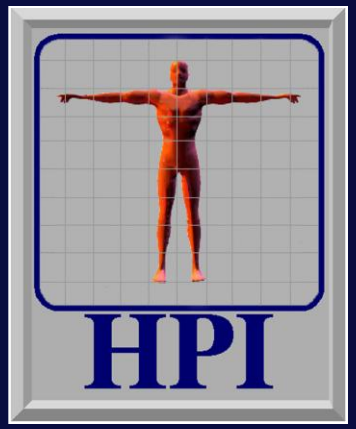
Frameworks for Human Systems Integration (HSI): General Systems Performance Theory (GSPT) and the Elemental Resource Model (ERM)



NDIA Systems Engineering Conference
San Diego, CA

Oct 27, 2011

George V. Kondraske, Ph.D.
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University of Texas at Arlington
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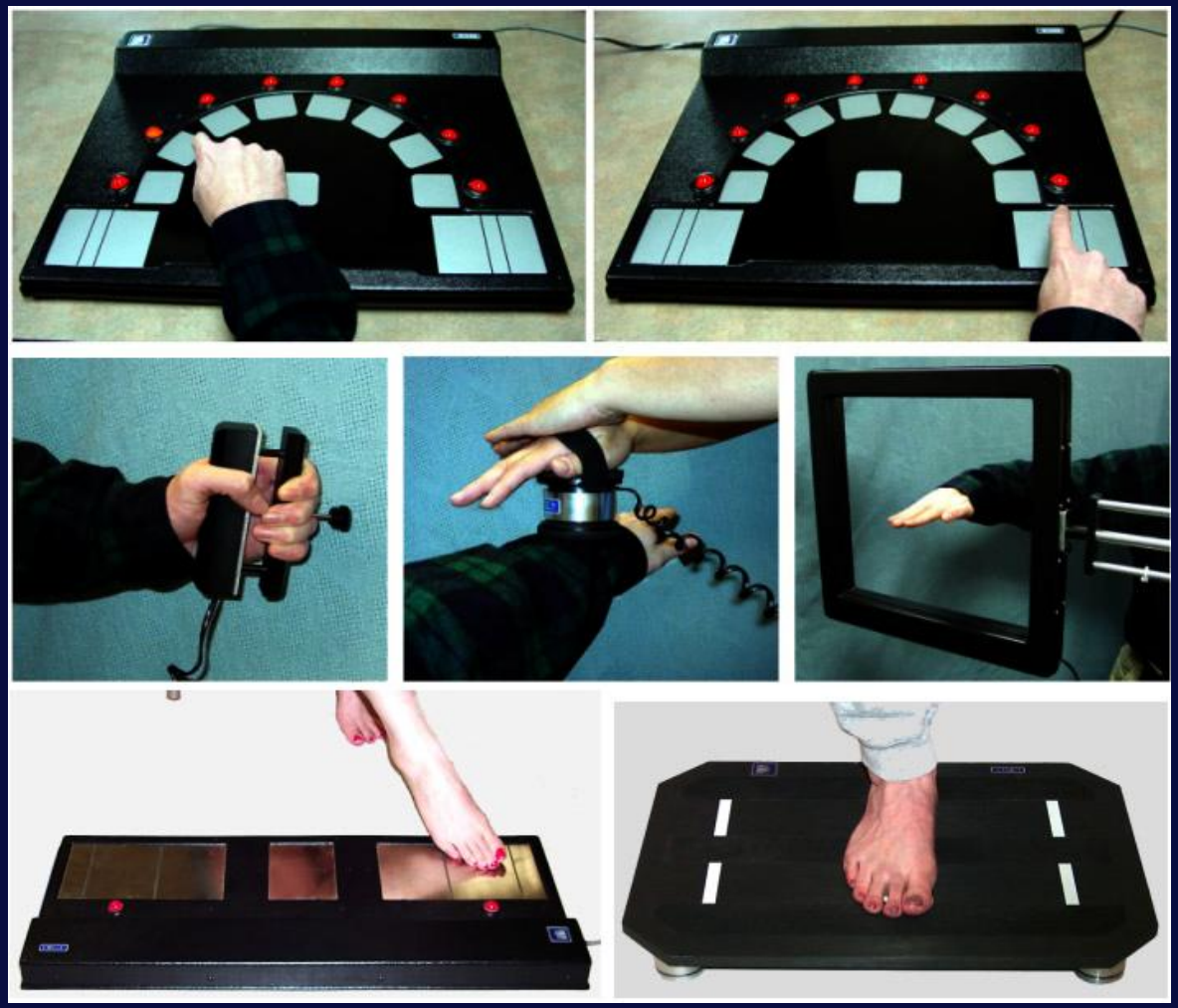
MOTIVATION and BACKGROUND..
OBJECTIVE PERFORMANCE CAPACITY MEASUREMENTS



