1.2: Digital Processing
      - 1.1.2.1: Converter & Noise Reduction
      - 1.1.2.2: Data Processing
      - 1.1.2.3: Purchased Memory
      - 1.1.2.4: Interconnect - Data Bus
      - 1.1.2.5: Instrumentation Panel
      - 1.1.2.6: Digital Processing Chassis
      - 1.1.2.7: Controller Software
    - Σ 1.1.3: Misc Equipment
      - 1.1.3.1: Wire Interconnects
      - 1.1.3.2: Purchased Racks
      - 1.1.3.3: Purchased Power Supply
  - Σ 1.2: Operational and Support Sites
    - 1.2.1: Northeast Auxiliary
    - 1.2.2: Atlantic Operations Center
    - 1.2.3: Western Operations Center
    - 1.2.4: Midwest Repairs
    - 1.2.5: Express Repairs

Sample Cost Model was selected from library

Inputs

Parameters | Schedule & Qtys | Labor Rates, Costs & Factors | Ops & Support | Labor Category Allocation

Electronics: Data Processing	Least	Likely	Most	Note
PRODUCT DESCRIPTION				
Total Printed Circuit Boards	2.00	2.00	3.00	
PCB Size(in²)	30.00	30.00	30.00	
PCB Type		Glass Epoxy		
CIRCUITRY COMPOSITION				
Percent Analog	0.00%	0.00%	0.00%	
Percent Digital	80.00%	90.00%	100.00%	
Percent Hybrid	0.01%	10.00%	15.00%	
Discrete Components Per PCB	150	250	400	
Surface Mount Discretes	100.00%	100.00%	100.00%	
Integrated Circuits Per PCB	500	750	800	
Surface Mount ICs	100.00%	100.00%	100.00%	
Input/Output Pins Per PCB	95	230	300	
Clock Speed (MHz)	12.00	20.00	33.00	
Packaging Density	Nom	Nom	Nom+	
Component Technology	Low	Nom	Nom+	
Custom Chip Usage		NO		
MISSION DESCRIPTION				
Operating Environment		Ground		
Electronics Classification		Computational		
Electronics Fault Detection	0.01%	0.01%	0.01%	
Electronics Fault Isolation	0.01%	0.01%	0.01%	
PROGRAM DESCRIPTION				
New Design	50.00%	60.00%	70.00%	
Design Replication	0.00%	0.00%	0.00%	
Design Complexity	Nom	Nom	Nom	
Certification Level	Low	Low	Low+	
Subsystem Integration Level	Nom	Nom+	Hi	
DEVELOPMENT ENVIRONMENT				
Developer Capability & Experience	Low+	Nom	Hi	
Development Tools & Practices	Nom+	Hi	Hi+	
Requirements Volatility	Nom-	Nom	VHi	
Prototype Insertion Method	Nom	Nom	Nom	
Prototype Soldering Method	Nom	Nom	Nom	
PRODUCTION ENVIRONMENT				
Production Experience	Nom-	Nom	Hi	
Production Tools & Practices	Low-	Low	Low	
PCB Insertion Method	Low	Hi	Hi	

