A Paradigm for Modeling & Simulation in Support of Mission-Based Test & Evaluation

James N. Walbert, Ph.D.
Chief Scientist
SURVICE Engineering Company

March, 2011

SURVICE ENGINEERING COMPANY

TOPICS

What is Mission-Based Modeling and Simulation?

The Value of Intermediate Results

Applicability, Precision, and Accuracy

So, exactly what's in that Field and Test Data?
(and therefore, what should be in the Simulation Output?)

What constitutes a "good" model?

If you don't have a road map, don't take the M&S trip

What is Mission-Based Modeling and Simulation?

SURVICE ENGINEERING COMPANY

All T&E is (should be) Mission-Based
All M&S is (should be) Mission-Based

The following three (evaluation) missions require
three different levels of data to evaluate, and
three different levels of modeling to simulate:

See ***if*** threat x can perforate target y

See ***by how much*** threat x perforates target y

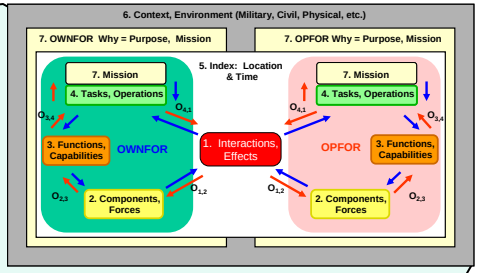
See ***how*** threat x perforates target y

If I complete a certain (evaluation) mission, haven't I completed each (evaluation) mission above it?

NOT NECESSARILY!!

SURVICE ENGINEERING COMPANY

Mission-Based Test & Evaluation



Perforation (Y/N)

Residual Mass, Velocity, etc.

Petalling, Plugging, etc.

Striking Velocity, Obliquity

Mission, Task

Remaining Capability

Component Damage

Initial Conditions

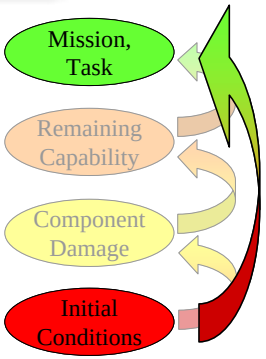
Enough?

By How Much?

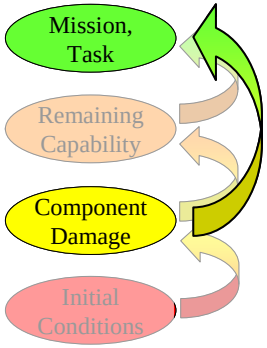
How?

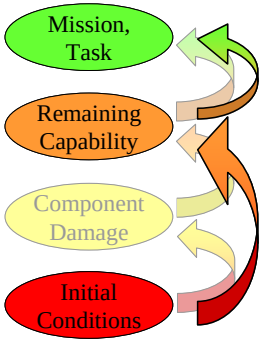
SURVICE ENGINEERING COMPANY

There are many possible paths

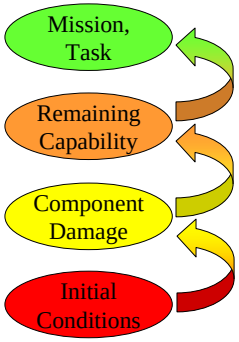


See ***if*** threat x can perforate target y





See ***by how much*** threat x perforates target y



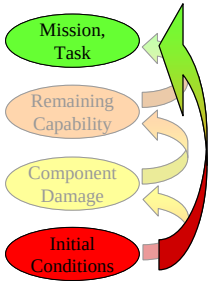
See ***how*** threat x perforates target y

The Value of Intermediate Results

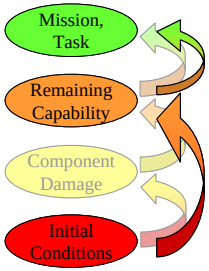
SURVICE ENGINEERING COMPANY

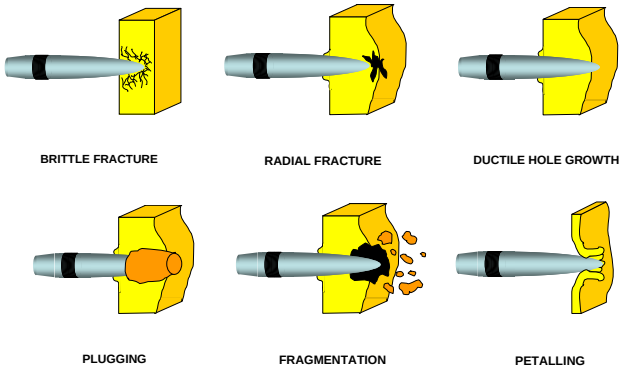
Mission-Based Test & Evaluation

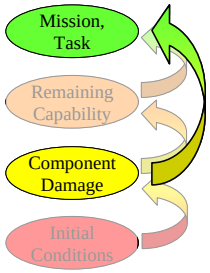
THREAT TYPE	VELOCITY (Ft/Sec)	MATERIAL TYPE	MATERIAL THICKNESS (Inches)	V50 (Ft/Sec)
X	500	ALUMINUM 5083	0.1250	288.39

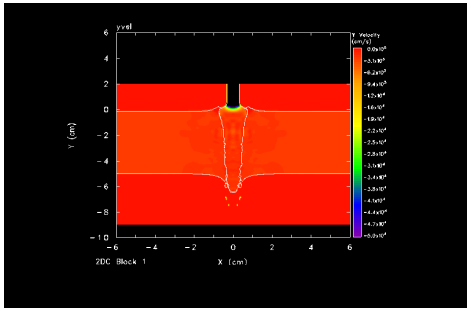


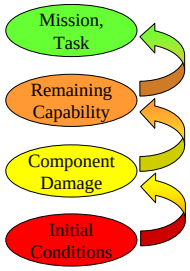
THREAT TYPE	VELOCITY (Ft/Sec)	MATERIAL TYPE	MATERIAL THICKNESS (Inches)	V50 (Ft/Sec)	RESIDUAL VELOCITY (Ft/Sec)	RESIDUAL MASS (Grains)	YAW (Degrees)
X	500	ALUMINUM 5083	0.1250	288.39	408.45	745.00	0.49











SURVICE ENGINEERING COMPANY

Mission-Based T&E and M&S

Less "Precise"
More General

Less Complex
Less Costly

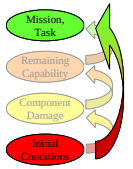
Analysis

Testing

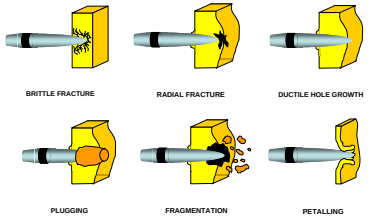
More "Precise"
Less General

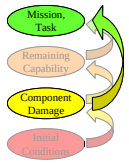
More Complex
More Costly

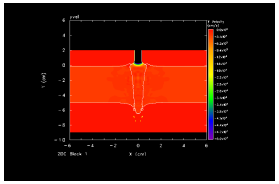
THREAT TYPE	VELOCITY (Ft/Sec)	MATERIAL TYPE	MATERIAL THICKNESS (Inches)	V50 (Ft/Sec)
X	500	ALUMINUM 5083	0.1250	288.39



THREAT TYPE	VELOCITY (Ft/Sec)	MATERIAL TYPE	MATERIAL THICKNESS (Inches)	V50 (Ft/Sec)	RESIDUAL VELOCITY (Ft/Sec)	RESIDUAL MASS (Grains)	YAW (Degrees)
X	500	ALUMINUM 5083	0.1250	288.39	408.45	745.00	0.49

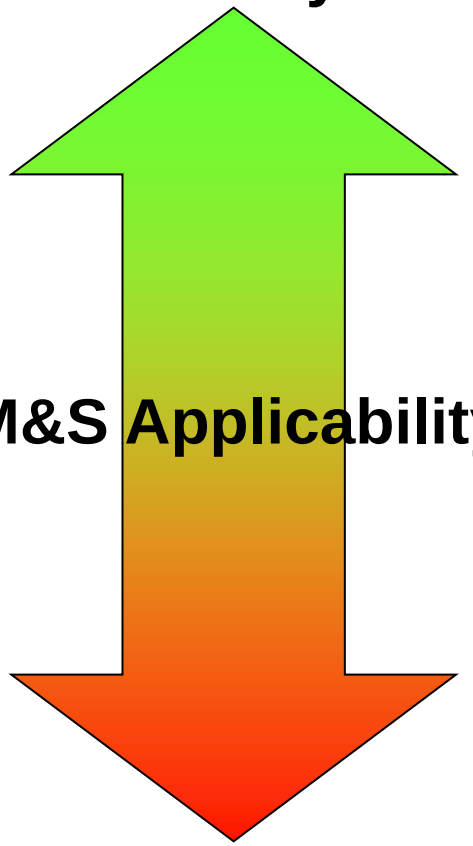






The dangers of a very specific model

More Universally Accurate



Less Universally Accurate

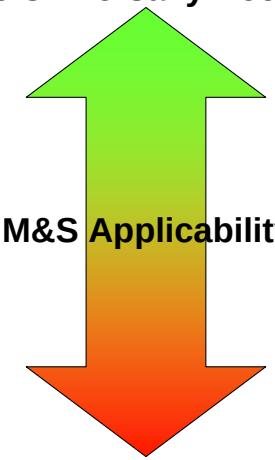
A President was Elected
(very general, but correct)

Thomas Dewey was Elected President
(very specific, but incorrect)