MOTIVATION:
CORE "GENERIC" CHALLENGES

How do we quantitatively determine (i.e., model, predict):

What the human can or can't do?

How _well_ he or she can do a task?

If he or she can't do better - _why_?

MOTIVATION and BACKGROUND ..

Human Factors Engineering (C.W. Simon 1987)

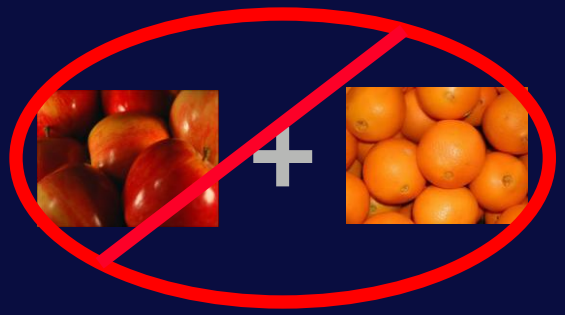
”The methodology employed today is a hodgepodge of quick fixes that evolved over the years ..

..into a paradigm that is taught and employed as sacrosanct ..

..when in fact it is woefully inadequate and frequently incompetent.”

SOME EVIDENCE of a PERFORMANCE THEORY VOID

SATs, GREs **=> Overall Score = Math (Skill) + Verbal (Skill)**



Countless Human Performance (and Other System Performance) "Rating Scales" Where..