Sample Set – Parameters of a Component

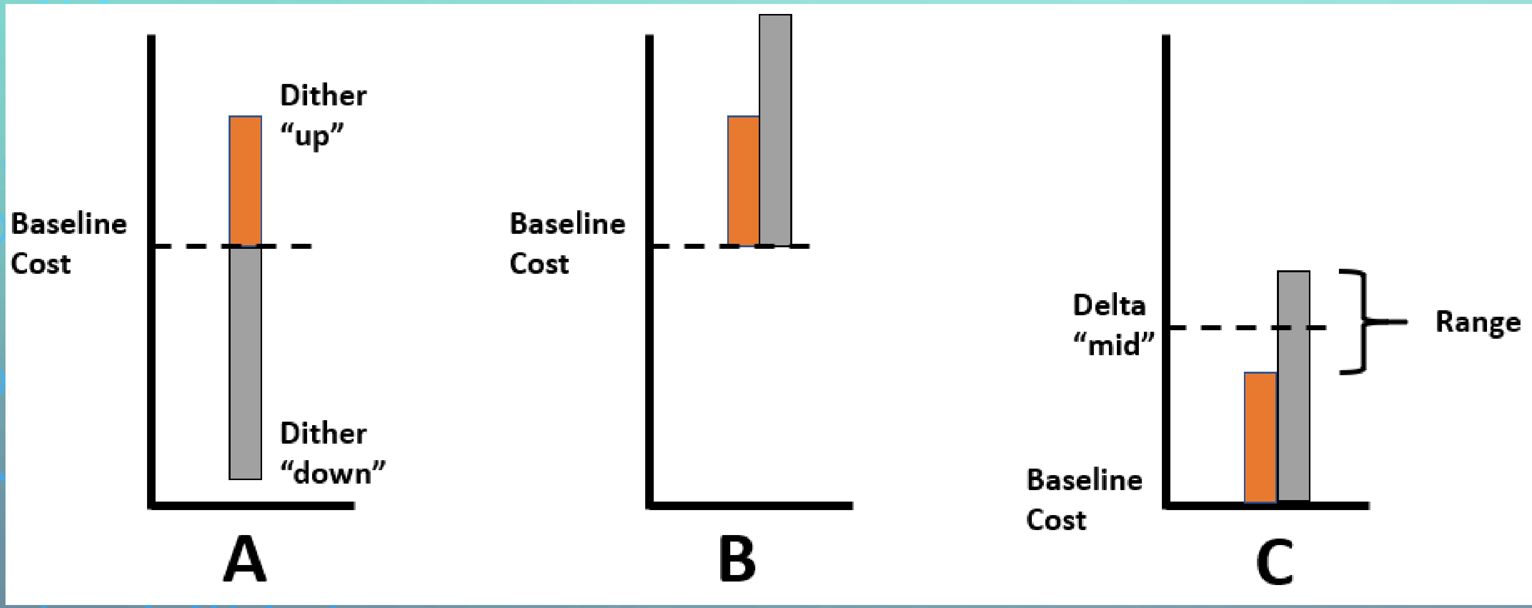
Electrical Impactful Parameters	Mechanical Impactful Parameters
Total CCAs	Weight
PCB Size	Volume
Discreet Components per PCB	
Integrated Components per PCB	
Clock Speed	

Impactful Parameters were identified

It is necessary to determine which Parameters could be considered Minor Parameters vs. Impactful Parameters. Primarily this was accomplished by adjusting the Parameters and observing the impact to overall system cost. In addition, some amount of Engineering judgement was used.

Hardware	Parameters					Calculated System Cost			Interpretation of Cost Data			
Component	Parameter	Parameter Value	Dither amount	Dither "Up" Parameter Value	Dither "Down" Parameter Value	Baseline Cost	Dither "up" cost	Dither "Down" cost	delta "up" cost	delta "down" cost	delta "mid"	delta range
Receiver	Total CCAs	2	20%	2.4	1.6	8464002	8635812	8292434	171810	171568	171689	121

Single Parameter Example



When a Parameter is dithered from its baseline value, it has the effect of driving the overall System cost away from the baseline. By taking the absolute value of both delta costs, the deltas are essentially folded over in the positive direction and can be compared.

Folding Dither Cost

Hardware	Parameters					Calculated System Cost			Interpretation of Cost Data			
Component	Parameter	Parameter Value	Dither amount	Dither "Up" Parameter Value	Dither "Down" Parameter Value	Baseline Cost	Dither "up" cost	Dither "Down" cost	delta "up" cost	delta "down" cost	delta "mid"	delta range
Receiver	Total CCAs	2	20%	2.4	1.6	8464002	8635812	8292434	171810	171568	171689	121
RF Module	Total CCAs	0.5	20%	0.6	0.4	8464002	8532808	8368659	68806	95343	82074	13269

In this example, it can be seen that dithering the number of PCBs in the Receiver had roughly twice the impact to the overall cost as that in the RF Module. Clearly the Receiver is more SENSITIVE to this parameter.

This became the "Ah-Ha" moment which demonstrated different cost sensitivities for different Components with the same Parameter.

