FOUNDATION OF STRUCTURED ARCHITECTURE, SYSTEM & COST MODELING©

Submitted by:
Danny Israel Polidi
Mike Crist
Dr. V. Chandrasekar
Department Of System Engineering
Colorado State University

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Agenda

- ❑Problem Statement
- ❑Problem Illustrated – Simple Terms
- ❑Section 1: Block Diagram
- ❑Section 2: System Engineering Model
- ❑Section 3: System Cost Model
- ❑Further Research: Cost Sensitivity
- ❑Summary
- ❑Questions

Problem Statement

For a complex system, Methods are needed to determine which components in a system would benefit from additional modeling such as using a Multiphysics approach, and which design approach provides the best value (cost vs. performance) to the system. These methods are needed during concept development to aid in system scoping and cost estimation. In order to develop these tools, it is necessary to have standardized system models upon which to perform the tool development.

This paper begins the development of a structured System Engineering approach to System design by defining a standardized modular WBS structure for a RADAR System applied to military applications in the aerospace industry and then uses that standardized WBS structure to begin both a System model and a cost model.

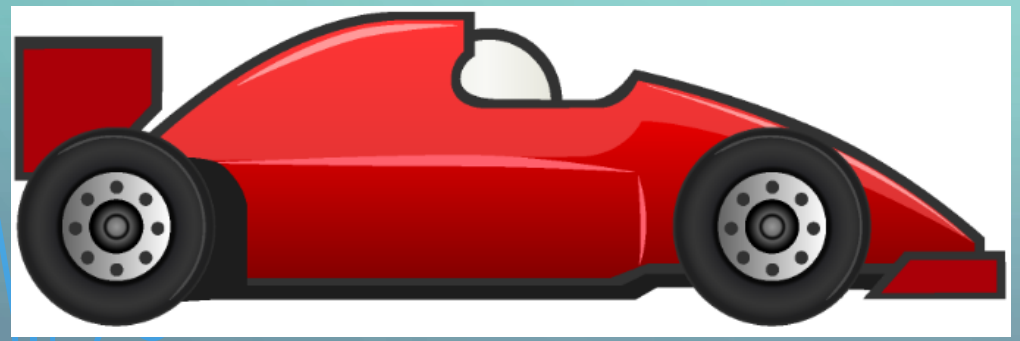
Problem - Illustrated

Sports

Moon

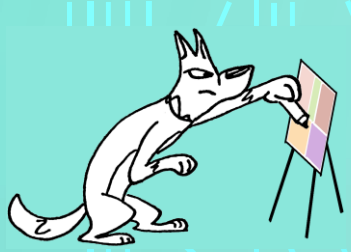
Family

A car as a System:
Even when the System is specific, there still remains a large set of variations within the literature.



Race

Economy



Problem – Illustrated Architecture

Sports

"other" things

Steering

"other" things

"other" things

"other" things

Moon

"other" things

MTBF

"other" things

"other" things

"other" things

Family

"other" things

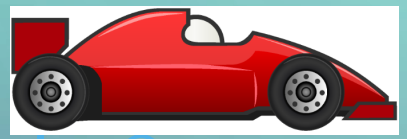
Volume

"other" things

"other" things

"other" things

Every block diagram is different because a different element is emphasized.



Race

"other" things

Acceleration

"other" things

"other" things

"other" things

Economy

"other" things

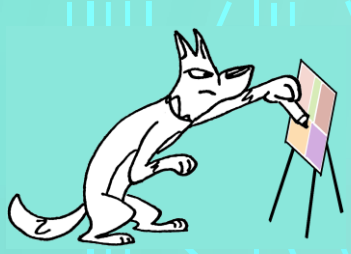
MPG

"other" things

"other" things

"other" things

"other" things

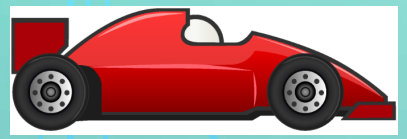


Problem – Illustrated Architecture

In order to develop tools, it is desirable to have standardized system models upon which to perform the tool development.

Taking a more global view, it should be possible to define the System in such a way that the existing block diagrams become a subset of the more general form.

Sports

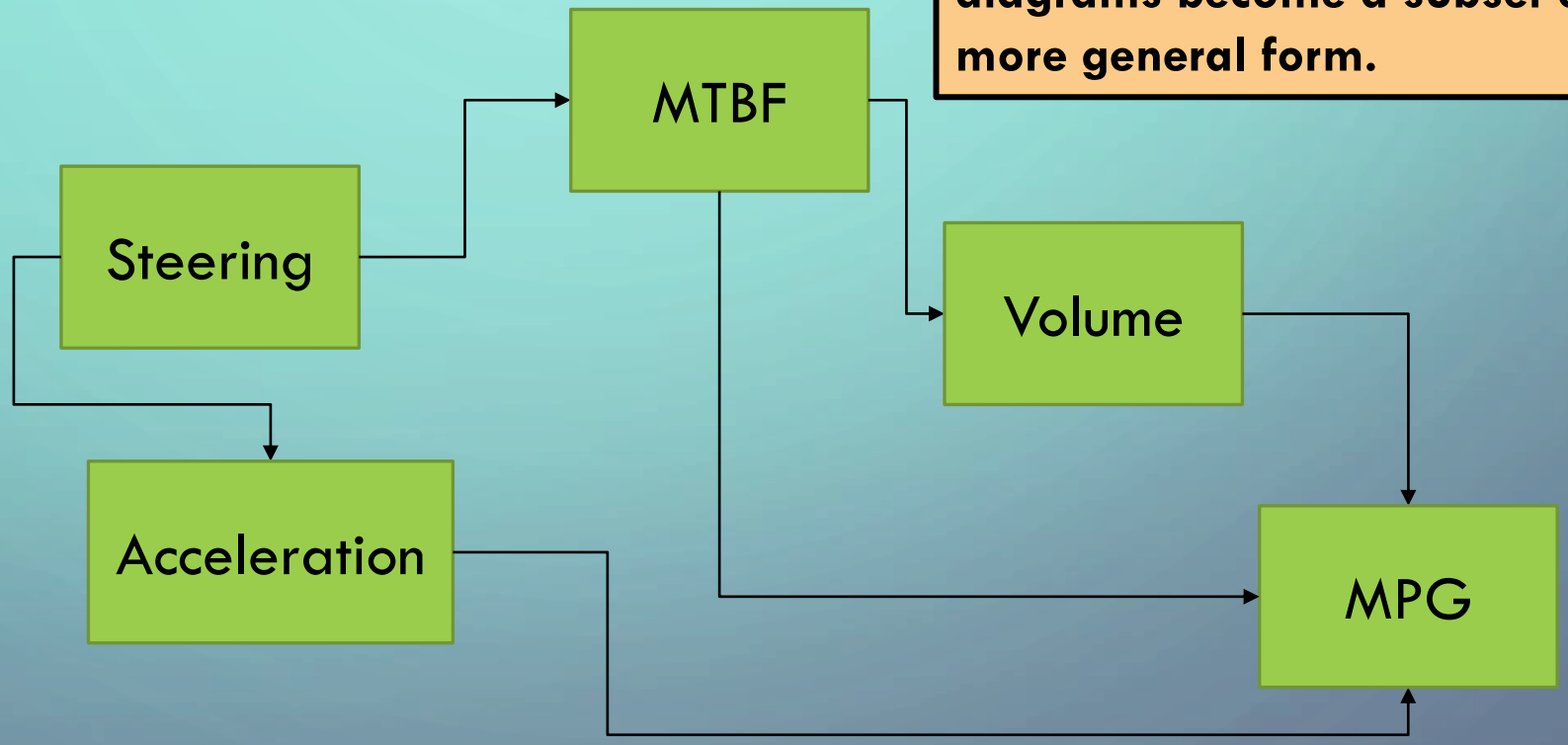


Race

Moon

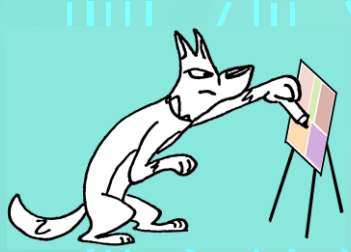
Family

Economy



Problem – Illustrated

Cost



Sports

"other" things

$? Steering

"other" things

"other" things

"other" things

Moon

"other" things

$? TBF

"other" things

"other" things

"other" things

Family

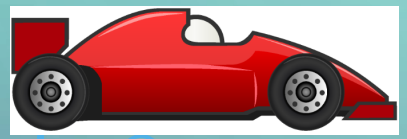
"other" things

$? Volume

"other" things

"other" things

"other" things



Race

"other" things

$? Acceleration

"other" things

"other" things

"other" things

Economy

"other" things

$? MPG

"other" things

"other" things

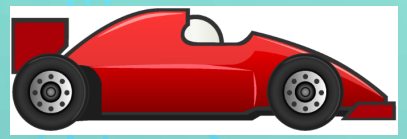
"other" things

With substantially different block diagrams, the effort to cost the System begins from scratch for every System.