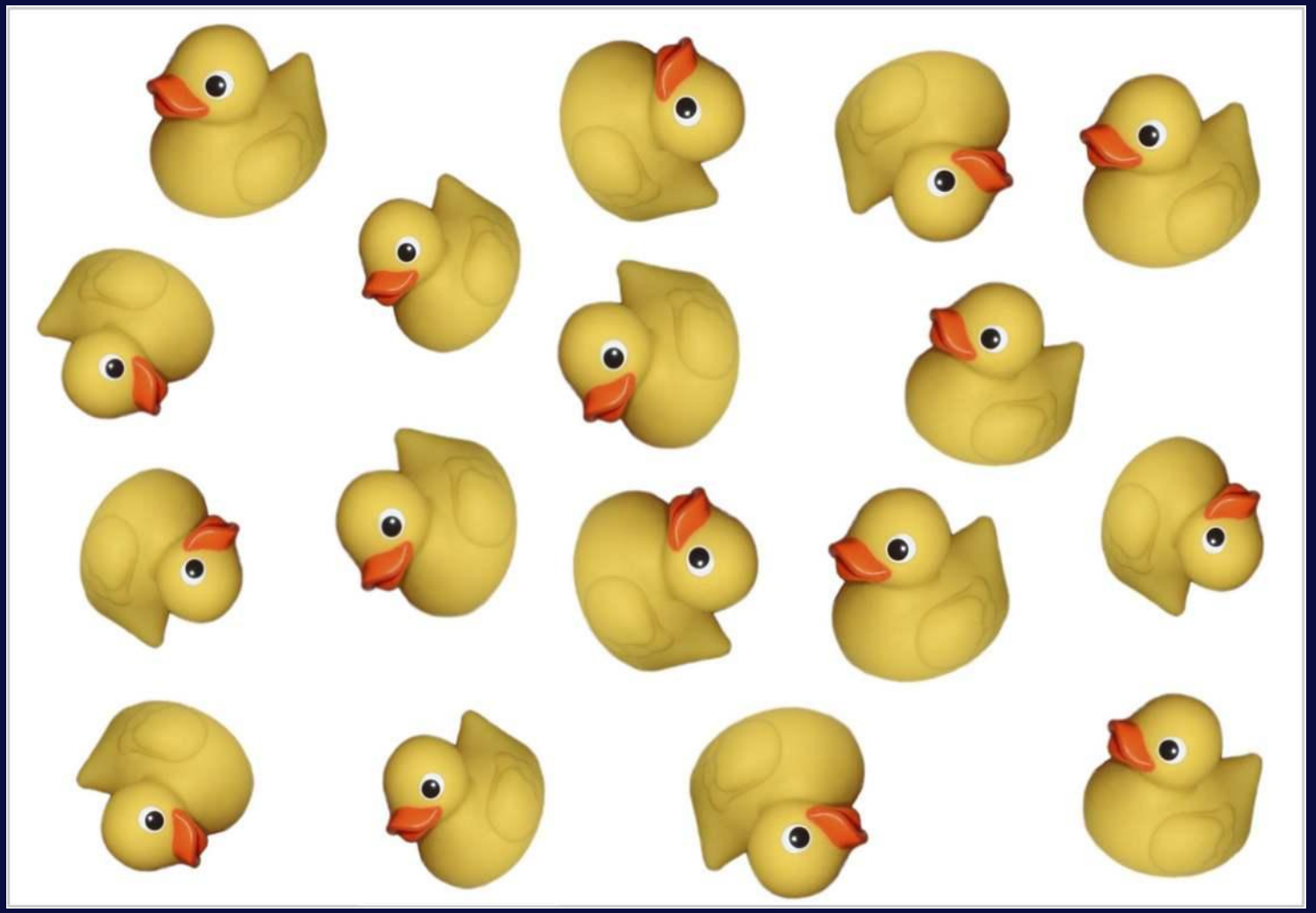
Overall Score = Sum of "N" "Essentially Orthogonal" Items

Also, Linear Regression Predictive Models..

(e.g., ADD Strength to Memory Capacity, etc.

Many Implications! Beyond Scope of This Presentation.

STATE of UNDERSTANDING?



BACKGROUND


DSOC Program Review
Human Systems Integration
Task Force
DEPARTMENT OF DEFENSE
UNITED STATES OF AMERICA
Major General Tom Travis, Chair
Col Lex Brown, Deputy Chair
April 23, 2009

BACKGROUND

Strategic Frameworks for
Human Performance and Human Systems Integration

Spotlight on
General Systems Performance Theory and
Nonlinear Causal Resource Analysis

Workshop
Motivated and Convened by the
Human Systems Integration Task Force
Defense Safety Oversight Council
Major General Thomas Travis, Chair HSI TF

December 13-14, 2010
Human Performance Institute
The University of Texas at Arlington
Arlington, TX

BACKGROUND

This document represents the dedicated work of twenty five participants from eighteen organizations over two days, attacking the problem of finding an organizing framework for human performance. Participants from Army, Navy, Air Force, Marine Corp, NASA, and civilian organizations contributed. Each of those participants was chosen for experience and expertise in fields touching human performance and HSI. Their objective was to make specific recommendations for use by the Defense Safety Oversight Council on adoption of a framework for human performance for the Department of Defense.

I am pleased to endorse their recommendations, along with summaries of the presentations and debates that led to these recommendations. This is an important step forward for the safe, effective employment of our service members and a critical step in support of Human Performance and HSI programs in all the services.

THOMAS W. TRAVIS
Major General, USAF, MC, CFS
Deputy Surgeon General

Workshop Proceedings - Strategic frameworks for human performance and human systems integration: Spotlight on General Systems Performance Theory and Nonlinear Causal Resource Analysis, Dept of Defense Case # 88ABW-2011-0912

OVERVIEW

General Systems Performance Theory (GSPT)

Apply to
Human System

Elemental Resource Model (ERM)
and Human Performance Capacity Measurements

GSPT: What is Performance?