Cost Sensitivity Data for Sample Cost Model – Uniform Dither Factor

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1		Hardware			Parameters					Calculated System Cost				Interpretation of Cost Data				
2	Coun	SubSystem Block	Component	Parameter	Parameter Value	Dither amount	Dither "Up" Parameter Value	Dither "Down" Parameter Value	blank	Baseline Cost	Dither "up" cost	Dither "Down" cost	blank	delta "up" cost	delta "down" cost	delta "mid"	delta "range"	Rank of impact
3		Receiver Module																
4			Receiver															
5	1		Receiver	Total CCAs	2	20%	2.4	1.6		8464002.22	8,635,812.46	8,292,433.94		171810.2	171568.28	$ 171,689.26	$ 120.98	3
6	2		Receiver	PCB Size	30	20%	36	24		8464002.22	8,464,233.55	8,463,702.28		231.33	299.94	$ 265.64	$ 34.31	30
7	3		Receiver	Discreet Components per PCB	40	20%	48	32		8464002.22	8,465,383.18	8,460,652.70		1380.96	3349.52	$ 2,365.24	$ 984.28	23
8	4		Receiver	Integrated Components per PCB	45	20%	54	36		8464002.22	8,554,945.20	8,355,277.79		90942.98	108724.43	$ 99,833.70	$ 8,890.73	6
9	5		Receiver	Clock Speed	240	20%	288	192		8464002.22	8,470,484.81	8,454,122.15		6482.59	9880.07	$ 8,181.33	$ 1,698.74	16
10			RF Module							8464002.22								39
11	6		RF Module	Total CCAs	0.5	20%	0.6	0.4		8464002.22	8,532,807.84	8,368,659.13		68805.62	95343.09	$ 82,074.36	$ 13,268.74	7
12	7		RF Module	PCB Size	30	20%	36	24		8464002.22	8,465,564.17	8,462,440.24		1561.95	1561.98	$ 1,561.96	$ 0.02	25
13	8		RF Module	Discreet Components per PCB	6	20%	7	5		8464002.22	8,464,372.53	8,463,261.73		370.31	740.49	$ 555.40	$ 185.09	27
14	9		RF Module	Integrated Components per PCB	4	20%	5	3		8464002.22	8,480,702.51	8,446,047.29		16700.29	17954.93	$ 17,327.61	$ 627.32	13
15	10		RF Module	Clock Speed	800	20%	960	640		8464002.22	8,471,923.88	8,457,593.74		7921.66	6408.48	$ 7,165.07	$ 756.59	17
16			RF Machined Housing							8464002.22								40
17	11		RF Machined Housing	Weight	3.5	20%	4.2	2.8		8464002.22	8,482,247.52	8,445,424.14		18245.3	18578.08	$ 18,411.69	$ 166.39	12
18	12		RF Machined Housing	Volume	0.4	20%	0.48	0.32		8464002.22	8,464,044.43	8,463,937.79		42.21	64.43	$ 53.32	$ 11.11	34
19			Rcv Chassis							8464002.22								41
20	13		Rcv Chassis	Weight	15	20%	18	12		8464002.22	8,477,619.85	8,439,276.92		13617.63	24725.3	$ 19,171.46	$ 5,553.84	11
21	14		Rcv Chassis	Volume	4	20%	4.8	3.2		8464002.22	8,464,006.54	8,463,997.89		4.32	4.33	$ 4.32	$ 0.01	37
22		Digitial Processing								8464002.22								42
23			Converter & Noise Reduction							8464002.22								43
24	15		Converter & Noise Reduction	Total CCAs	3	20%	3.6	2.4		8464002.22	8,906,581.20	8,338,727.59		442579	125274.63	$ 283,926.81	$ 158,652.17	2
25	16		Converter & Noise Reduction	PCB Size	30	20%	36	24		8464002.22	8,464,443.78	8,463,560.64		441.56	441.58	$ 441.57	$ 0.01	28
26	17		Converter & Noise Reduction	Discreet Components per PCB	35	20%	42	28		8464002.22	8,470,804.09	8,462,063.69		6801.87	1938.53	$ 4,370.20	$ 2,431.67	20
27	18		Converter & Noise Reduction	Integrated Components per PCB	120	20%	144	96		8464002.22	8,598,093.70	8,303,686.24		134091.5	160315.98	$ 147,203.73	$ 13,112.25	4
28	19		Converter & Noise Reduction	Clock Speed	20	20%	24	16		8464002.22	8,465,109.02	8,442,527.46		1106.8	21474.76	$ 11,290.78	$ 10,183.98	14
29			Data Processing							8464002.22								44
30	20		Data Processing	Total CCAs	2	20%	2.4	1.6		8464002.22	8,669,291.54	7,967,017.62		205289.3	496984.6	$ 351,136.96	$145,847.64	1
31	21		Data Processing	PCB Size	30	20%	36	24		8464002.22	8,464,401.74	8,463,640.14		399.52	362.08	$ 380.80	$ 18.72	29
32	22		Data Processing	Discreet Components per PCB	250	20%	300	200		8464002.22	8,466,172.83	8,460,963.97		2170.61	3038.25	$ 2,604.43	$ 433.82	22
33	23		Data Processing	Integrated Components per PCB	750	20%	900	600		8464002.22	8,601,269.25	8,377,674.05		137267	86328.17	$ 111,797.60	$ 25,469.43	5
34	24																	
35																		
36	25																	
37	26																	
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45	33																	
46	34																	
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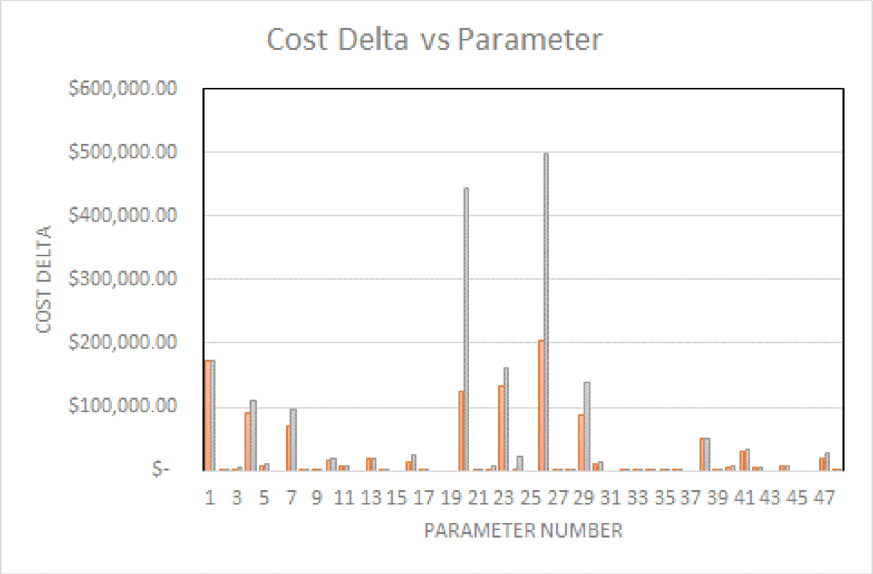
48	35																	
49	36																	
50																		
51	37																	
52	38																	