Problem – Illustrated
Cost

With a standardized architecture, a cost model could be reused reducing time to results.

Sports

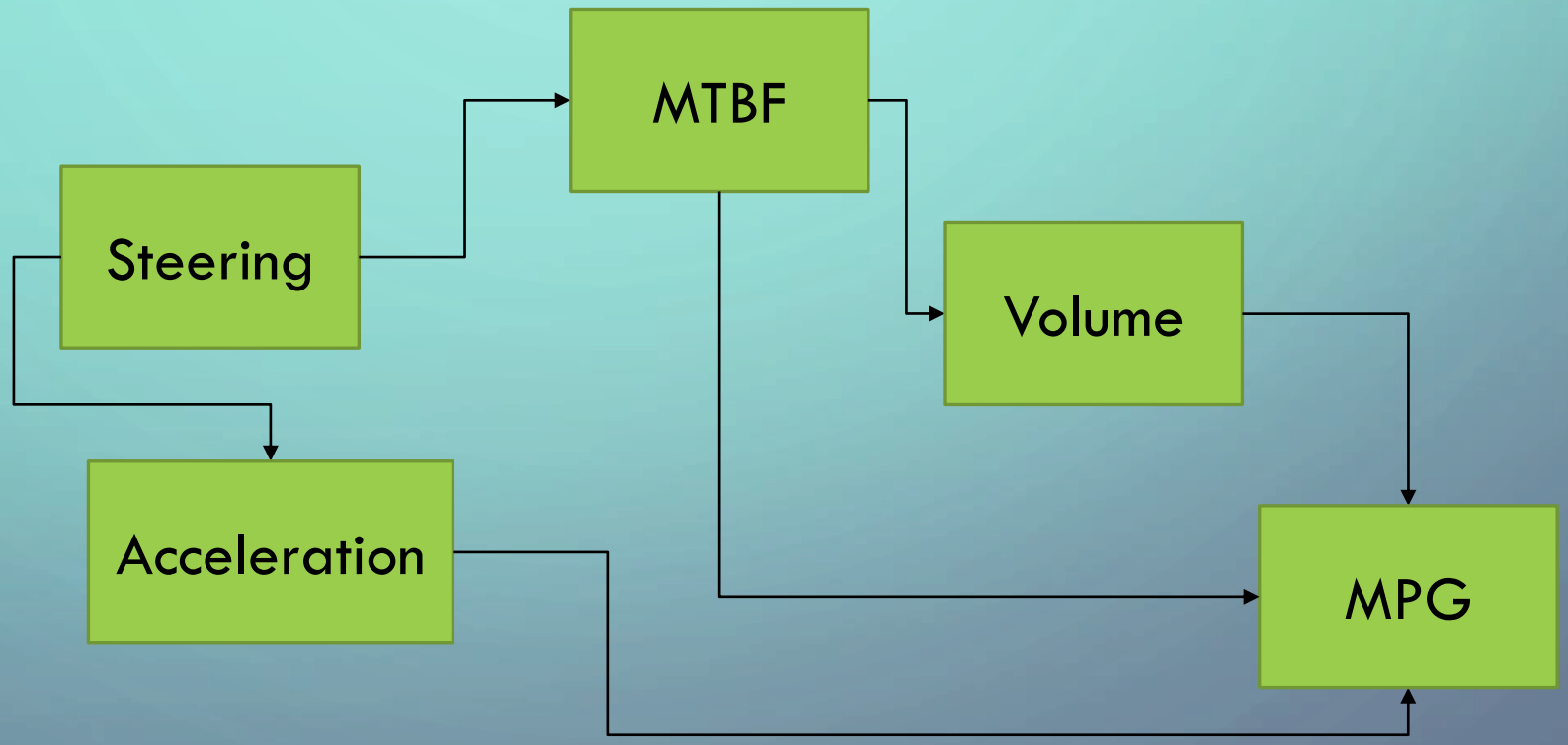


Race

Moon

Family

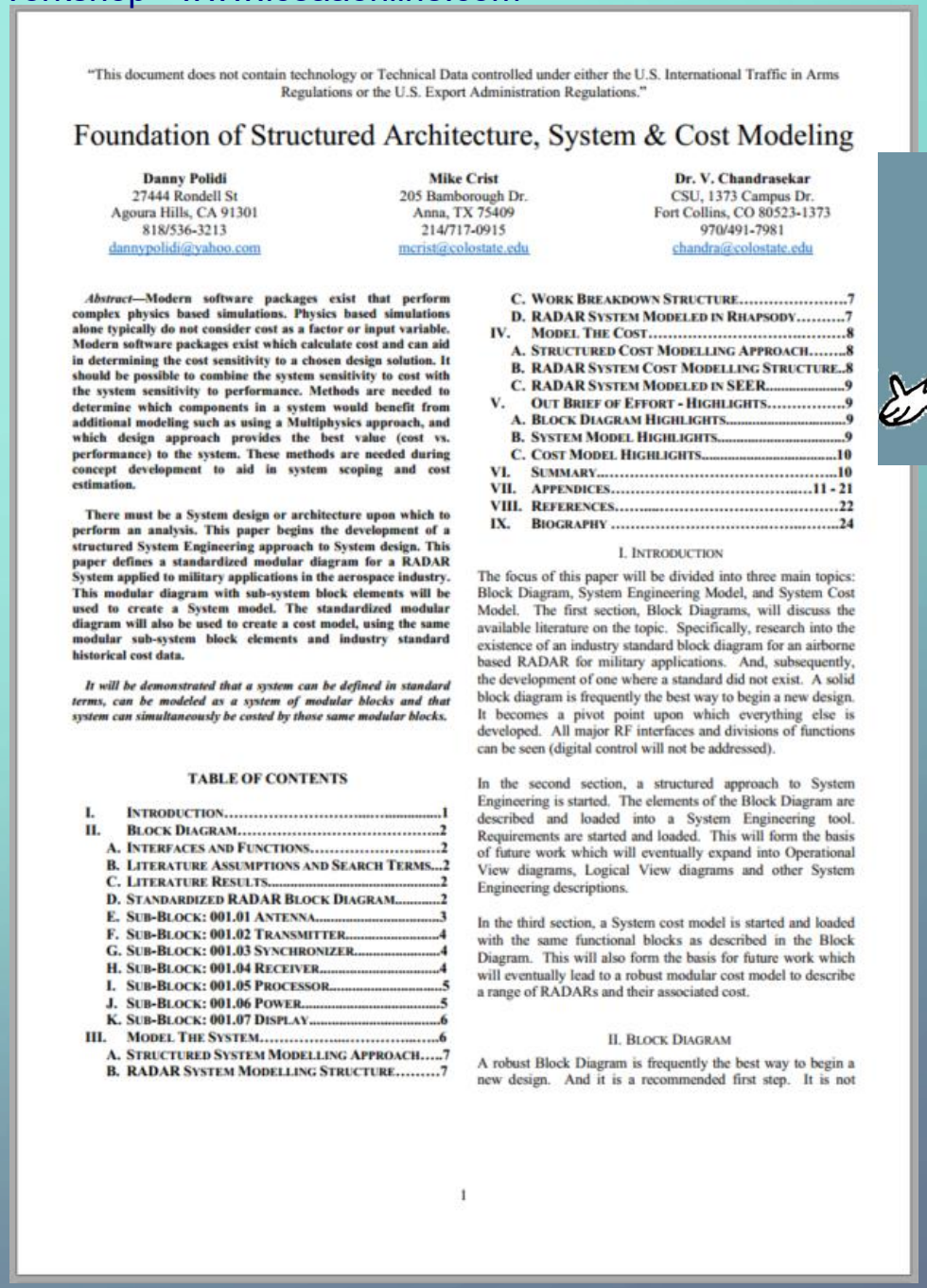
Economy



Presentation = Overview

The information presented here is a high level summary of the contents of the full paper.

The presentation is meant to inspire curiosity and touch upon the contents.