SURVICE ENGINEERING COMPANY

The dangers of a very specific model

More Universally Accurate



M&S Applicability

Less Universally Accurate

A President was Elected

Thomas Dewey was Elected President

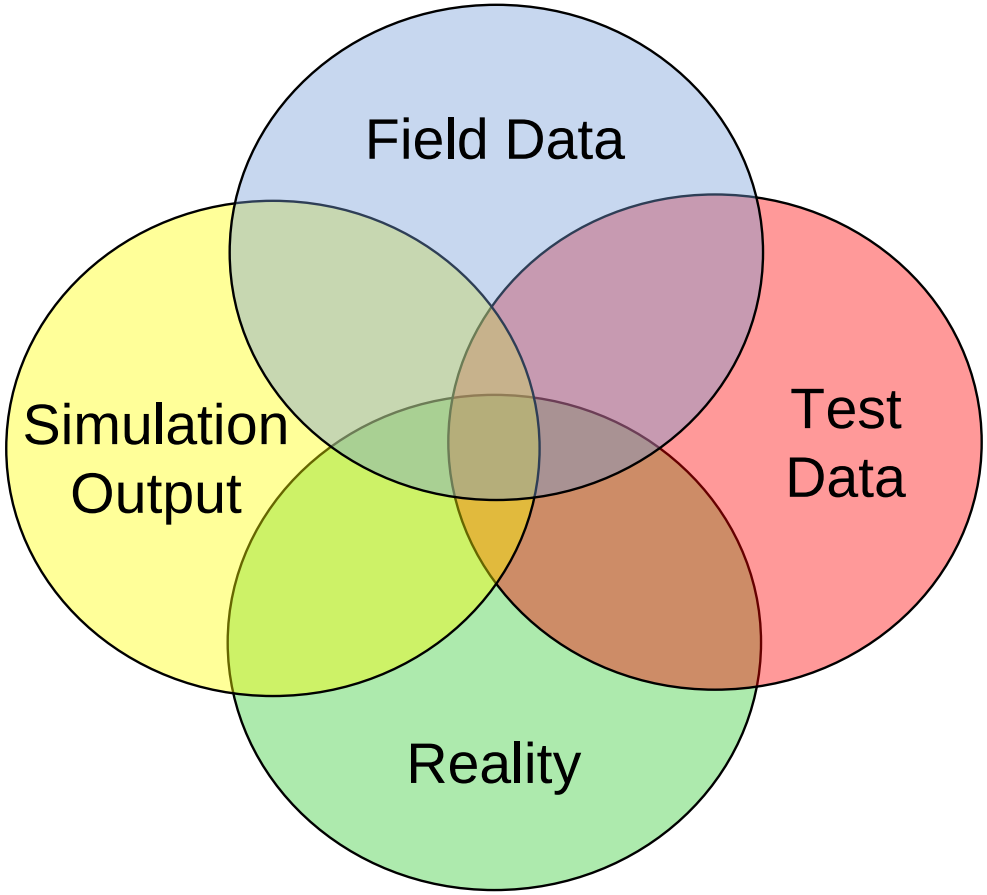
This very precise model does ***not*** explain ***how*** the President was elected. The model of at least one of the mappings is flawed; everything that follows is probably incorrect, such as ***by how much*** (how many votes).

If the prediction was precisely incorrect because 17 precincts voted the opposite from the assumption, then "tweaking" the model to change the way those 17 precincts vote may or may not to produce "better" results in the next election.