Cost sensitivity algorithm was applied to every Impactful Parameter in the sample cost model and calculated all cost sensitivities.

Includes: Impactful Parameters, dither amount (20%), dither "up" & dither "down" Parameter values, overall system cost, delta "mid" & delta "range", ranking and color coded indicators. Ten most Impactful Parameters are Red, the next ten as Yellow, the next ten as Green, and the remainder as uncolored,



Cost Deltas vs. Parameters for All Parameters

Parameter	Component	Sensitivity or Delta "mid"	Rank of impact
Clock Speed	Converter & Noise Reduction	$ 11,290.78	14
	Data Processing	$ 11,154.92	15
	Interconnect - Data Bus	$ 3,666.51	21
	Purchased Memory	$ 115.70	32
	Receiver	$ 8,181.33	16
	RF Module	$ 7,165.07	17
Discreet Components per PCB	Converter & Noise Reduction	$ 4,370.20	20
	Data Processing	$ 2,604.43	22
	Interconnect - Data Bus	$ 5,908.91	19
	Purchased Memory	$ 237.46	31
	Receiver	$ 2,365.24	23
	RF Module	$ 555.40	27
Integrated Components per PCB	Converter & Noise Reduction	$ 147,203.73	4
	Data Processing	$ 111,797.60	5
	Interconnect - Data Bus	$ 31,839.08	9
	Purchased Memory	$ 1,537.09	26
	Receiver	$ 99,833.70	6
	RF Module	$ 17,327.61	13
Volume	Digital Processing Chassis	$ 4.92	36
	Instrumentation Panel	$ 0.10	38
	Rcv Chassis	$ 4.32	37
	RF Machined Housing	$ 53.32	34
Weight	Digital Processing Chassis	$ 22,367.06	10
	Instrumentation Panel	$ 7,089.54	18
	Rcv Chassis	$ 19,171.46	11
	RF Machined Housing	$ 18,411.69	12
Total CCAs	Converter & Noise Reduction	$ 283,926.81	2
	Data Processing	$ 351,136.96	1
	Interconnect - Data Bus	$ 50,923.68	8
	Purchased Memory	$ 1,685.79	24
	Receiver	$ 171,689.26	3
	RF Module	$ 82,074.36	7
PCB Size	Converter & Noise Reduction	$ 441.57	28
	Data Processing	$ 380.80	29
	Interconnect - Data Bus	$ 61.00	33
	Purchased Memory	$ 13.23	35
	Receiver	$ 265.64	30
	RF Module	$ 1,561.96	25

All System Sensitivities

Component	Parameter	Rank of impact
Data Processing	Total CCAs	1
Converter & Noise Reduction	Total CCAs	2
Receiver	Total CCAs	3
Converter & Noise Reduction	Integrated Components per PCB	4
Data Processing	Integrated Components per PCB	5
Receiver	Integrated Components per PCB	6
RF Module	Total CCAs	7
Interconnect - Data Bus	Total CCAs	8
Interconnect - Data Bus	Integrated Components per PCB	9
Digital Processing Chassis	Weight	10
Rcv Chassis	Weight	11
RF Machined Housing	Weight	12
RF Module	Integrated Components per PCB	13
Converter & Noise Reduction	Clock Speed	14
Data Processing	Clock Speed	15
Receiver	Clock Speed	16
RF Module	Clock Speed	17
Instrumentation Panel	Weight	18
Interconnect - Data Bus	Discreet Components per PCB	19
Converter & Noise Reduction	Discreet Components per PCB	20
Interconnect - Data Bus	Clock Speed	21
Data Processing	Discreet Components per PCB	22
Receiver	Discreet Components per PCB	23
Purchased Memory	Total CCAs	24
RF Module	PCB Size	25
Purchased Memory	Integrated Components per PCB	26
RF Module	Discreet Components per PCB	27
Converter & Noise Reduction	PCB Size	28
Data Processing	PCB Size	29
Receiver	PCB Size	30