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Foundation of Structured Architecture, System & Cost Modeling

Danny Polidi
27444 Rondell St
Agoura Hills, CA 91301
818/536-3213
dannypolidi@yahoo.com

Mike Crist
205 Bamborough Dr.
Anna, TX 75409
214/717-0915
mcrist@colostate.edu

Dr. V. Chandrasekar
CSU, 1373 Campus Dr.
Fort Collins, CO 80523-1373
970/491-7981
chandra@colostate.edu

***Abstract*—Modern software packages exist that perform complex physics based simulations. Physics based simulations alone typically do not consider cost as a factor or input variable. Modern software packages exist which calculate cost and can aid in determining the cost sensitivity to a chosen design solution. It should be possible to combine the system sensitivity to cost with the system sensitivity to performance. Methods are needed to determine which components in a system would benefit from additional modeling such as using a Multiphysics approach, and which design approach provides the best value (cost vs. performance) to the system. These methods are needed during concept development to aid in system scoping and cost estimation.**

There must be a System design or architecture upon which to perform an analysis. This paper begins the development of a structured System Engineering approach to System design. This paper defines a standardized modular diagram for a RADAR System applied to military applications in the aerospace industry. This modular diagram with sub-system block elements will be used to create a System model. The standardized modular diagram will also be used to create a cost model, using the same modular sub-system block elements and industry standard historical cost data.

It will be demonstrated that a system can be defined in standard terms, can be modeled as a system of modular blocks and that system can simultaneously be costed by those same modular blocks.

TABLE OF CONTENTS

I. INTRODUCTION

The focus of this paper will be divided into three main topics: Block Diagram, System Engineering Model, and System Cost Model. The first section, Block Diagrams, will discuss the available literature on the topic. Specifically, research into the existence of an industry standard block diagram for an airborne based RADAR for military applications. And, subsequently, the development of one where a standard did not exist. A solid block diagram is frequently the best way to begin a new design. It becomes a pivot point upon which everything else is developed. All major RF interfaces and divisions of functions can be seen (digital control will not be addressed).

In the second section, a structured approach to System Engineering is started. The elements of the Block Diagram are described and loaded into a System Engineering tool. Requirements are started and loaded. This will form the basis of future work which will eventually expand into Operational View diagrams, Logical View diagrams and other System Engineering descriptions.

In the third section, a System cost model is started and loaded with the same functional blocks as described in the Block Diagram. This will also form the basis for future work which will eventually lead to a robust modular cost model to describe a range of RADARs and their associated cost.

II. BLOCK DIAGRAM

A robust Block Diagram is frequently the best way to begin a new design. And it is a recommended first step. It is not

1

Section I: Block Diagram

A robust Block Diagram is frequently the best way to begin a new design. And it is a recommended first step. It is not uncommon for Engineers to jump right into a design and begin designing. Each Engineer responsible for a portion of the System has ideas on how to best proceed. And frequently, those best ideas are competing rather than complimenting one another. This is why a robust discussion early on regarding System goals is so critical. Without a clear set of System goals, there is no way a System will be designed right the first time through. And a first step towards defining those goals is to create a Block Diagram. It becomes a pivot point upon which everything else is developed. All major interfaces and divisions of functions can be observed.

Section I: Block Diagram

The Local Oscillator is an oscillator which is used to change the frequency of the signal.

The Low Noise Amplifier boosts the signal while adding as little additional noise as possible. The goal is to maximize the Signal to Noise Ratio (SNR) of the echo signal.

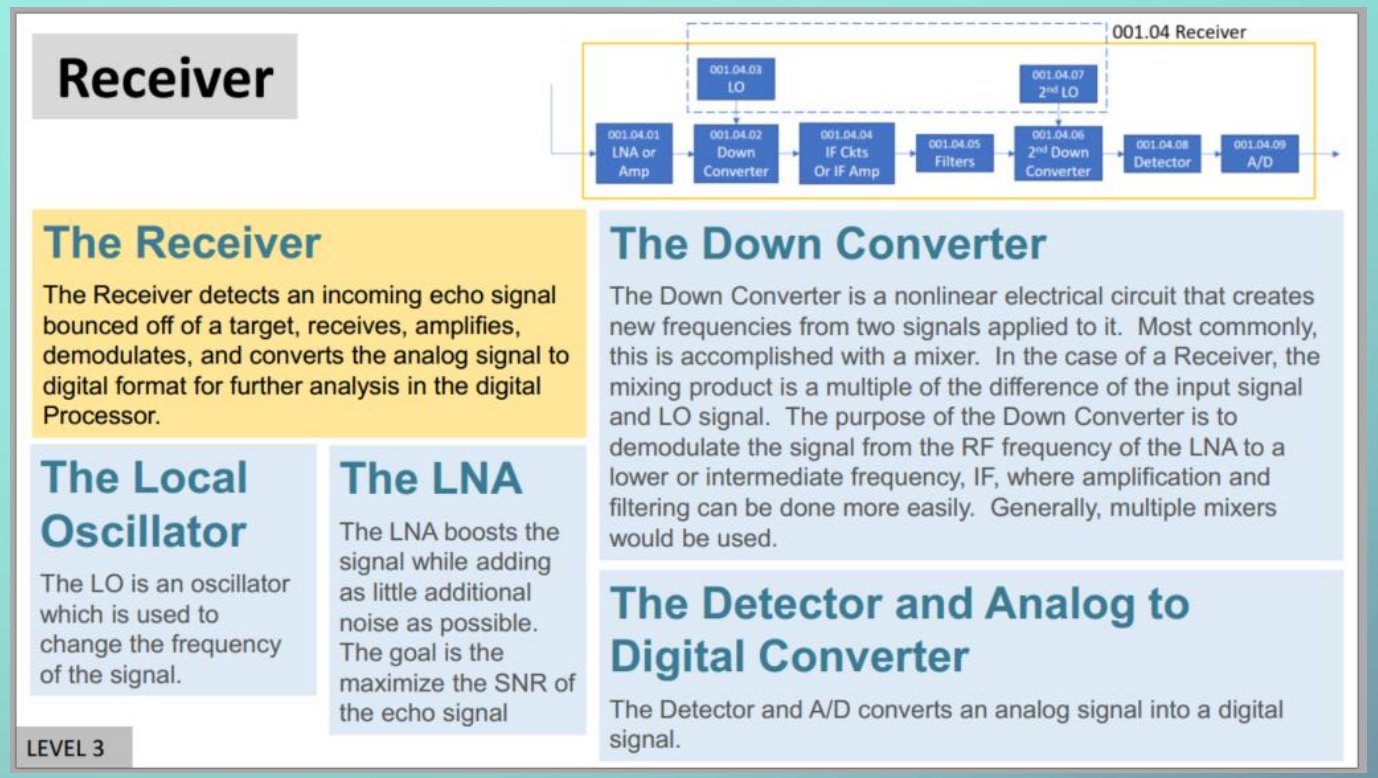
In a receive chain, the Signal to Noise Ratio is determined primarily by the first element. The first element of the chain dominates the entire chains performance. Low Noise Amplifiers, as the name suggests, is a special sub-class of amplifiers designed for this purpose. This is why an architect should assume an LNA as a first element.

The Down Converter is a nonlinear electrical circuit that creates new frequencies from two signals applied to it. Most commonly, this is accomplished with a mixer. In the case of a Receiver, the mixing product is a multiple of the difference of the inputs signal and LO signal. The purpose of the Down Converter is to demodulate the signal and the RF frequency of the LNA to a lower or intermediate frequency, IF, where amplification and filtering can be done more easily. Generally, multiple mixers would be used.

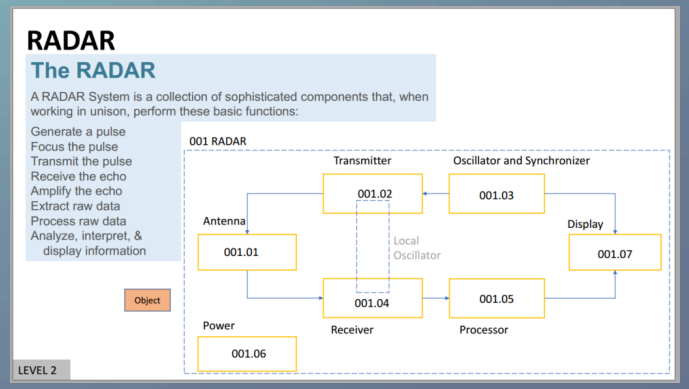
Later in the chain, the signal will be converted from analog to digital. The signal must be digitized for meaningful data processing of a modern System. At some future time it may be possible to directly convert an X-band signal to digital, but in today's practical terms that is not yet possible. Therefore, the conversion is required.

The Detector and Analog to Digital Converter, as the name implies, converts an analog signal into a digital signal.