Applicability, Precision, and Accuracy

SURVICE ENGINEERING COMPANY

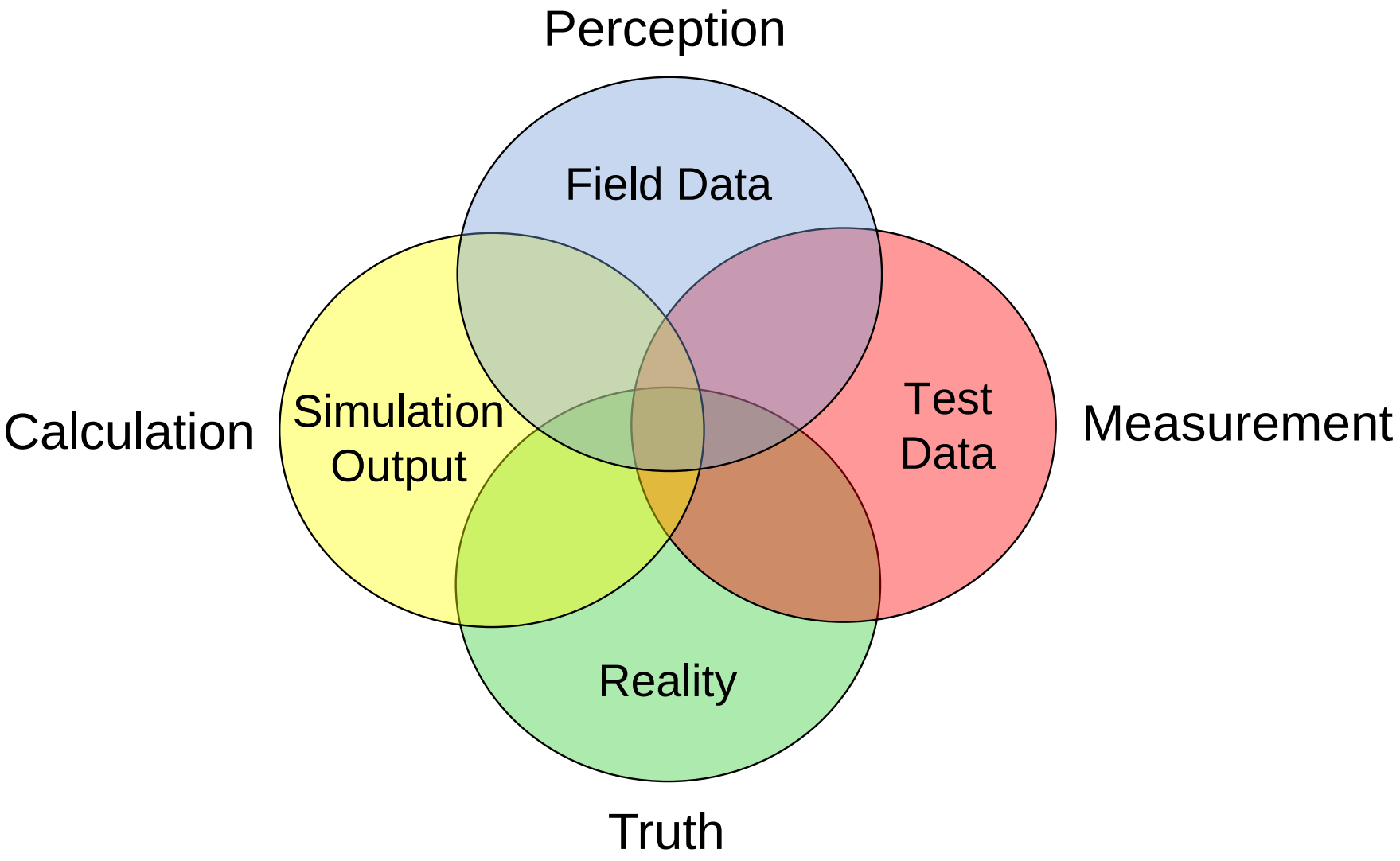
Walbert's view of the world**



**Not to scale

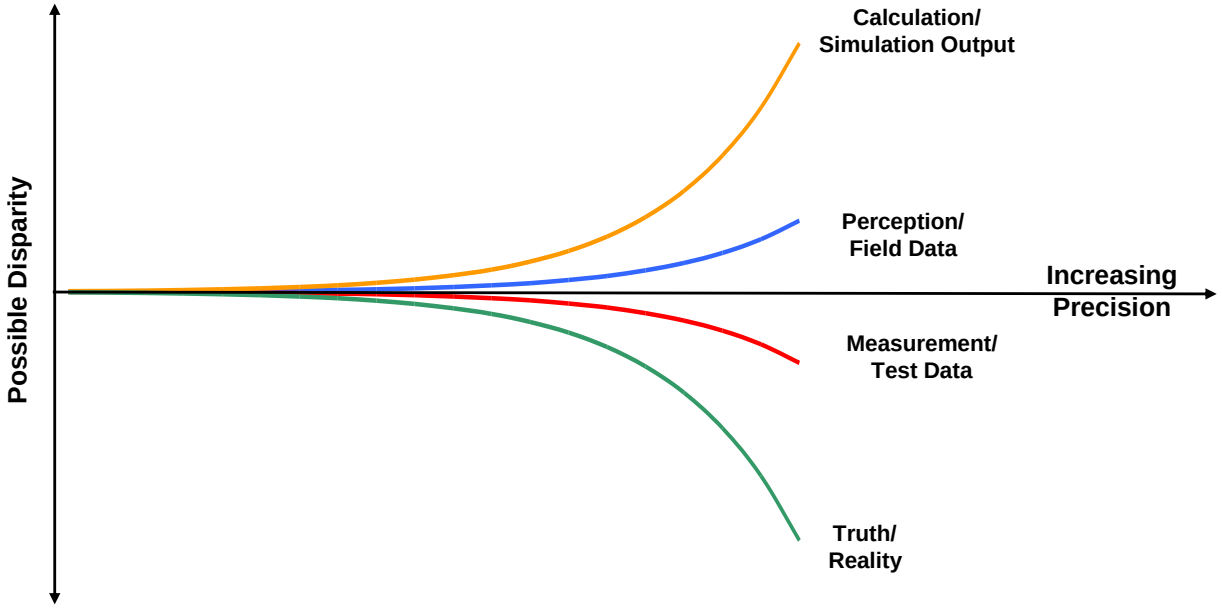
SURVICE ENGINEERING COMPANY

Walbert's view of the world

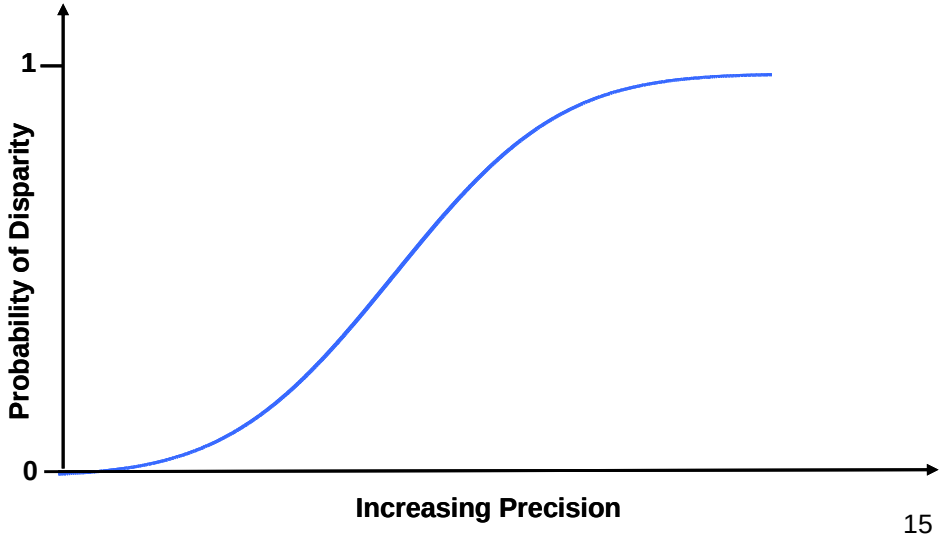


SURVICE ENGINEERING COMPANY

Walbert's view of the world

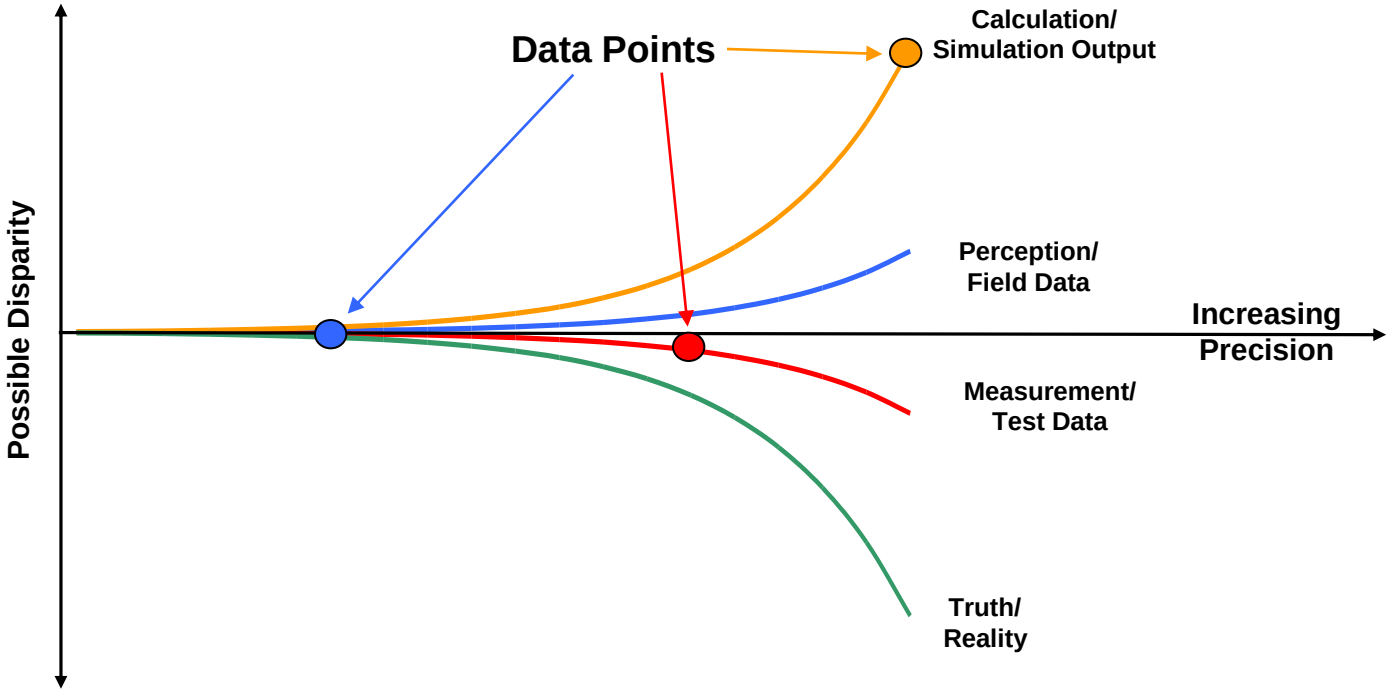


The greater the precision in any one of the domains, the more likely it is that it will disagree with the other domains.



SURVICE ENGINEERING COMPANY

Walbert's view of the world: An Event (Field, Test, Simulation)



If the data points from the domains are at differing levels of precision (granularity), then comparison is "difficult."

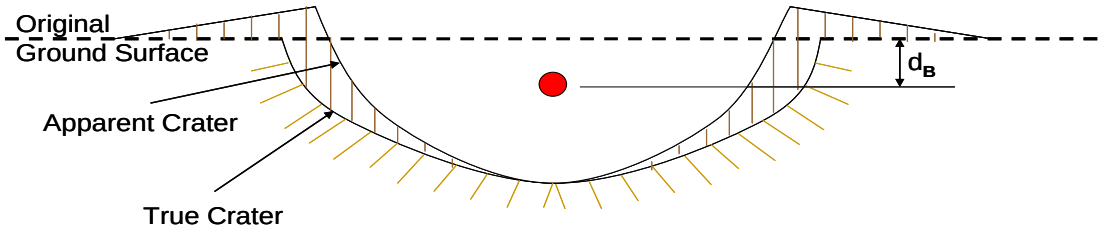
The location of the data point on the "Truth" curve is unknown.

So, exactly what's in that Field and Test Data?

(and therefore, what should be in the Simulation Output?)

An Example: Craters

Truth



Perception/ Field Data

MEASURED DIAMETER feet	MEASURED DEPTH feet
13.00	4.00

Measurement/ Test Data

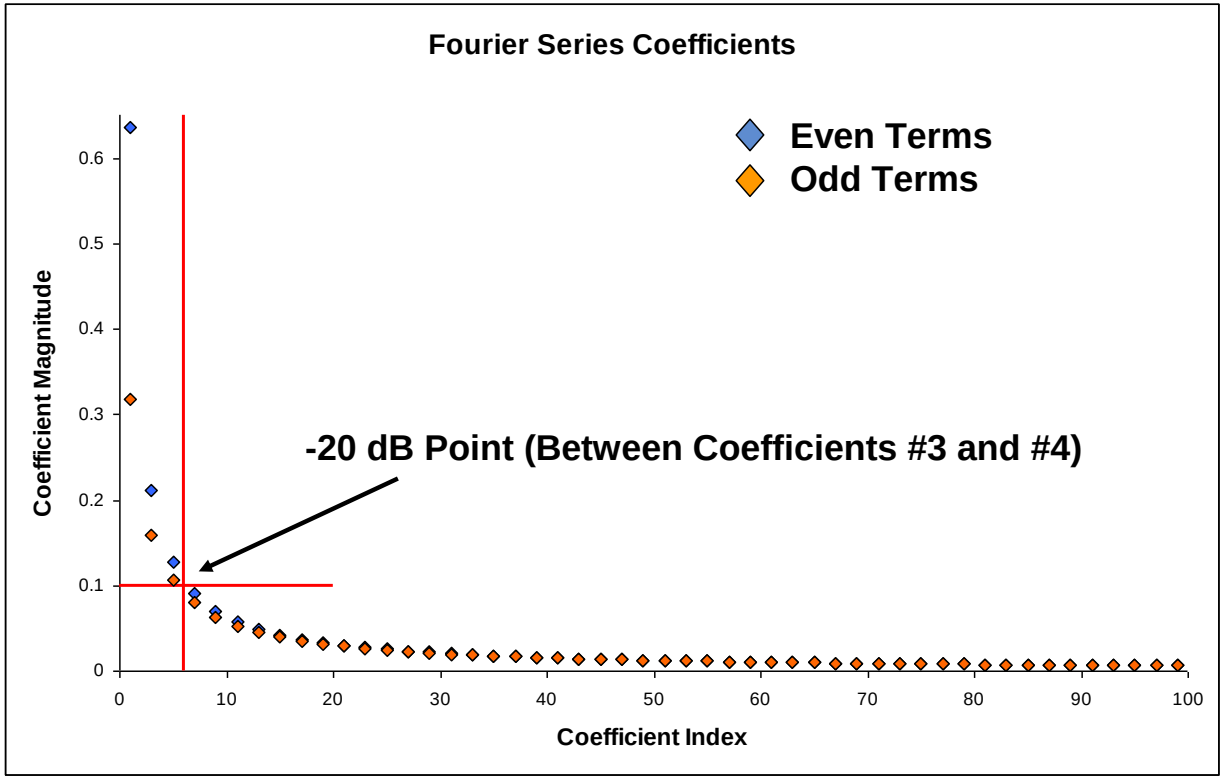
SOIL TYPE	MOISTURE CONTENT (% of Satur)	ENERGETIC MATERIAL	CHARGE WEIGHT lbs	DEPTH of BURST feet	MEASURED DIAMETER feet	MEASURED DEPTH feet
Mixed Soil	100	XXX	21.00	1.75	12.80	3.95

Calculation

SOIL TYPE	MOISTURE CONTENT (% of Satur)	ENERGETIC MATERIAL	CHARGE WEIGHT lbs	DEPTH of BURST feet	ESTIMATED DIAMETER feet	ESTIMATED DEPTH feet
Mixed Soil	100	XXX	20.28	2.06	13.00	5.07
			22.49	8.18	13.00	4.23
			44.09	0.00	11.74	4.00
			64.82	13.16	16.09	4.00