Top 30 Cost Sensitivities

Parameter	Dither Factor	Component	Sensitivity or Delta "mid"
Total CCAs	20%	Data Processing	$351,136.96
Integrated Components per PCB	20%	Converter & Noise Reduction	$147,203.73
Weight	20%	Digital Processing Chassis	$22,367.06
Clock Speed	20%	Converter & Noise Reduction	$11,290.78
Discreet Components per PCB	20%	Interconnect - Data Bus	$5,908.91
PCB Size	20%	RF Module	$1,561.96
Volume	20%	RF Machined Housing	$189.47

Sorted By Most Impactful Parameters

Results of Cost Sensitivity Algorithm on Sample Cost Model using Uniform dither factor

Developing the Cost Algorithm

KSMs

Expected Parameter Sequence	New KSMs to yield the expected sequence
Total CCAs	20%
Weight	60%
Integrated Components per PCB	5%
Clock Speed	20%
PCB Size	40%
Discreet Components per PCB	10%
Volume	75%

One significant issue requiring resolution was the uniform dither factor of 20% for every Parameter. A uniform dither factor is insufficient and may yield misleading results

To overcome the limitation, a set of Key Size Metrics, or KSMs, was developed. The KSMs would specify a unique value (other than a uniform 20%) for each Parameter.