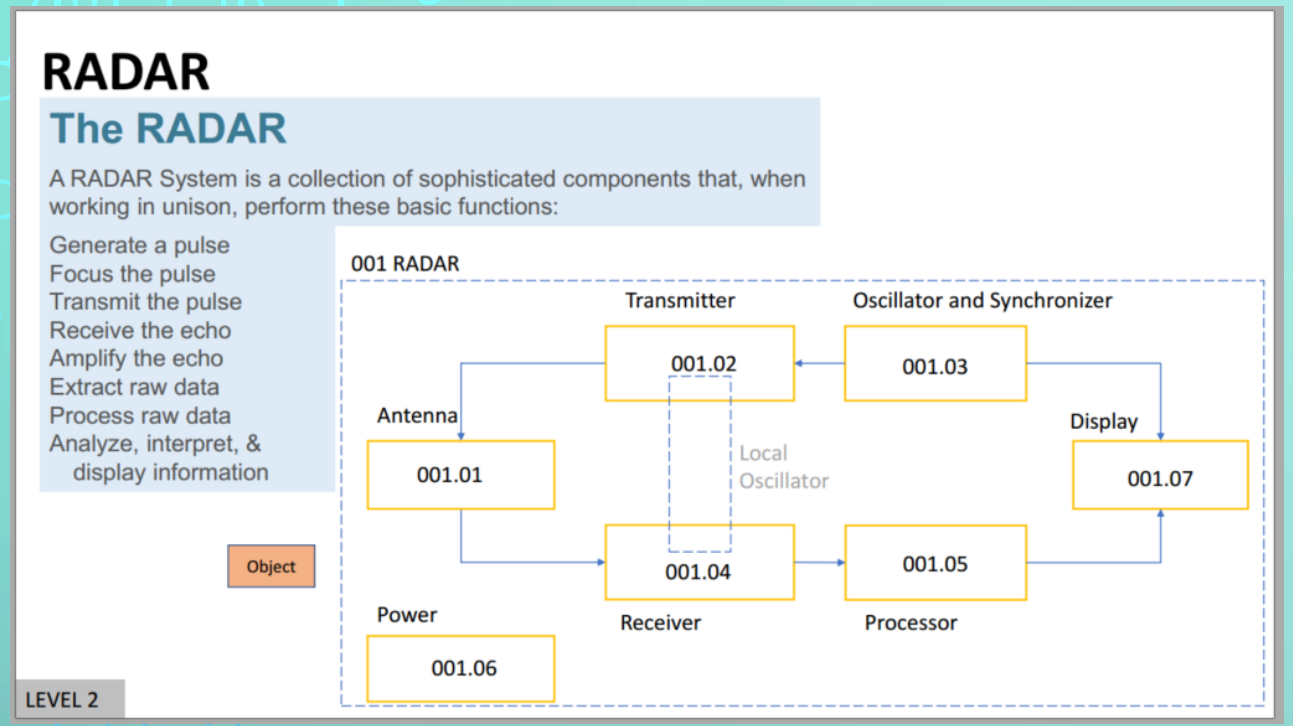
To convert the signal from analog to digital, a digital clock must be used. If the transmitted signal is "high", using the Nyquist criteria, the sampling frequency must be "higher". This is the fundamental limitation of the A/D converter. As mentioned, as time passes the technology is improving, but in today's practical solutions, the architect's options are still somewhat limited.



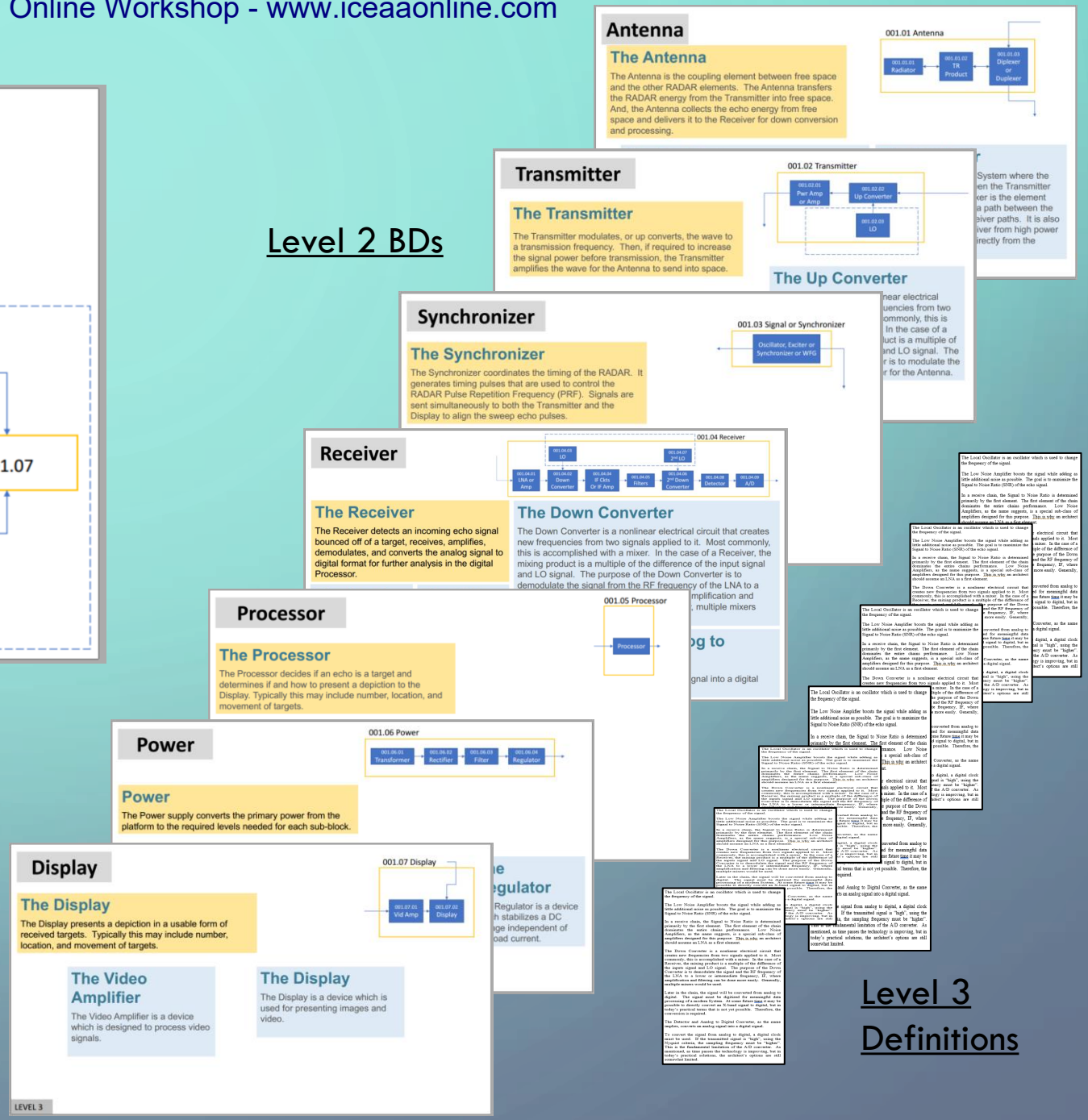
Definitions of Level 3 components were established …
which support the Level 2 sub-system blocks …
which support the Level 1 System



Section I: Block Diagram



Level 2 BDs



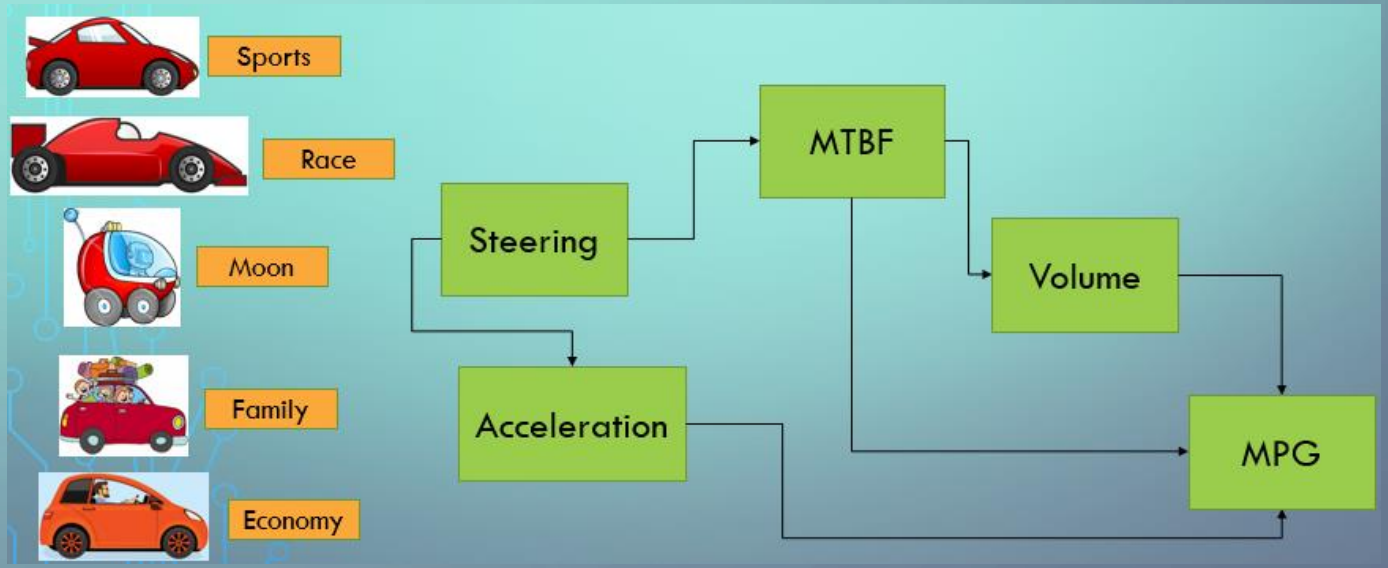
Level 3 Definitions

Using the available literature

- **A more generic or "universal" architecture was created for Level 1, 2 and 3 components**
- **Definitions were established**
- **Comparisons were made against literature examples establishing a more generalized form**

Section I: Block Diagram

The manuscript demonstrates that even for a complex system, it is possible to define blocks generically such that it can be applicable in “all” cases where any established case becomes a subset of the more general form.