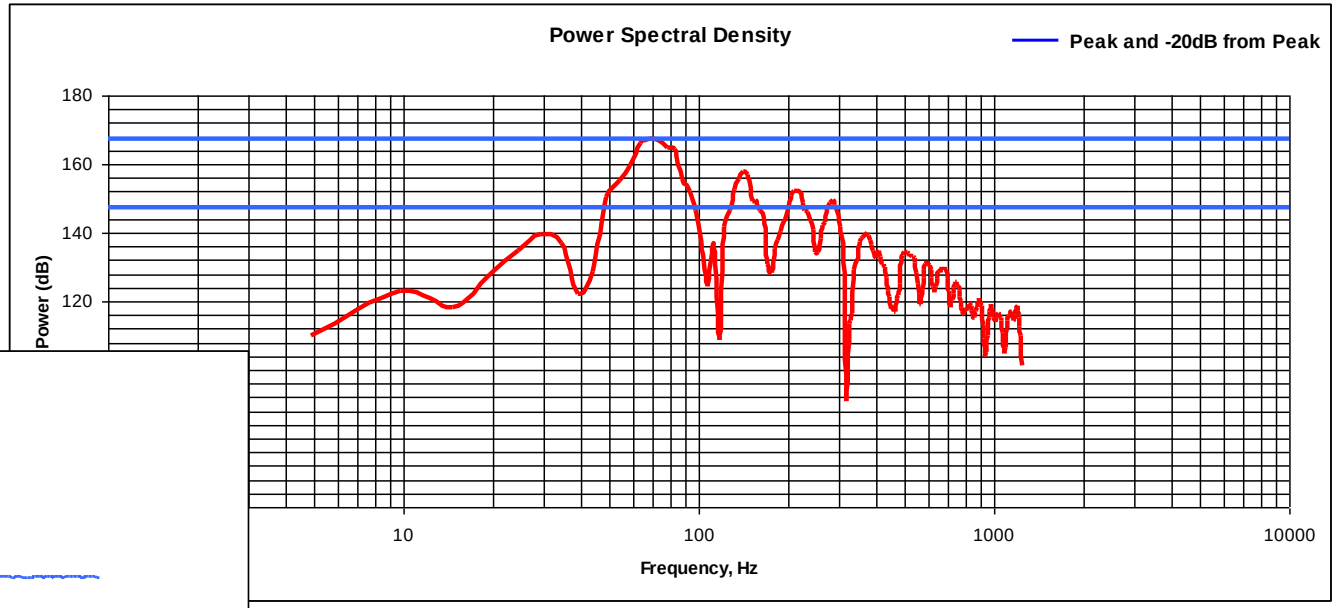
Match the analysis to the data content

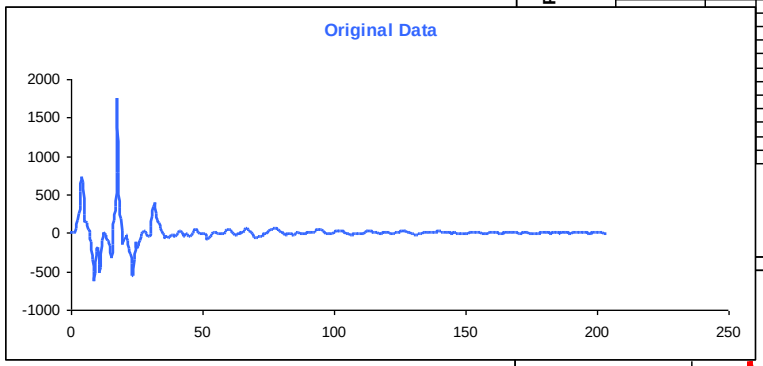
$$F(t) = \frac{a_0}{2} + \sum_{n=1}^{\infty} \{a_n \cos(nt) + b_n \sin(nt)\}$$