Developing the Cost Algorithm

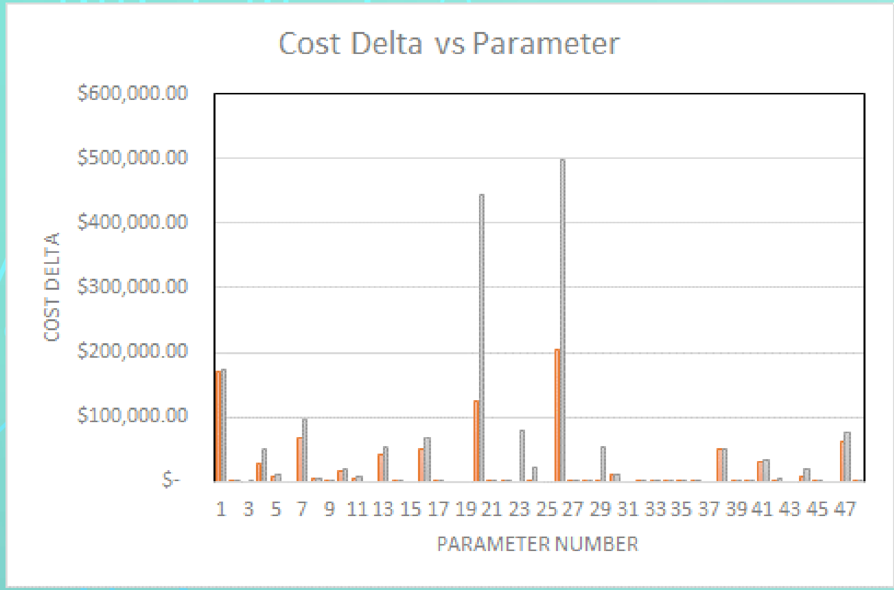
Apply KSMs to Sample Cost Model

Cost Sensitivity Data for Sample Cost Model – Using KSMs

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1		Hardware			Parameters					Calculated System Cost				Interpretation of Cost Data				
2	Count	SubSystem Block	Component	Parameter	Parameter Value	Dither amount (KSM)	Dither "Up" Parameter Value	Dither "Down" Parameter Value	blank	Baseline Cost	Dither "up" cost	Dither "Down" cost	blank	delta "up" cost	delta "down" cost	delta "mid"	delta "range"	Rank of impact
3		Receiver Module																
4			Receiver															
5	1		Receiver	Total CCAs	2	20%	2.4	1.6		8464002.22	8,635,812.46	8,292,433.94		171810.2	171568.28	$ 171,689.26	$ 120.98	3
6	2		Receiver	PCB Size	30	65%	49.5	10.5		8464002.22	8,464,754.08	8,463,050.16		751.86	952.06	$ 851.96	$ 100.10	26
7	3		Receiver	Discreet Components per PCB	40	5%	42	38		8464002.22	8,463,607.88	8,462,425.19		-394.34	1577.03	$ 591.35	$ 985.69	28
8	4		Receiver	Integrated Components per PCB	45	5%	48	42		8464002.22	8,513,752.23	8,436,029.19		49750.01	27973.03	$ 38,861.52	$ 10,888.49	9
9	5		Receiver	Clock Speed	240	20%	288	192		8464002.22	8,470,484.81	8,454,122.15		6482.59	9880.07	$ 8,181.33	$ 1,698.74	17
10			RF Module							8464002.22								39
11	6		RF Module	Total CCAs	0.5	20%	0.6	0.4		8464002.22	8,532,807.84	8,368,659.13		68805.62	95343.09	$ 82,074.36	$ 13,268.74	4
12	7		RF Module	PCB Size	30	65%	49.5	10.5		8464002.22	8,469,078.38	8,458,925.63		5076.16	5076.59	$ 5,076.38	$ 0.21	19
13	8		RF Module	Discreet Components per PCB	6	5%	7	5		8464002.22	8,464,372.53	8,463,261.73		370.31	740.49	$ 555.40	$ 185.09	29
14	9		RF Module	Integrated Components per PCB	4	5%	5	3		8464002.22	8,480,702.51	8,446,047.29		16700.29	17954.93	$ 17,327.61	$ 627.32	13
15	10		RF Module	Clock Speed	800	20%	960	640		8464002.22	8,471,923.88	8,457,593.74		7921.66	6408.48	$ 7,165.07	$ 756.59	18
16			RF Machined Housing							8464002.22								40
17	11		RF Machined Housing	Weight	3.5	60%	5.6	1.4		8464002.22	8,517,543.41	8,423,335.13		53541.19	40667.09	$ 47,104.14	$ 6,437.05	8
18	12		RF Machined Housing	Volume	0.4	75%	0.7	0.1		8464002.22	8,464,119.95	8,463,741.00		117.73	261.22	$ 189.47	$ 71.75	31
19			Rcv Chassis							8464002.22								41
20	13		Rcv Chassis	Weight	15	60%	24	6		8464002.22	8,514,311.26	8,397,694.59		50309.04	66307.63	$ 58,308.33	$ 7,999.30	6
21	14		Rcv Chassis	Volume	4	75%	7	1		8464002.22	8,464,018.44	8,463,986.00		16.22	16.22	$ 16.22	$ 0.00	37
22		Digitial Processing								8464002.22								42
23			Converter & Noise Reduction							8464002.22								43
24	15		Converter & Noise Reduction	Total CCAs	3	20%	3.6	2.4		8464002.22	8,906,581.20	8,338,727.59		442579	125274.63	$ 283,926.81	$ 158,652.17	2
25	16		Converter & Noise Reduction	PCB Size	30	65%	49.5	10.5		8464002.22	8,465,682.72	8,462,709.00		1680.5	1293.22	$ 1,486.86	$ 193.64	24
26	17		Converter & Noise Reduction	Discreet Components per PCB	35	5%	37	33		8464002.22	8,464,556.30	8,463,448.34		554.08	553.88	$ 553.98	$ 0.10	30
27	18		Converter & Noise Reduction	Integrated Components per PCB	120	5%	126	114		8464002.22	8,542,729.00	8,470,211.05		78726.78	-6208.83	$ 36,258.97	$ 42,467.80	10
28	19		Converter & Noise Reduction	Clock Speed	20	20%	24	16		8464002.22	8,465,109.02	8,442,527.46		1106.8	21474.76	$ 11,290.78	$ 10,183.98	15
29			Data Processing							8464002.22								44
30	20		Data Processing	Total CCAs	2	20%	2.4	1.6		8464002.22	8,669,291.54	7,967,017.62		205289.3	496984.6	$ 351,136.96	$145,847.64	1
31	21		Data Processing	PCB Size	30	65%	49.5	10.5		8464002.22	8,465,300.70	8,462,880.34		1298.48	1121.88	$ 1,210.18	$ 88.30	25
32	22		Data Processing	Discreet Components per PCB	250	5%	263	237		8464002.22	8,464,245.19	8,462,891.10		242.97	1111.12	$ 677.04	$ 434.08	27
33	23		Data Processing	Integrated Components per PCB	750	5%	788	712		8464002.22	8,517,175.27	8,460,534.43		53173.05	3467.79	$ 28,320.42	$ 24,852.63	12
34	24																	
35																		
36	25																	
37	26																	
38	27																	
39	28																	
40	29																	
41																		
42	30																	
43	31																	
44	32																	
45	33																	
46	34																	
47																		
48	35																	
49	36																	
50																		
51	37																	
52	38																	

Cost sensitivity algorithm was applied to every Impactful Parameter in the sample cost model and calculated all cost sensitivities.