Once a rigorous block diagram for a System has been created, the next step is to begin modeling the System or, as is commonly referred to as, architecting a System.

There is a very important book on the topic entitled "Architecting Information-Intensive Aerospace Systems" by Dr. John M. Borky. Paraphrasing, and/or quoting from his book, it tells us that the System architecture is the critical foundation for developing a design.

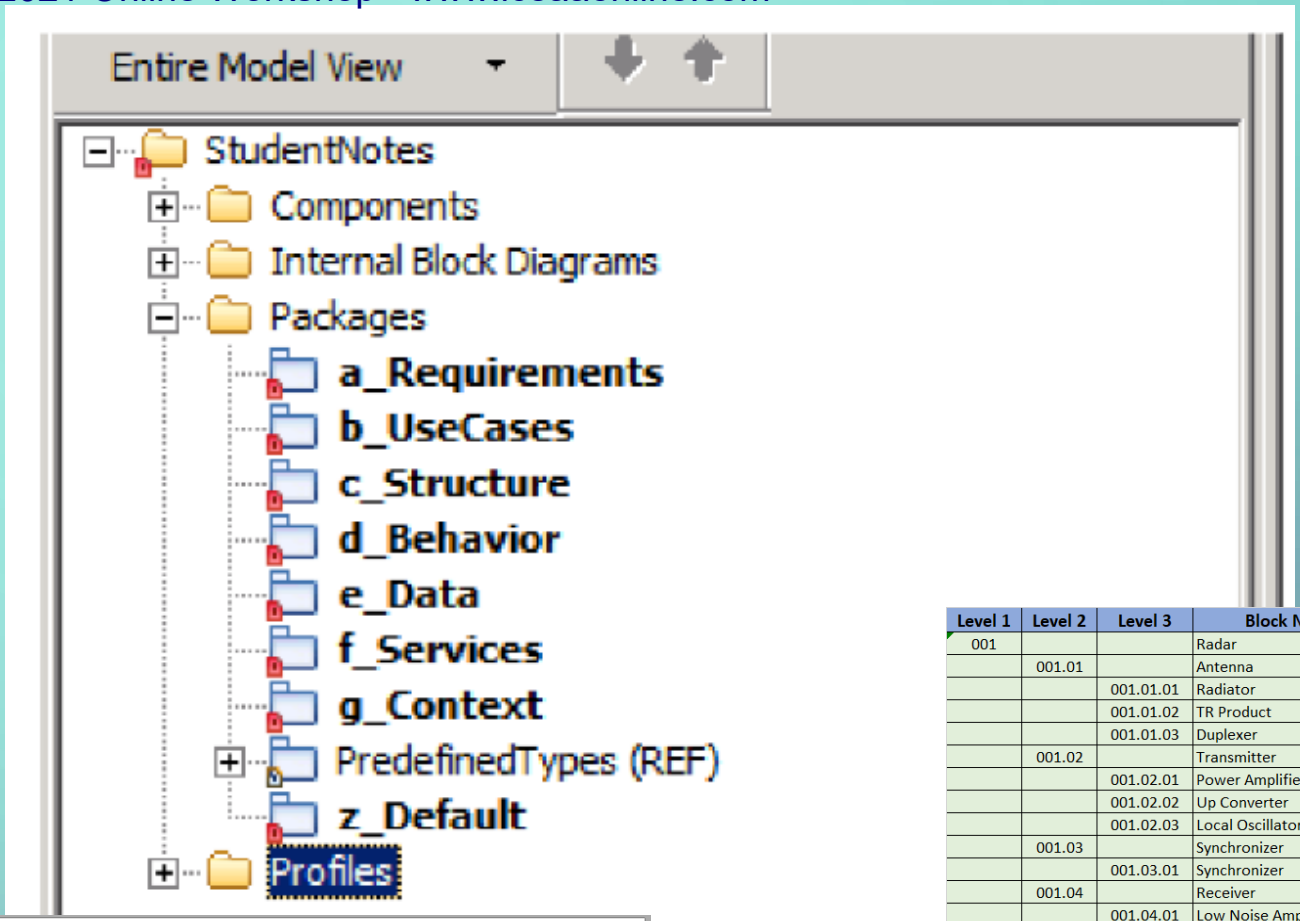
Architecting is done "to create systems and enterprises that are well organized, expandable and evolvable, robust under the stresses of real-world use, and affordable to own and operate. In short, the essence of the art and science of architecture is manifested in results that are beautiful in the eyes of their users while satisfying those users' practical needs."

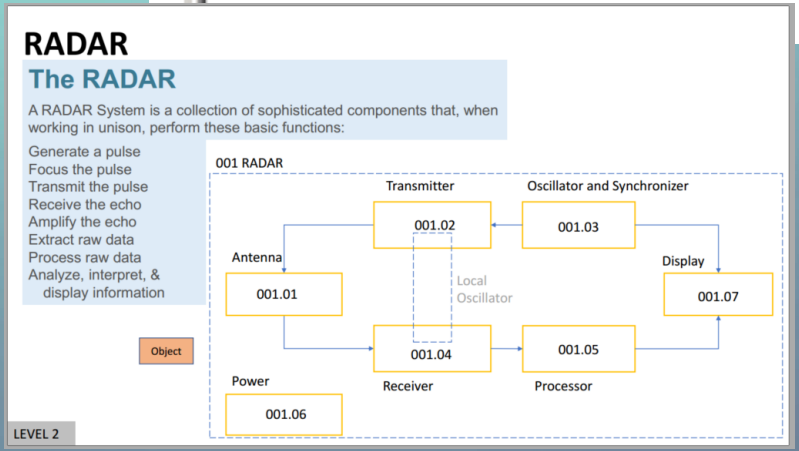
Section 2: System Engineering Model

Dr. Borky's book *Architecting Information-Intensive Aerospace Systems* describes a structured approach for developing a MBE System Model.

The structed approach was used here in conjunction with the developed standardized block diagram.

This yields a standardized WBS structure for a RADAR System applied to military applications in the aerospace industry