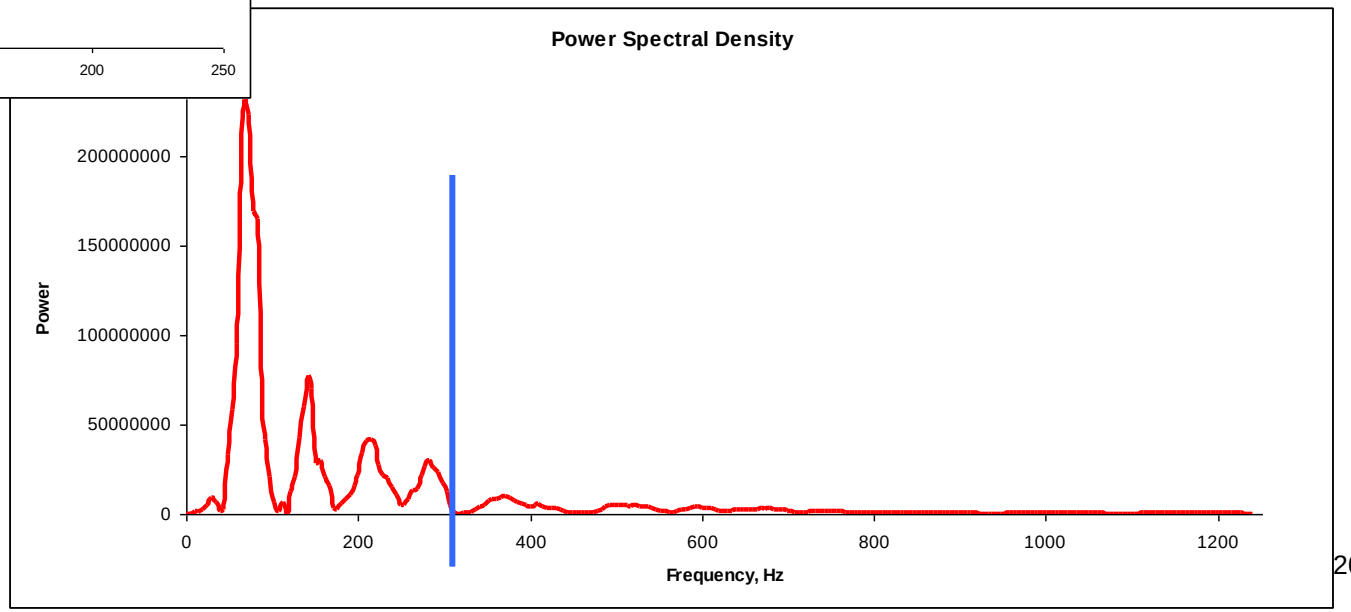


SURVICE ENGINEERING COMPANY

Match the analysis to the data content
An example: Acceleration Data

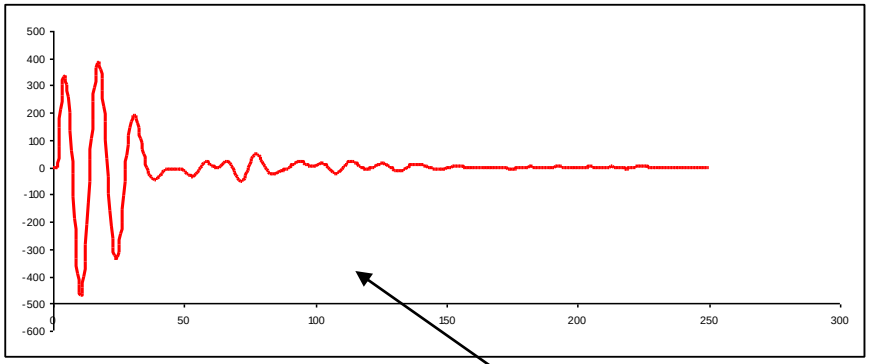


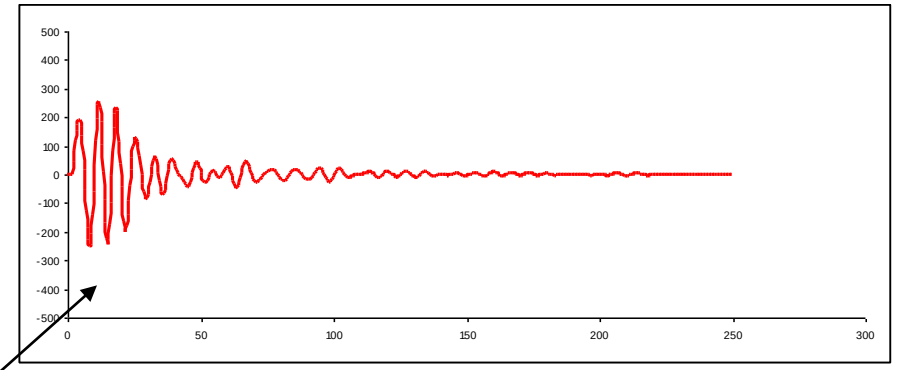


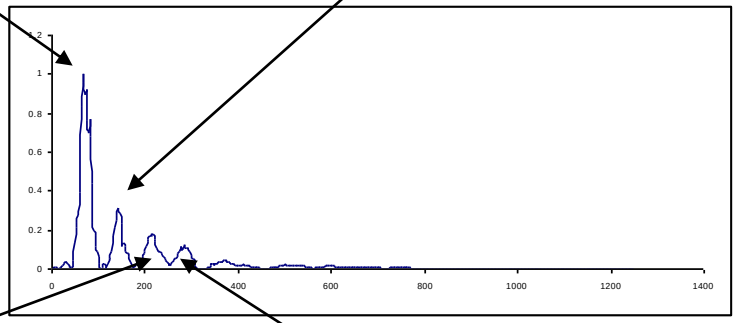


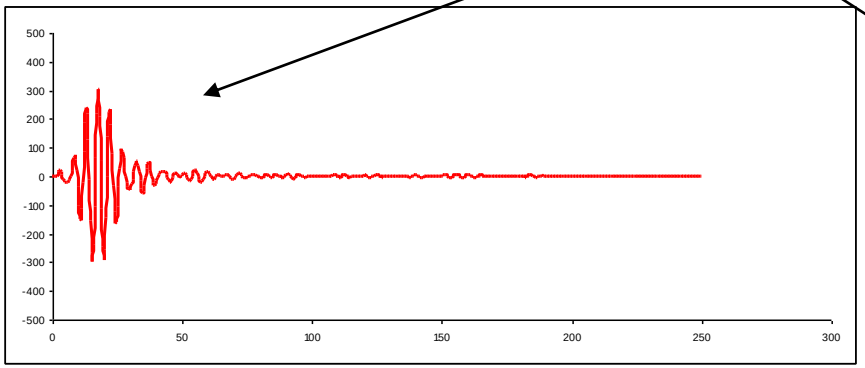
SURVICE ENGINEERING COMPANY

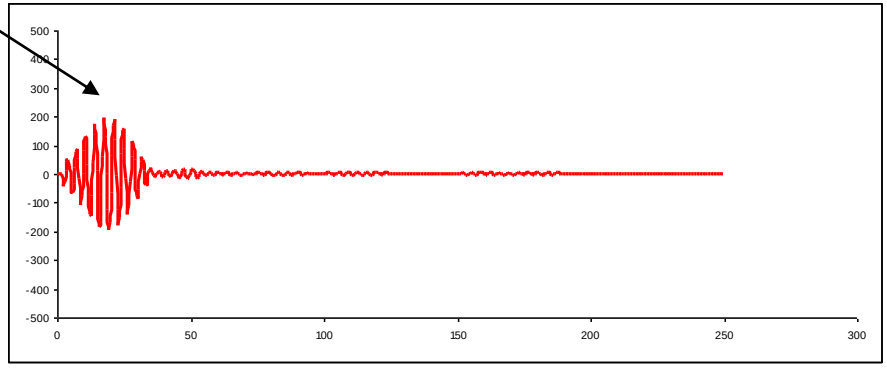
Match the analysis to the data content





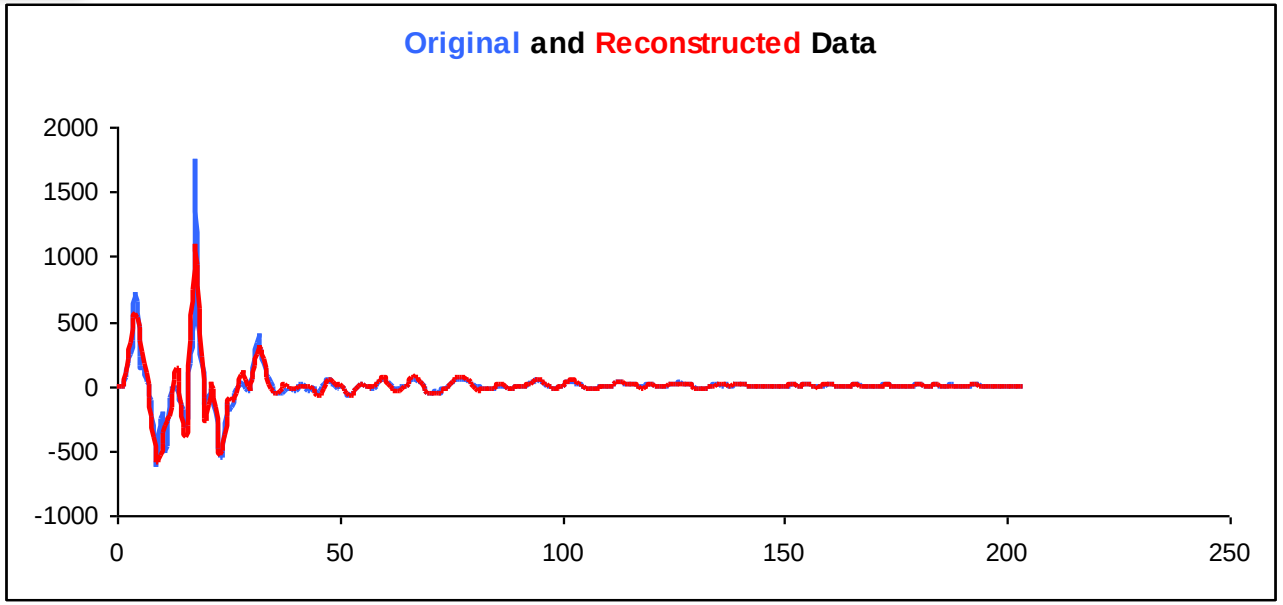


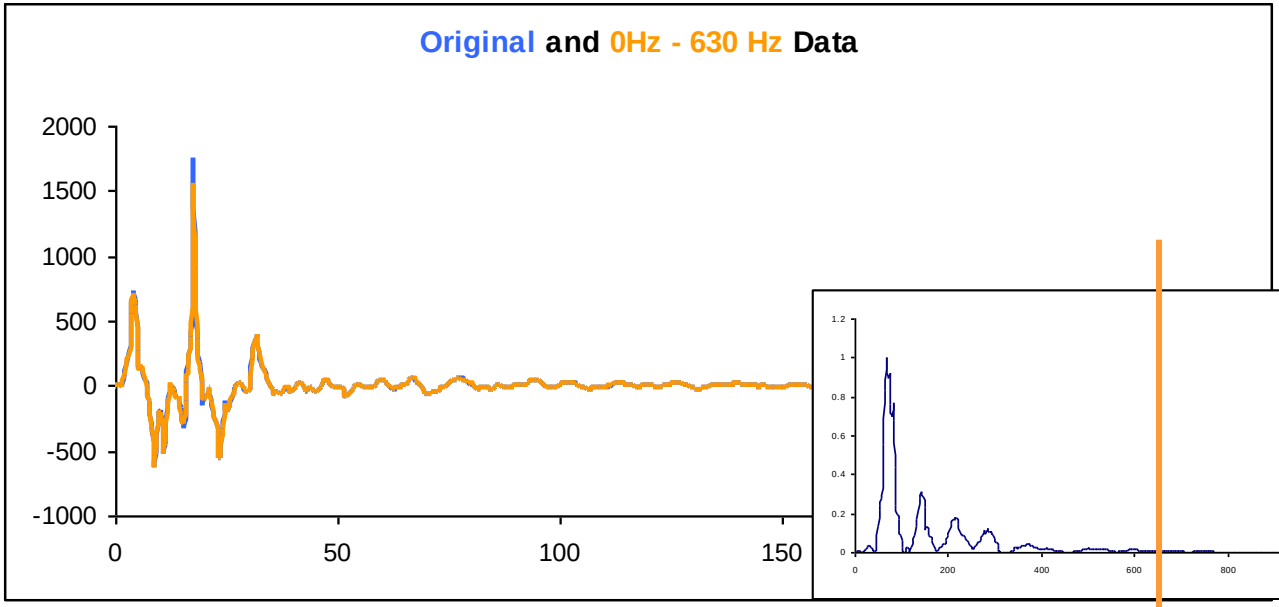




SURVICE ENGINEERING COMPANY

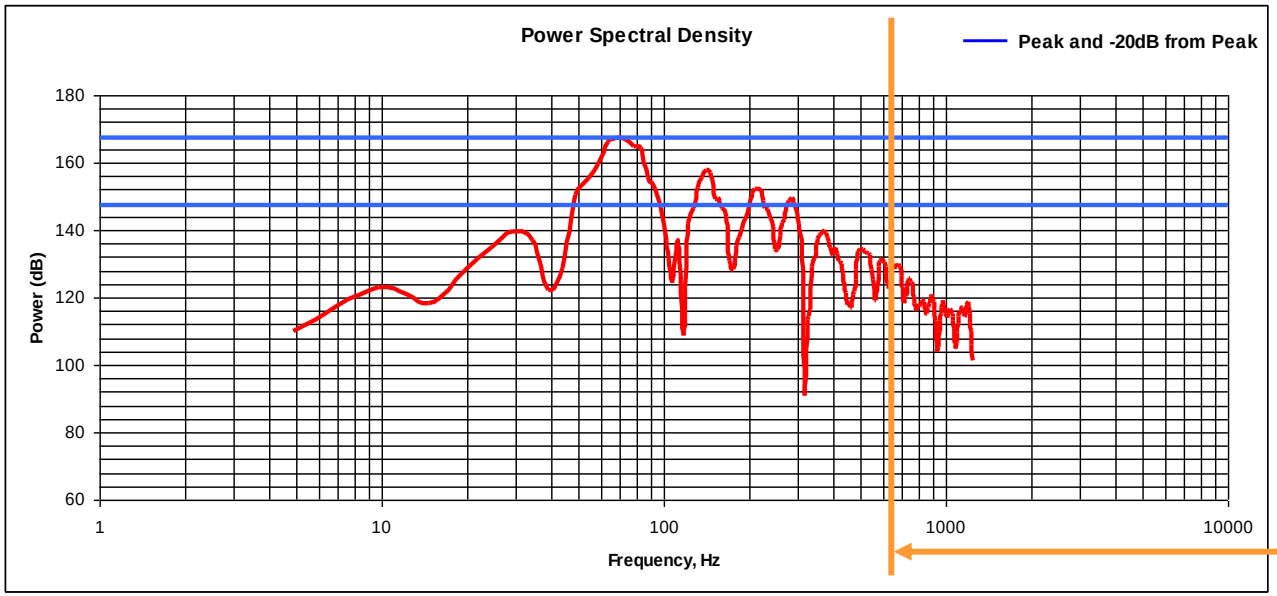
Match the analysis to the data content



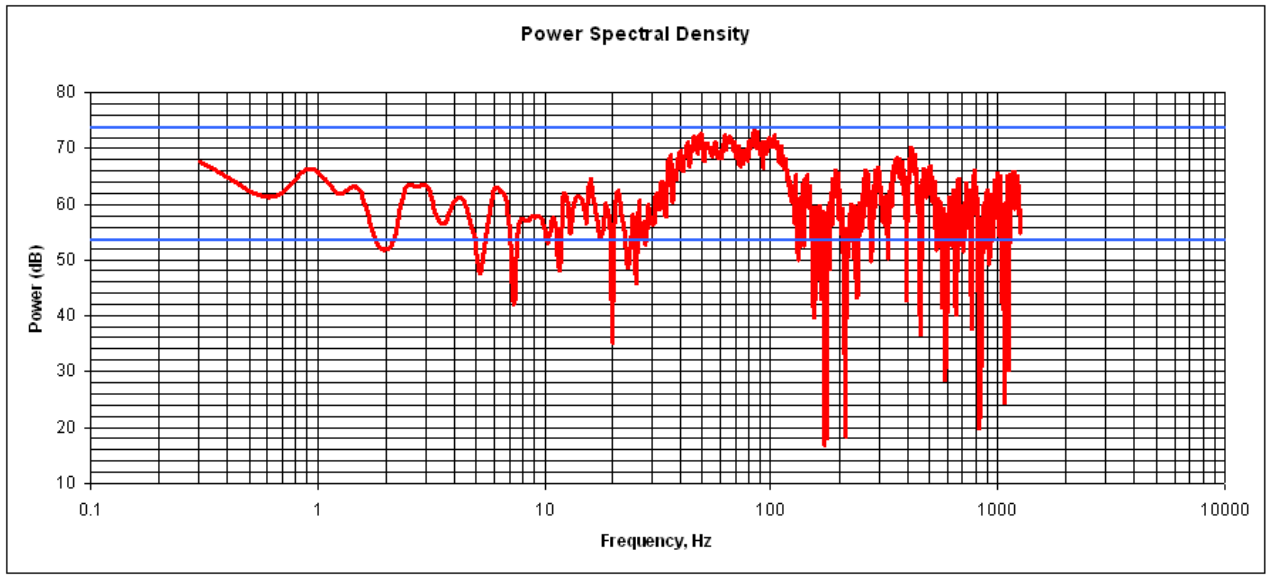


SURVICE ENGINEERING COMPANY

Match the analysis to the data content



630Hz is –40dB



You can’t get blood from a turnip!

What constitutes a "good" model?

SURVICE ENGINEERING COMPANY

HOW TO TELL A "GOOD" MODEL FROM A "BAD" MODEL

Which question is more appropriate?

1) How well did the model predict the outcome of the test?

2) Was the outcome of the test a member of the population of possible outcomes predicted by the model?