Includes: Impactful Parameters, dither factor (KSMs), dither "up" & dither "down" Parameter values, overall system cost, delta "mid" & delta "range", ranking and color coded indicators. Ten most Impactful Parameters are Red, the next ten as Yellow, the next ten as Green, and the remainder as uncolored.



Cost Deltas vs. Parameters for All Parameters

Parameter	Component	Sensitivity or Delta "mid"	Rank of impact
Clock Speed	Converter & Noise Reduction	$ 11,290.78	15
	Data Processing	$ 11,154.92	16
	Interconnect - Data Bus	$ 3,666.51	20
	Purchased Memory	$ 115.70	33
	Receiver	$ 8,181.33	17
	RF Module	$ 7,165.07	18
Discreet Components per PCB	Converter & Noise Reduction	$ 553.98	30
	Data Processing	$ 677.04	27
	Interconnect - Data Bus	$ 1,996.28	21
	Purchased Memory	$ 77.48	34
	Receiver	$ 591.35	28
	RF Module	$ 555.40	29
Integrated Components per PCB	Converter & Noise Reduction	$ 36,258.97	10
	Data Processing	$ 28,320.42	12
	Interconnect - Data Bus	$ 31,839.08	11
	Purchased Memory	$ 1,537.09	23
	Receiver	$ 38,861.52	9
	RF Module	$ 17,327.61	13
Weight	Digital Processing Chassis	$ 67,948.22	5
	Instrumentation Panel	$ 13,899.06	14
	Rcv Chassis	$ 58,308.33	6
	RF Machined Housing	$ 47,104.14	8
Volume	Digital Processing Chassis	$ 18.45	36
	Instrumentation Panel	$ 0.36	38
	Rcv Chassis	$ 16.22	37
	RF Machined Housing	$ 189.47	31
Total CCAs	Converter & Noise Reduction	$ 283,926.81	2
	Data Processing	$ 351,136.96	1
	Interconnect - Data Bus	$ 50,923.68	7
	Purchased Memory	$ 1,685.79	22
	Receiver	$ 171,689.26	3
	RF Module	$ 82,074.36	4
PCB Size	Converter & Noise Reduction	$ 1,486.86	24
	Data Processing	$ 1,210.18	25
	Interconnect - Data Bus	$ 172.78	32
	Purchased Memory	$ 37.45	35
	Receiver	$ 851.96	26
	RF Module	$ 5,076.38	19

All System Sensitivities

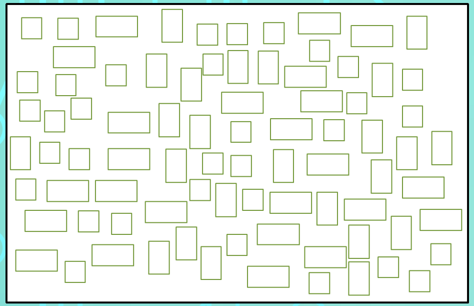
Component	Parameter	Rank of impact
Data Processing	Total CCAs	1
Converter & Noise Reduction	Total CCAs	2
Receiver	Total CCAs	3
RF Module	Total CCAs	4
Digital Processing Chassis	Weight	5
Rcv Chassis	Weight	6
Interconnect - Data Bus	Total CCAs	7
RF Machined Housing	Weight	8
Receiver	Integrated Components per PCB	9
Converter & Noise Reduction	Integrated Components per PCB	10
Interconnect - Data Bus	Integrated Components per PCB	11
Data Processing	Integrated Components per PCB	12
RF Module	Integrated Components per PCB	13
Instrumentation Panel	Weight	14
Converter & Noise Reduction	Clock Speed	15
Data Processing	Clock Speed	16
Receiver	Clock Speed	17
RF Module	Clock Speed	18
RF Module	PCB Size	19
Interconnect - Data Bus	Clock Speed	20
Interconnect - Data Bus	Discreet Components per PCB	21
Purchased Memory	Total CCAs	22
Purchased Memory	Integrated Components per PCB	23
Converter & Noise Reduction	PCB Size	24
Data Processing	PCB Size	25
Receiver	PCB Size	26
Data Processing	Discreet Components per PCB	27
Receiver	Discreet Components per PCB	28
RF Module	Discreet Components per PCB	29
Converter & Noise Reduction	Discreet Components per PCB	30