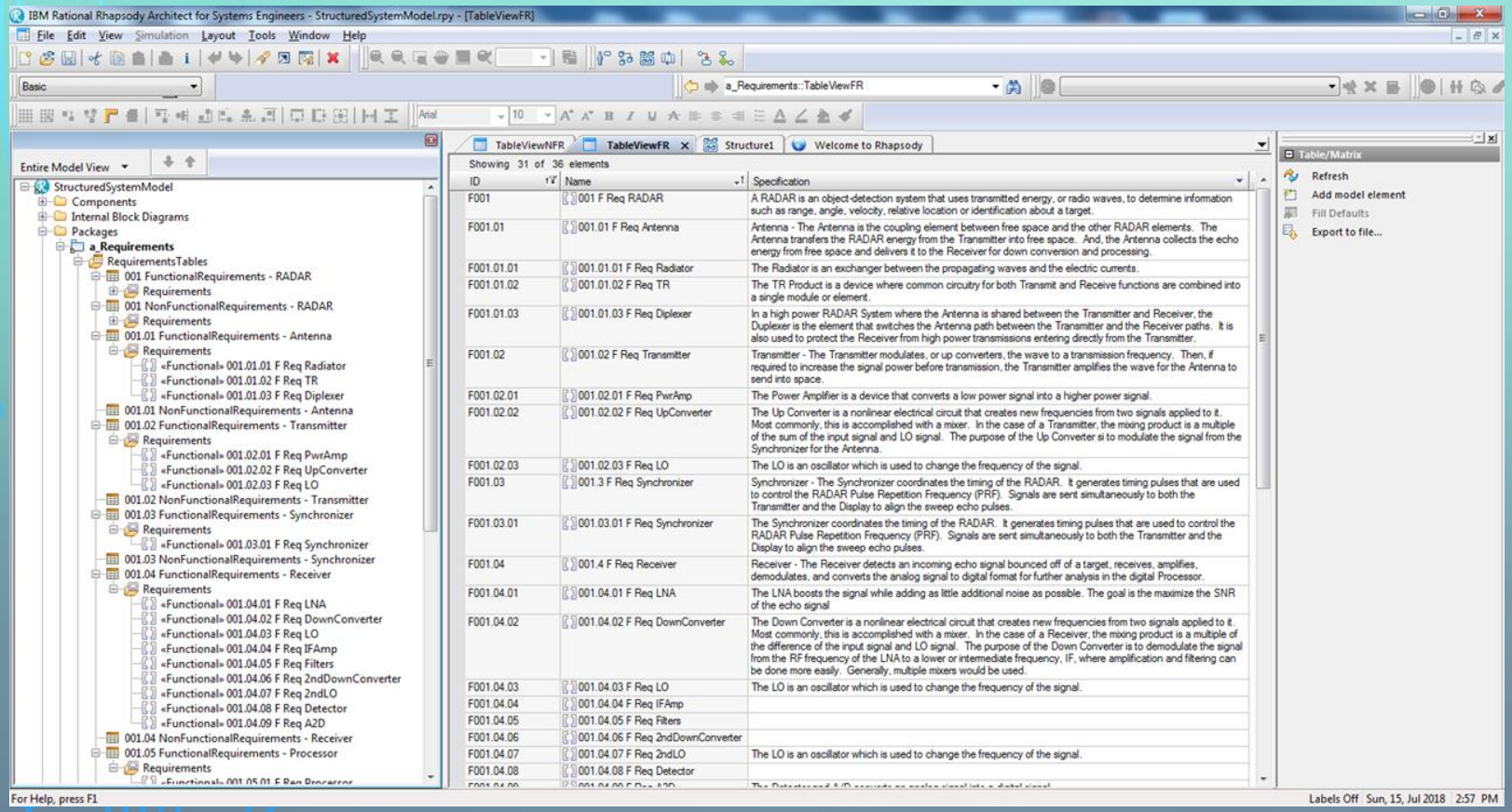




Level 1	Level 2	Level 3	Block Name
001			Radar
	001.01		Antenna
		001.01.01	Radiator
		001.01.02	TR Product
		001.01.03	Duplexer
	001.02		Transmitter
		001.02.01	Power Amplifier
		001.02.02	Up Converter
		001.02.03	Local Oscillator
	001.03		Synchronizer
		001.03.01	Synchronizer
	001.04		Receiver
		001.04.01	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

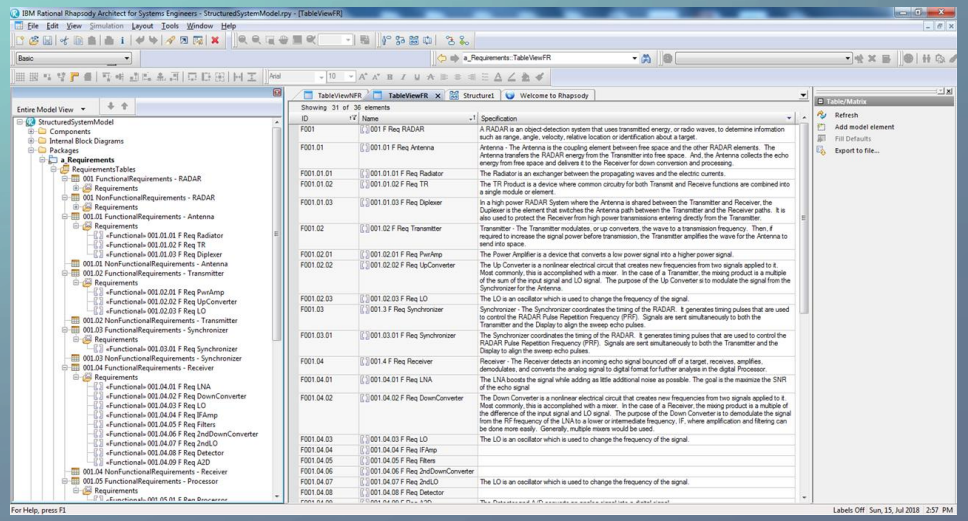
Section 2: System Engineering Model

In accordance with established MBE System Design techniques, the WBS structure was loaded into a system design tool (Rhapsody). All established definitions and terms were loaded as part of the specifications.



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

The manuscript demonstrates that given a complex system, a generic WBS structure could be established and used as the foundation for a structured MBE System Design model.



Section 3: System Cost Model

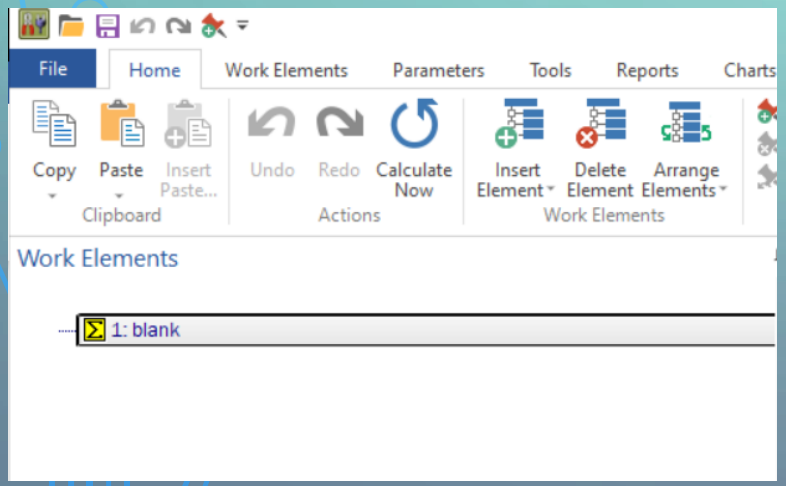
A new emphasis, introduced here, is the addition to a structured approach which includes a modular approach to modeling the System cost. At a later phase in the System design it will be necessary to perform trade studies. The most common trade will be between two performance profiles. For example, “better” performance using more power vs. “worse” performance using less power. This is a very common trade in industry.

To achieve the two profiles, a modular approach will be used to swap out blocks for either “better” or “worse” performance. This is the elegance of a modular approach to System architecture. If a parallel effort could be taken to create a corresponding cost model for each block, then as blocks are swapped in and out for performance trades, a cost trade could simultaneously be performed.