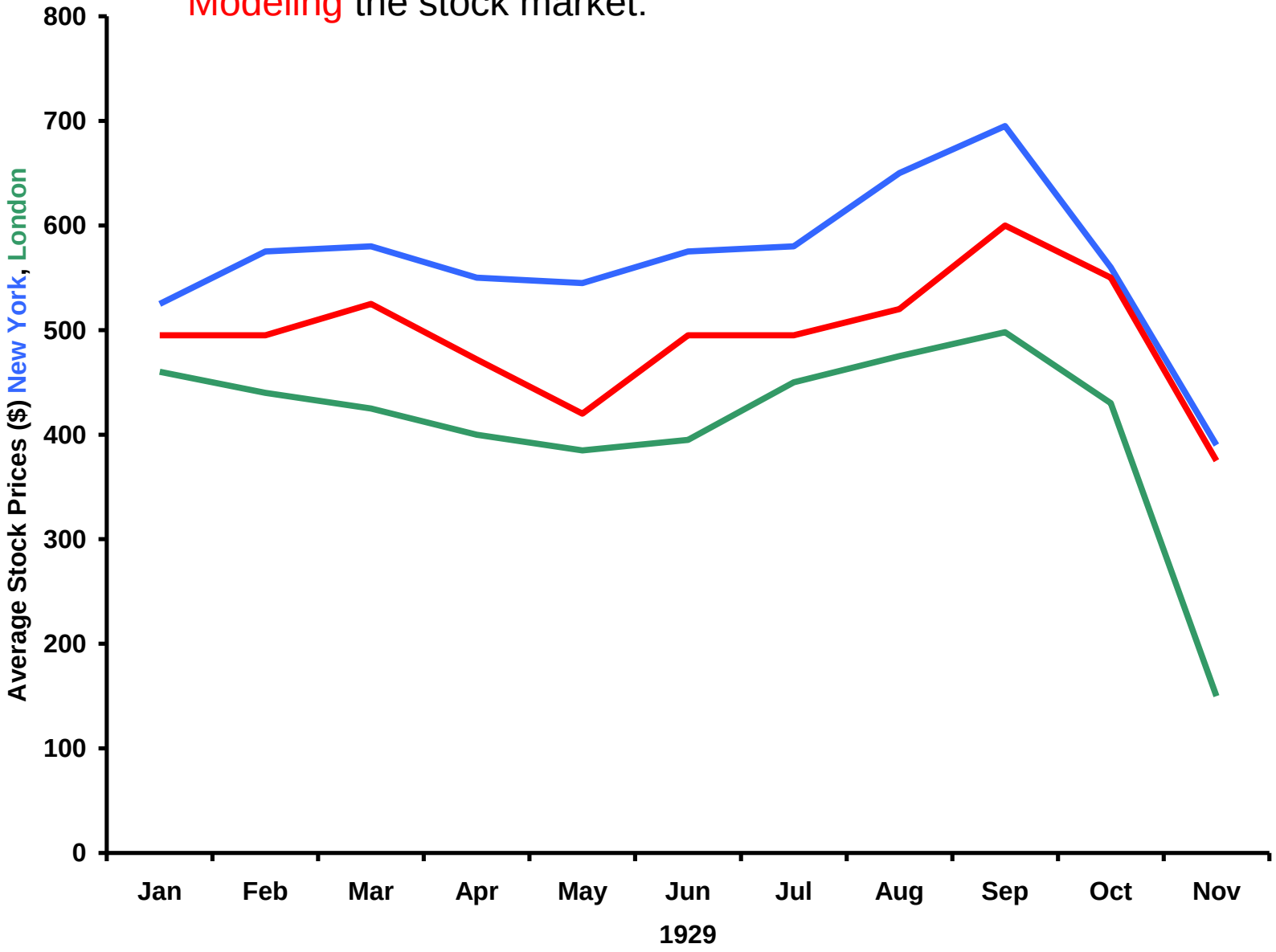
If my model gets the "right" answer, doesn't that mean I understand the phenomenon?

NOT NECESSARILY!!

SURVICE ENGINEERING COMPANY

HOW TO TELL A "GOOD" MODEL FROM A "BAD" MODEL

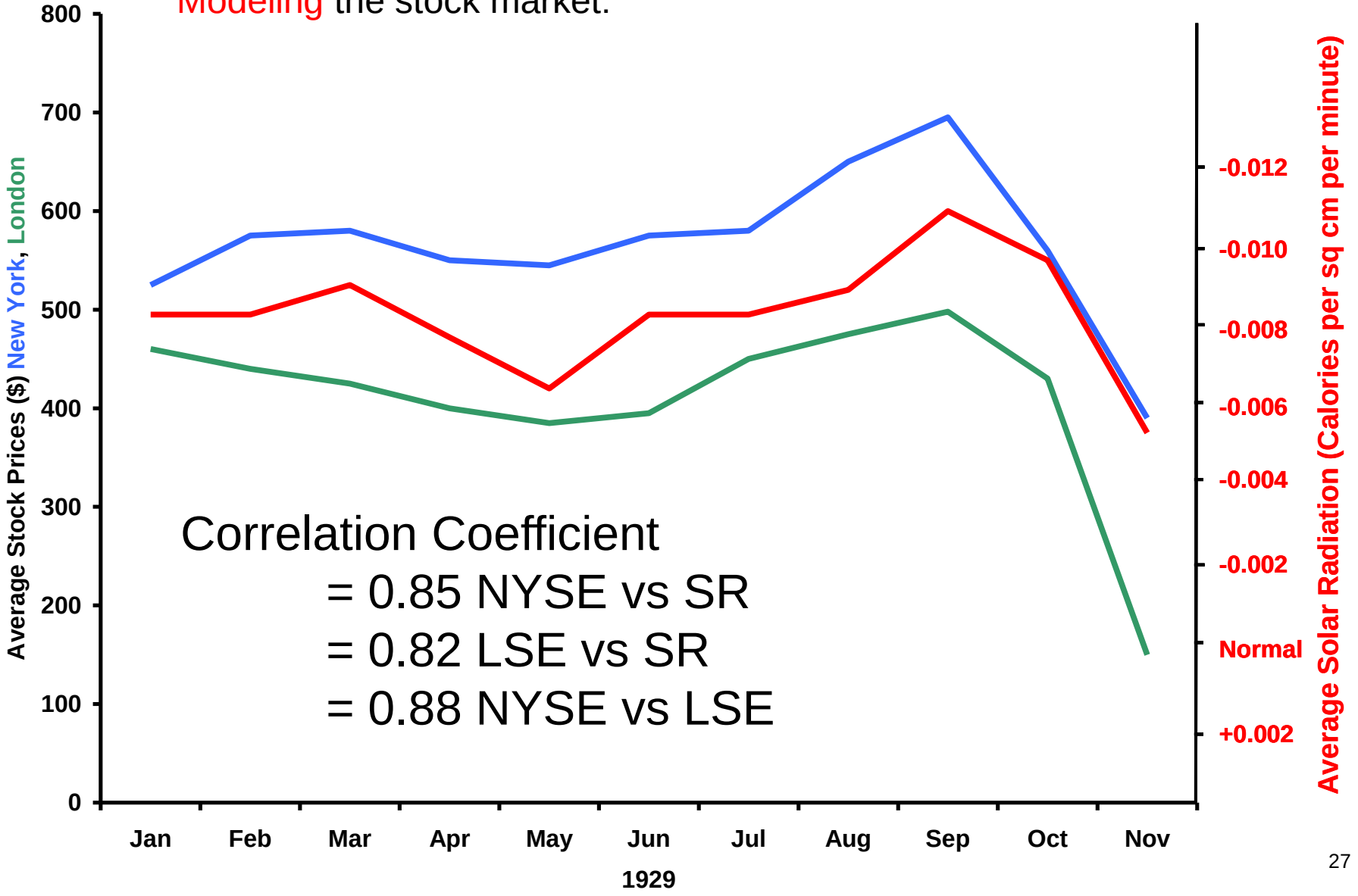
Modeling the stock market:



SURVICE ENGINEERING COMPANY

HOW TO TELL A "GOOD" MODEL FROM A "BAD" MODEL

Modeling the stock market:



Correlation Coefficient

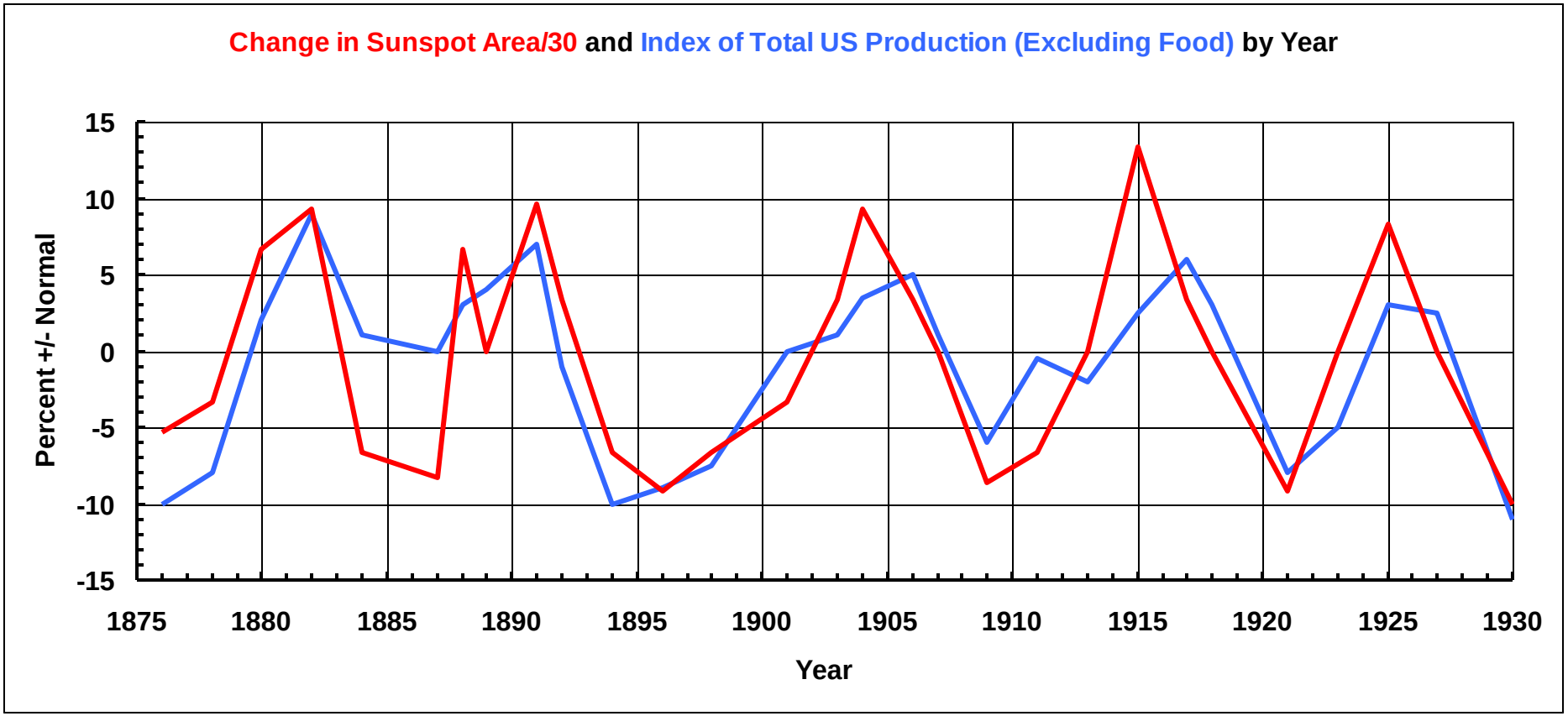
= 0.85 NYSE vs SR

= 0.82 LSE vs SR

= 0.88 NYSE vs LSE

SURVICE ENGINEERING COMPANY

SO, YOU *STILL* THINK THAT'S FUNNY?