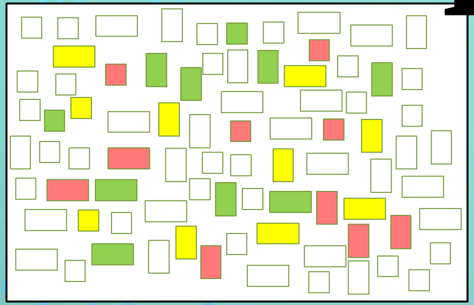
Top 30 Cost Sensitivities

Parameter	KSM	Component	Sensitivity or Delta "mid"
Total CCAs	20%	Data Processing	$351,136.96
Weight	60%	Digital Processing Chassis	$67,948.22
Integrated Components per PCB	5%	Receiver	$38,861.52
Clock Speed	20%	Converter & Noise Reduction	$11,290.78
PCB Size	40%	RF Module	$5,076.38
Discreet Components per PCB	10%	Interconnect - Data Bus	$1,996.28
Volume	75%	RF Machined Housing	$189.47

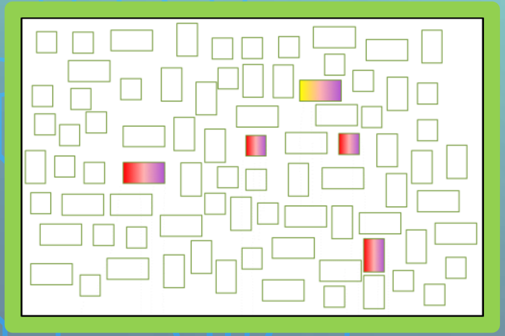
Sorted By Most Impactful Parameters

Results of Cost Sensitivity Algorithm on Sample Cost Model using KSM dither factors





Application of the Cost Algorithm

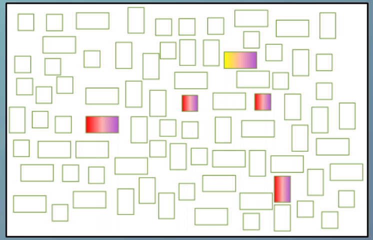


Using The Results, ROI

How can a system design be optimized in terms of performance and cost early on in the life cycle of a Program?

Modify a reasonable set of Impactful Parameters, observe affect to overall system cost.

The top five most impactful parameters were considered.



Component	Parameter	Rank of impact	Parameter "Was"	Parameter "Try"
Data Processing	Total CCAs	1	2	1
Converter & Noise Reduction	Total CCAs	2	3	2
Receiver	Total CCAs	3	2	1
RF Module	Total CCAs	4	0.5	0.5
Digital Processing Chassis	Weight	5	18	17
Rcv Chassis	Weight	6	15	14

Baseline Cost

Reports

Quick Estimate | Detail Estimate

Item	Estimate
Total Development Cost	8,464,002.22
Total Production Cost	7,155,282.14
Development Cost	6,531,301.71
Development Labor Hours	37,204.79
Production Cost	6,401,051.26
Total Production Units	250
APUC	25,604.21
Operating Site Cost	364,100,800.00
Total Equipment Support Cost	59,608,697.29
System Level Development Cost	1,932,700.50
System Level Production Cost	754,230.88
System Level APUC	3,016.92
Total System Level Cost	2,686,931.38
Element Weight	129

New Cost

Reports

Quick Estimate | Detail Estimate

Item	Estimate
Total Development Cost	6,682,902.18
Total Production Cost	6,139,255.99
Development Cost	5,164,241.31
Development Labor Hours	29,378.56
Production Cost	5,486,401.35
Total Production Units	250
APUC	21,945.61
Operating Site Cost	364,100,800.00
Total Equipment Support Cost	47,103,646.68
System Level Development Cost	1,518,660.88
System Level Production Cost	652,854.65
System Level APUC	2,611.42
Total System Level Cost	2,171,515.52
Element Weight	123

By simultaneously adjust all top five most impactful parameters, the overall system cost has been significantly affected.

$8,464,002.22	<-- Baseline System Cost
$6,682,902.18	<-- New Improved System Cost
$1,781,100.04	<-- Savings
21%	<-- % Improvement

An achievable percentage improvement of 21%, Significant impact!

Another way to interpret result is in terms of Return On Investment, or ROI. In order to modify a Parameter value, it is necessary to expend some resources in order to achieve the new value. In this case, if the System Designer remains below a $1.78M dollar investment then the project, overall, would demonstrate an improvement. Anything less than $1.78M contributes to profit margin.

Summary

This paper documents the generation of a cost sensitivity algorithm of the various Components in a System in order to analyze a System and determine which Subsystem Components in a chosen design solution have the highest sensitivity to cost for the overall System and highlights the areas to which a System Designer could apply focus in order to reduce the overall System cost early on in the life cycle of a Program. It was shown that a cost sensitivity algorithm was developed and was applied to a sample cost model. The results demonstrated which Component Parameters were most sensitive, and the biggest cost drivers in the System design. And finally, Return On Investment, or ROI, was calculated to suggested a Trade Study budget for achieving the potential cost improvements. The potential cost improvements with some realistic design alternatives was demonstrated to be a 21% improvement in overall system cost which is clearly a significant improvement.

Questions ?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