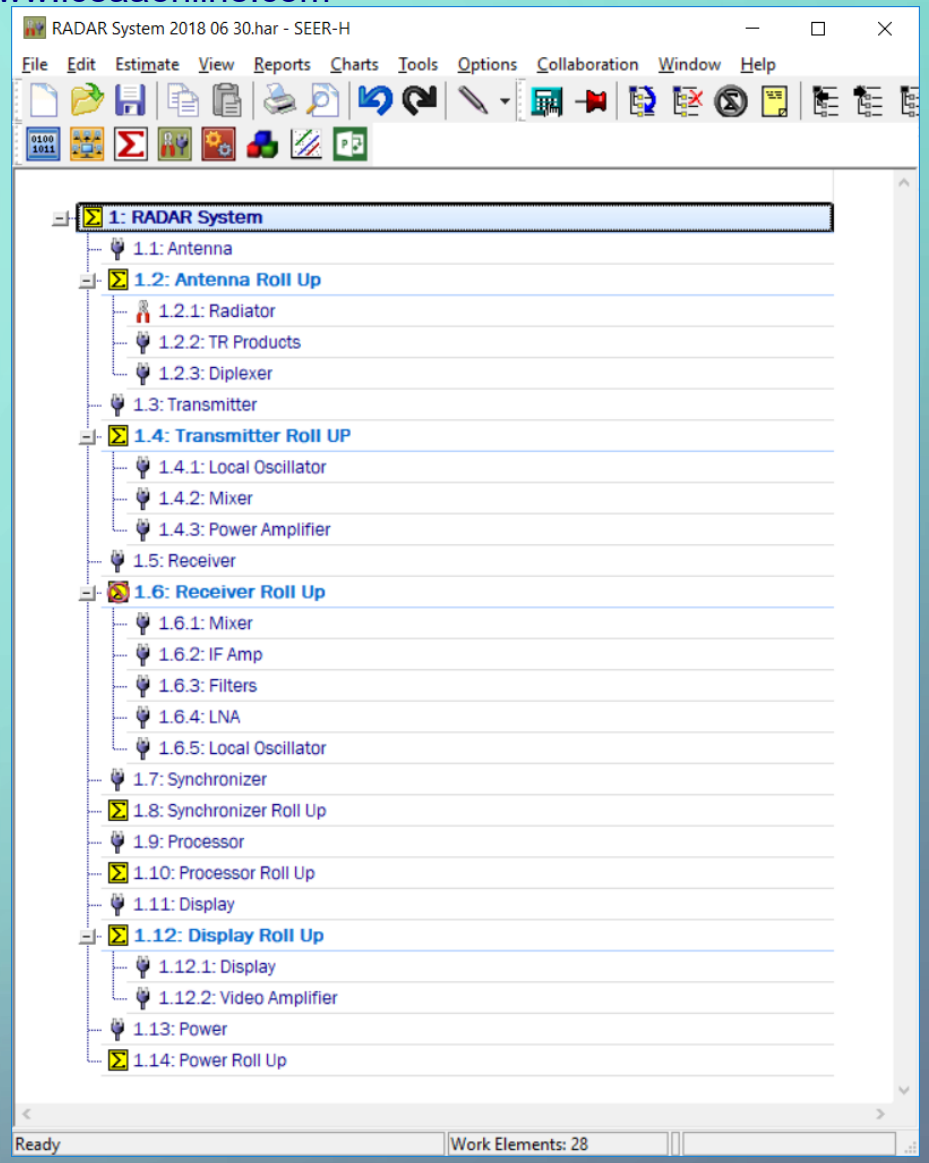
Section 3: System Cost Model

A COTS cost model package (SEER) was used with the derived standardized WBS structure to create a MBE System with swappable blocks.

Level 2 sub-system blocks were loaded along with their Level 3 component equivalents.

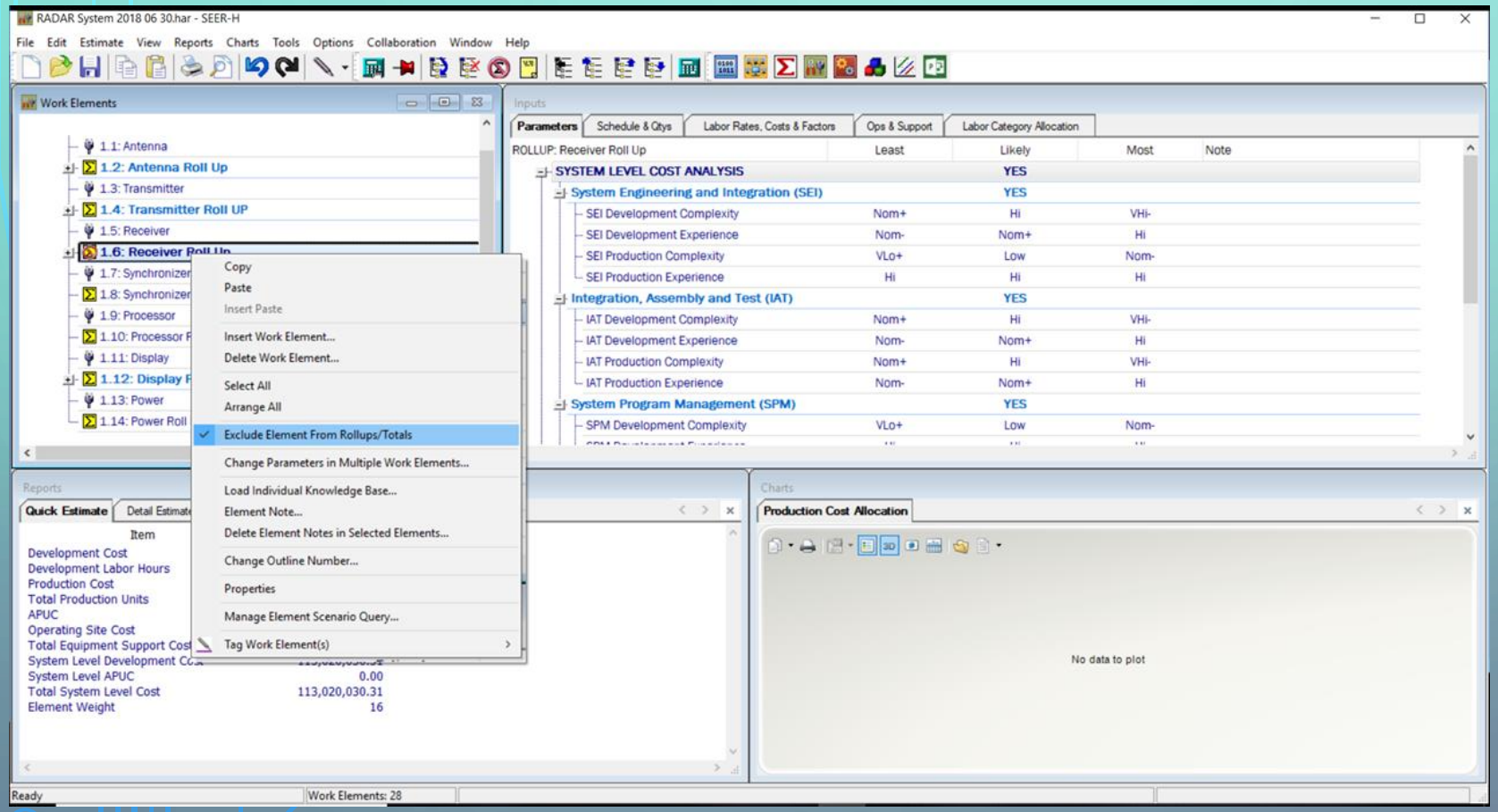


Level 1	Level 2	Level 3	Block Name
1			Radar
	1.1		Antenna
	1.2		Antenna Roll Up
		1.2.1	Radiator
		1.2.1	TR Product
		1.2.1	Duplexer
	1.3		Transmitter
	1.4		Transmitter Roll Up
		1.4.1	Local Oscillator
		1.4.2	Mixer
		1.4.3	Power Amplifier
	1.5		Receiver
	1.6		Receiver Roll Up
		1.6.1	Mixer
		1.6.2	IF Amplifier
		1.6.3	Filters
		1.6.4	Low Noise Amplifier
		1.6.5	Local Oscillator
	1.7		Synchronizer
	1.8		Synchronizer Roll Up
	1.9		Processor
	1.10		Processor Roll Up
	1.11		Display
	1.12		Display Roll Up
		1.12.1	Display
		1.12.2	Video Amplifier
	1.13		Power
	1.14		Power Roll Up



Section 3: System Cost Model

The completed System Cost Model allows the System Designer the not only to have a costed system, but also the opportunity to swap sub-system blocks or components for cost trade studies.



Level 1	Level 2	Level 3	Block Name
1			Radar
	1.1		Antenna
	1.2		Antenna Roll Up
		1.2.1	Radiator
		1.2.1	TR Product
		1.2.1	Duplexer
	1.3		Transmitter
	1.4		Transmitter Roll Up
		1.4.1	Local Oscillator
		1.4.2	Mixer
		1.4.3	Power Amplifier
	1.5		Receiver
	1.6		Receiver Roll Up
		1.6.1	Mixer
		1.6.2	IF Amplifier
		1.6.3	Filters
		1.6.4	Low Noise Amplifier
		1.6.5	Local Oscillator
	1.7		Synchronizer
	1.8		Synchronizer Roll Up
	1.9		Processor
	1.10		Processor Roll Up
	1.11		Display
	1.12		Display Roll Up
		1.12.1	Display
		1.12.2	Video Amplifier
	1.13		Power
	1.14		Power Roll Up

The manuscript demonstrates that given a complex system, and a generic WBS structure, a structured MBE System Cost model could be developed which allows a System Designer the opportunity to utilize swappable subsystem blocks or components in order to facilitate cost trade studies early on in the life cycle of a system design.