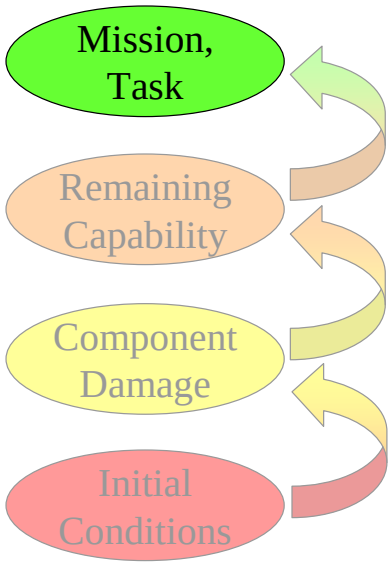


Correlation coefficient = 0.76

t-value = -1.15 (not in critical region, no stat. sign. diff. at 5% level)

Source: Center for Cosmic and Terrestrial Research, MIT, 1937

There may be no path at all!

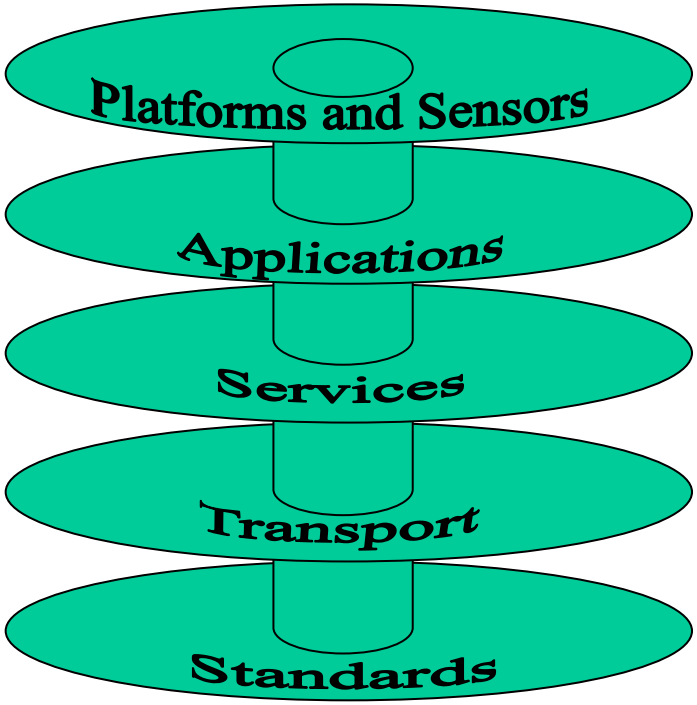


Does “Correlation” mean the same thing as “Cause and Effect?”

If you don’t have a road map, don’t take the M&S trip

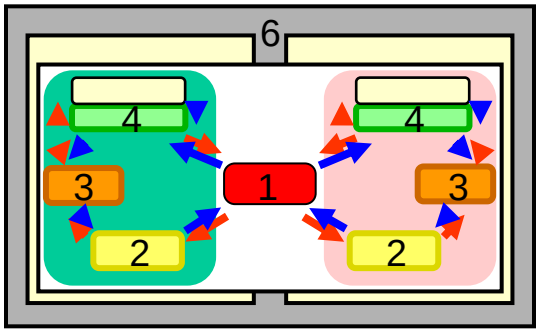
An Un-verifiable Model

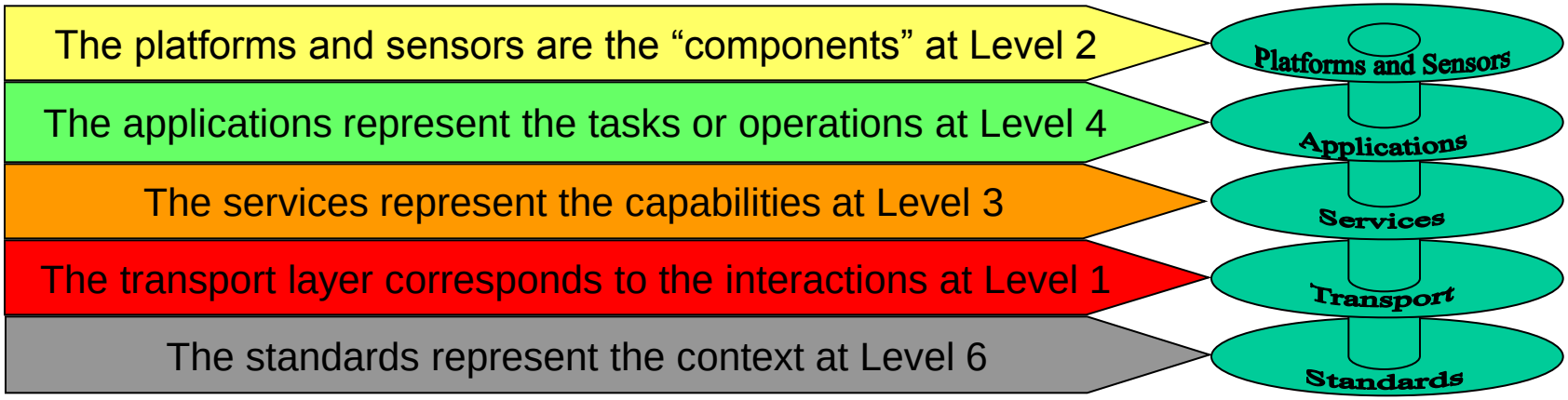
Future Combat Systems
Network Conceptual Representation



The mission is to see if the network does its job (i.e.: is effective)

An Un-verifiable Model



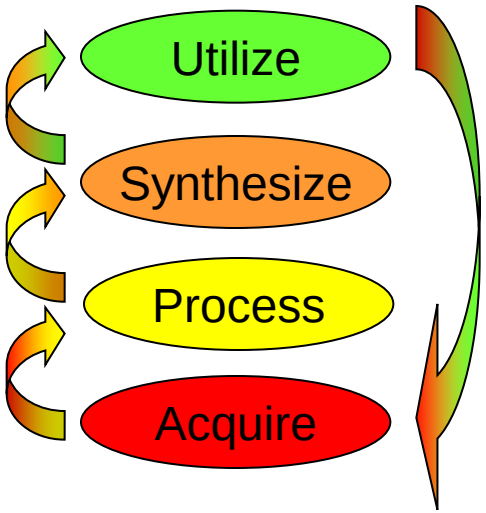


This conceptual representation has no reasonable logic flow

An Un-verifiable Model, Made Verifiable

If instead, we use the following:

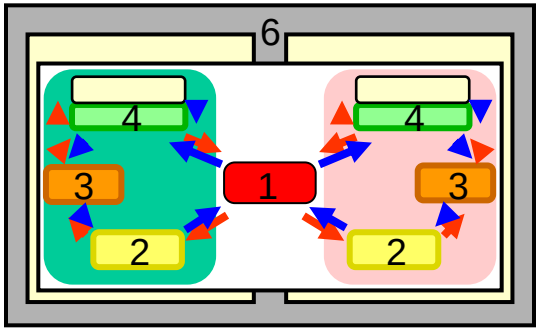
Node Functional Logic Flow



This encompasses all requisite network functions...

An Un-verifiable Model, Made Verifiable

...and follows a logical progression:



The utilize layer corresponds to task execution at Level 4

The synthesize layer corresponds to the capabilities at Level 3

The process layer corresponds to the “components” at Level 2

The acquire layer corresponds to the interactions at Level 1

Utilize

Synthesize

Process

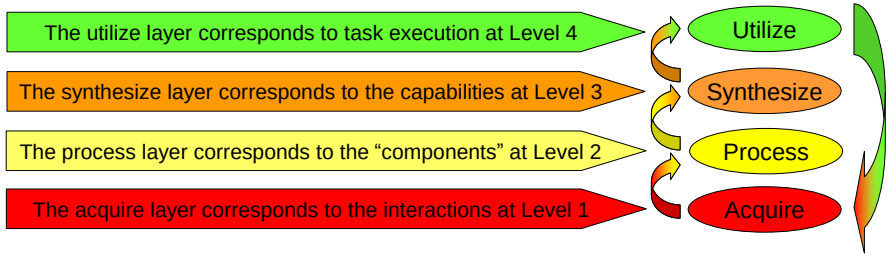
Acquire

If it all worked satisfactorily each time, the mission was completed. If not, the mission wasn’t completed.

SURVICE ENGINEERING COMPANY

An Un-verifiable Model, Made Verifiable

If it didn't work, why not?



Did the node

1) Get the information it needed when it needed it?

2) Understand the information?

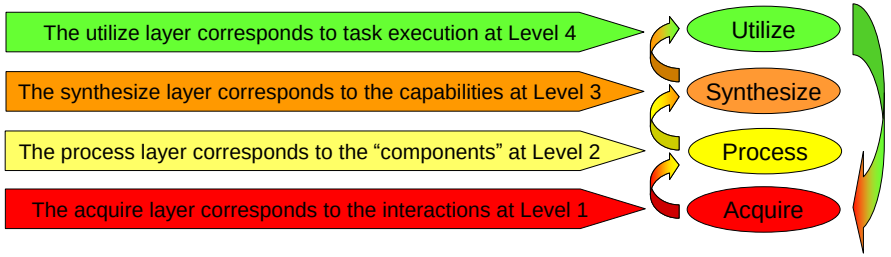
3) Process the information successfully?

4) Use the information?

All of these questions assume the information was in the appropriate context.

An Un-verifiable Model, Made Verifiable

If it didn't work, why not?



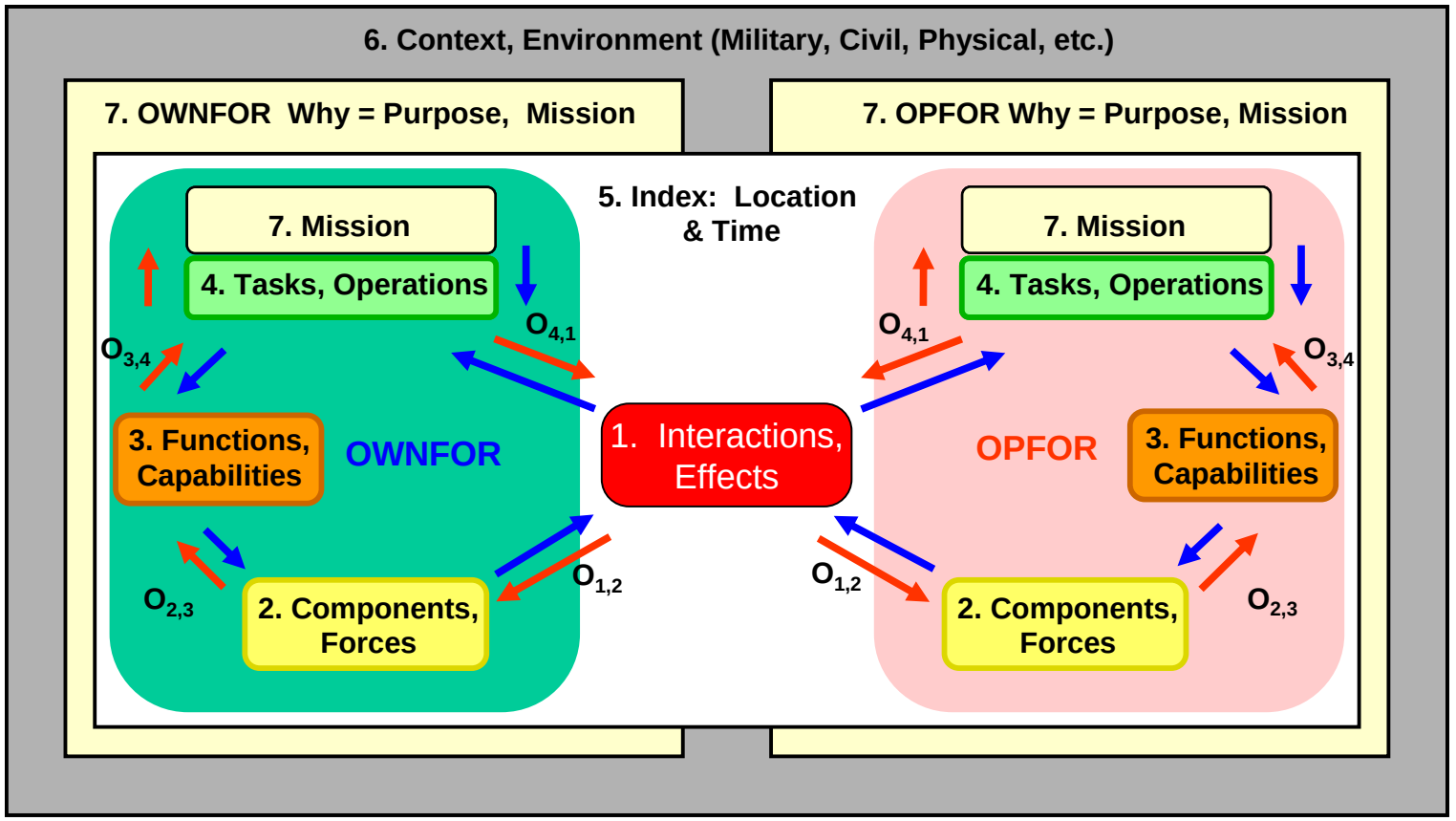
Did the node

1) Get the information it needed when it needed it?
   Did the Transport Layer work Properly?
2) Understand the information?
   Did the Platforms and Sensors Layer work Properly?
3) Process the information successfully?
   Did the Services Layer work Properly?
4) Use the information?
   Did the Applications Layer work Properly?

All of these questions assume the information was in the appropriate context. Did the Standards Layer work Properly?

SURVICE ENGINEERING COMPANY

The Missions and Means Framework

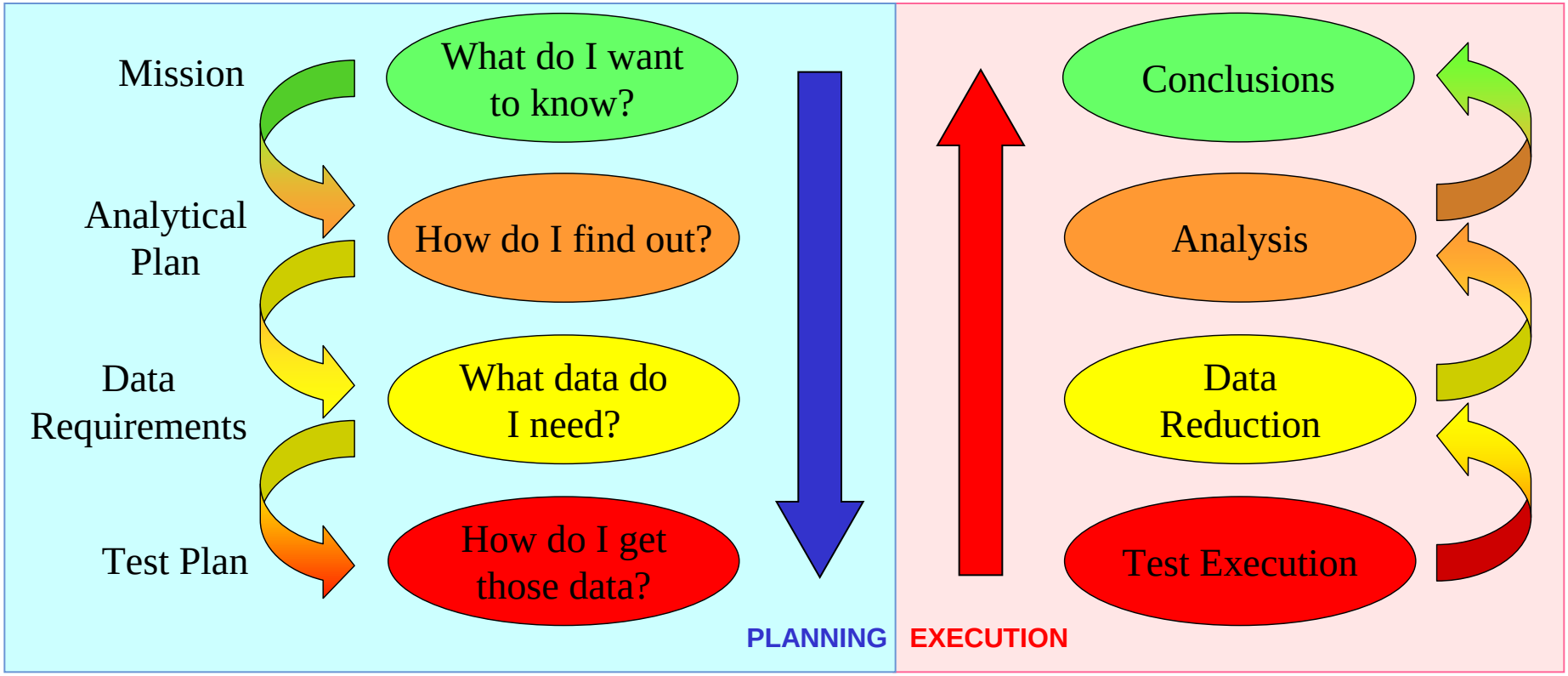


The blue arrows indicate "Planning"

The red arrows indicate "Execution"

SURVICE ENGINEERING COMPANY

A *Very* Old Concept



The analytical plan is based on the mission.
The data requirements are based on the analytical plan.
The test plan is based on the data requirements.

ANY OTHER ORDER FOR THESE EVENTS IS NONSENSE!

SURVICE ENGINEERING COMPANY

The Paradigm

Organize the M&S and T&E using the logic flow of MMF.

Determine the number of levels (intermediate outputs) required.

Align the data collection (instrumentation) with the levels.

Develop the M&S to output the same intermediate levels (values).

Don't **{ test / model }** ***more detail than you need, and***

don't **{ model / test }** ***more detail than you*** **{ test / model }** ***.***

Points to Ponder

Should we always design a { **test** / **model** } that fits all missions?

(just in case…*Scope, Time, Budget*)

Is it better to be ***precisely incorrect*** or ***approximately correct***?

("Dewey Beats Truman" vs "A President was Elected")

(If the test data value is 1.2 and the simulation output is 1.23564, which value is more nearly correct?)

Are we doing a certain level of M&S because we can, or because we need it to answer the "mission accomplished" question?

(How did we get to the moon without finite element codes?)

Don't be afraid to consider the possibility that there is ***no discernable cause/effect relationship*** in what you're trying to simulate.

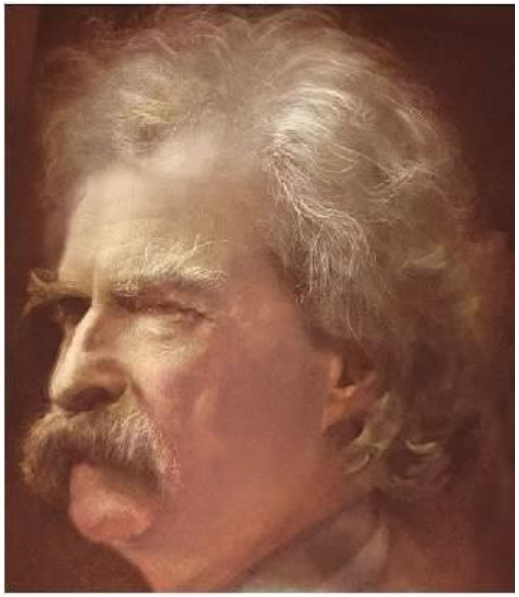
SURVICE ENGINEERING COMPANY

Sometimes, it's better to be lucky than good…

…but don't count on it!

"Noah had an absurd idea that he could navigate without any knowledge of navigation, and he ran into the only shoal place on earth."

-Mark Twain



James N. Walbert, Ph.D.
Chief Scientist

SURVICE Engineering Company
3700 Fettler Park Drive, Suite 401
Dumfries, VA 22025

703-221-7370
jim.walbert@survice.com