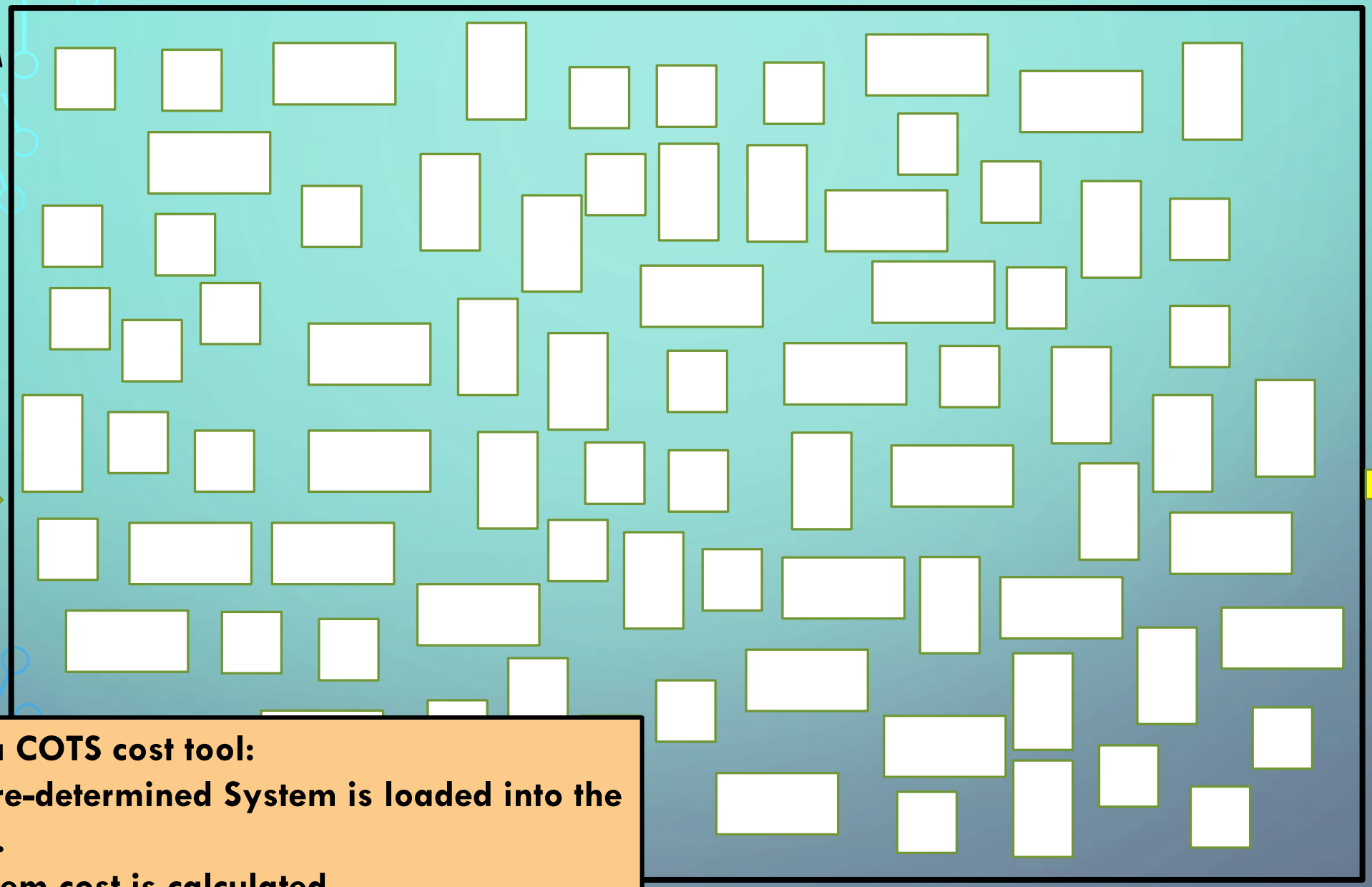
Further Research: Cost Sensitivities

The manuscript and preceding research are stepping stones along the path towards development of an algorithm to analyze a complex system and determine cost sensitivities of the system components to enable a system designer to optimize a solution early on in the life cycle of a system design.

Further research is required to develop the cost sensitivity algorithm for system analysis utilizing the standardized WBS.

Complex System

Load System into cost model tool.



Calculate System Cost

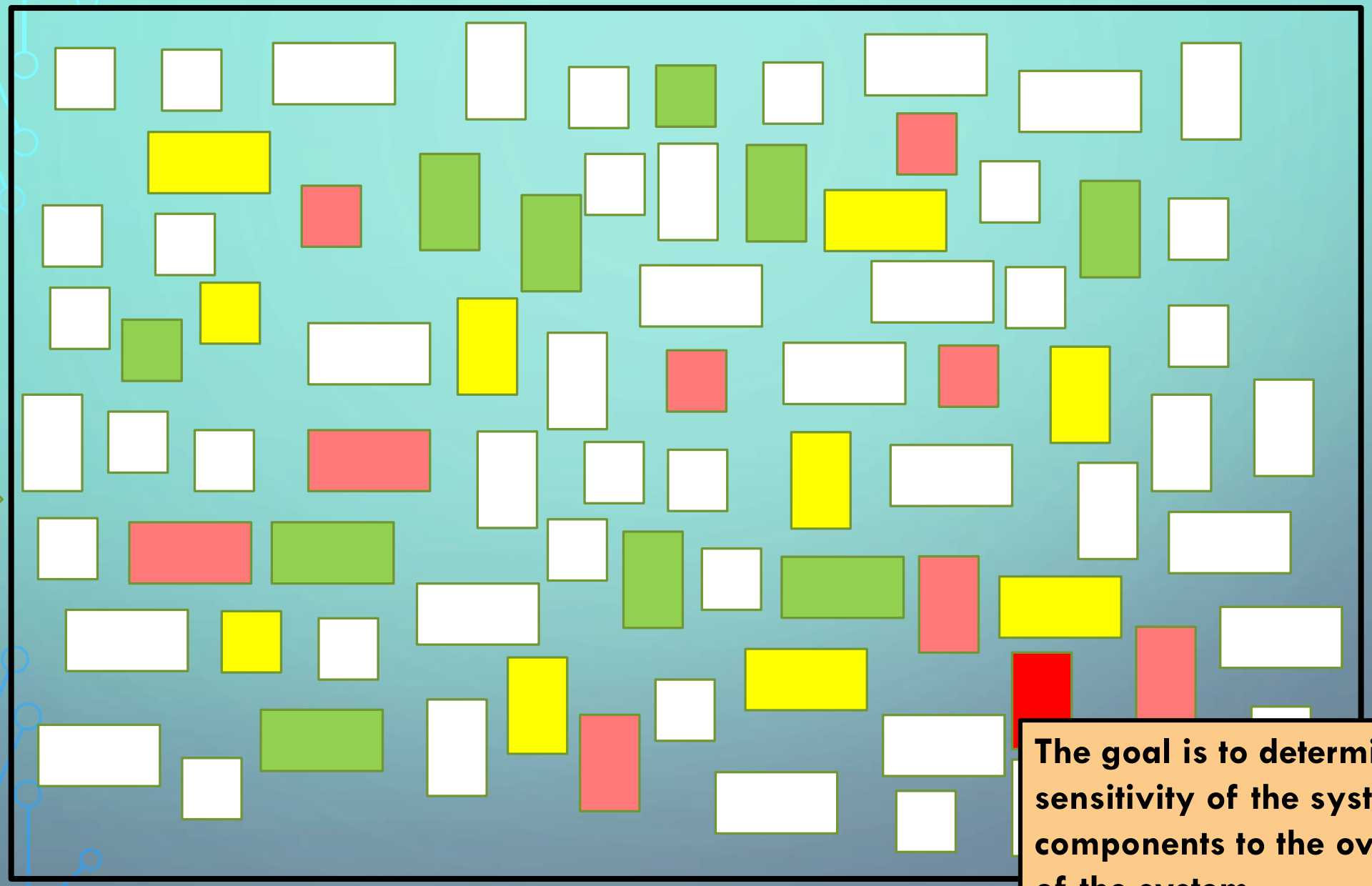
$$$

Using a COTS cost tool:

- **A pre-determined System is loaded into the tool.**
- **System cost is calculated.**

Complex System

Load System into cost model tool.



The goal is to determine sensitivity of the system components to the overall cost of the system.

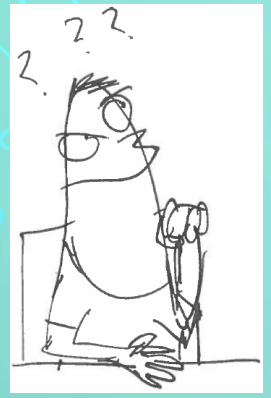
Summary

- This paper presents an approach to generating a set of high level block diagrams for describing a standardized modular RADAR System applied to military applications in the aerospace industry.

- The resulting block diagrams were created using a compilation of available industry data and references modified to encompass all of the examples into a higher more universal version. In addition to block diagrams, universal block descriptions were also created along with a universal numbering structure.

- This paper demonstrated an approach to implementing the high level block diagrams and numbering structure to create both a System model using Rhapsody as well as a cost model using SEER for the RADAR under consideration. By means of the structured numbering system, the System models could be generated in such a way as to be modular to facilitate eventual trade studies for performance.

- Further effort will be made to add additional details to the block diagrams and develop these models leading to analysis of sensitivity data. That sensitivity data will need to be analyzed and algorithms developed to assist a designer in performing trade studies as an element of structured System architecture design.



Questions ?

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