Consider Major Classes of System Attributes..

STRUCTURE	FUNCTION	PERFORMANCE
Tangible Aspects..	Purpose..	*How Well* Structure Executes Its Function (*Capacity* to Execute),..
that can be measured (e.g., length, width..)	Can be STATED (e.g., “to move”), but not measured	..with multiple attributes that can be measured

THE HUMAN SYSTEM IS COMPLICATED!

Consider a Simple, More Generic Situation..

.. to Gain Fundamental Insights

General Systems Performance Theory (GSPT)

GSPT Addresses:

- **Systems**
- **Tasks**
- **Their Interface**

from the *Perspective of Performance*

Provides a Theoretical Basis for "Performance Modeling"

GSPT: THE "Resource" CONSTRUCT

- Originally Applied to Physical, Tangible Items
  - e.g., coal, oil, grain, etc.
- Now => Notion of "Performance Resources"
- Adopt Attributes from Original, Physical Context
  - A resource is something *desirable/useful*
    - e.g., "accuracy", NOT "error"
  - A resource is measured in such a manner that:
    - the range is from zero to a finite positive value
    - a larger numerical value always represents "more" resource availability

All Principles of RESOURCE ECONOMICS Can Be Exploited

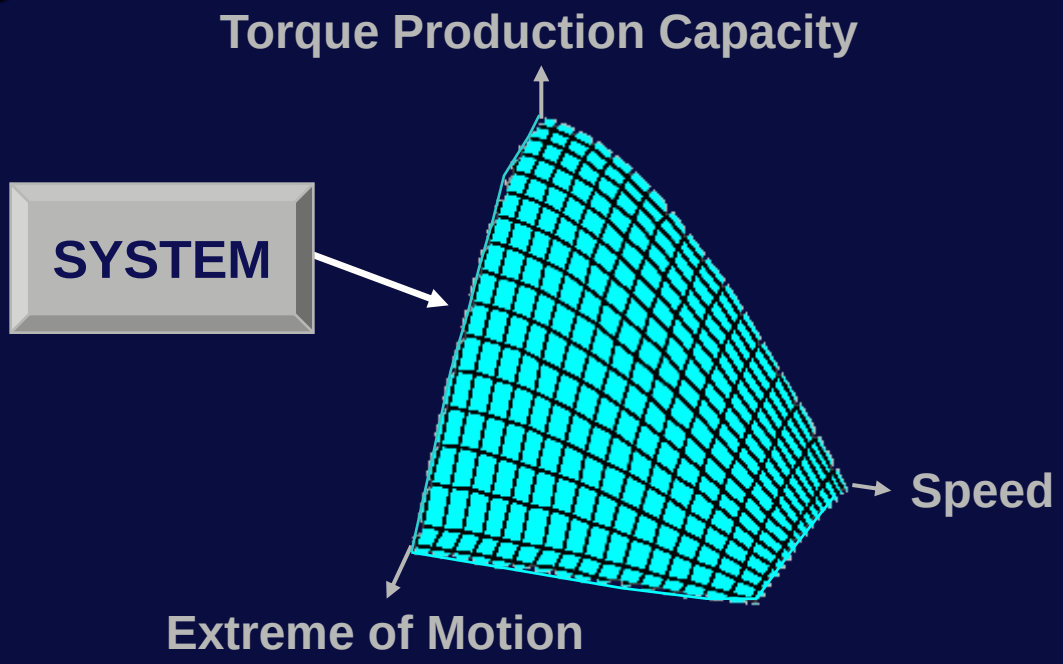
GSPT:
PERFORMANCE RESOURCES and PERFORMANCE CAPACITY ENVELOPE (PCE)

Performance Resources

Dimensions of Performance (DOP)

- Speed
- Strength
- Endurance
- Resilience
- Adaptability
- Motivation
- Confidence

More..

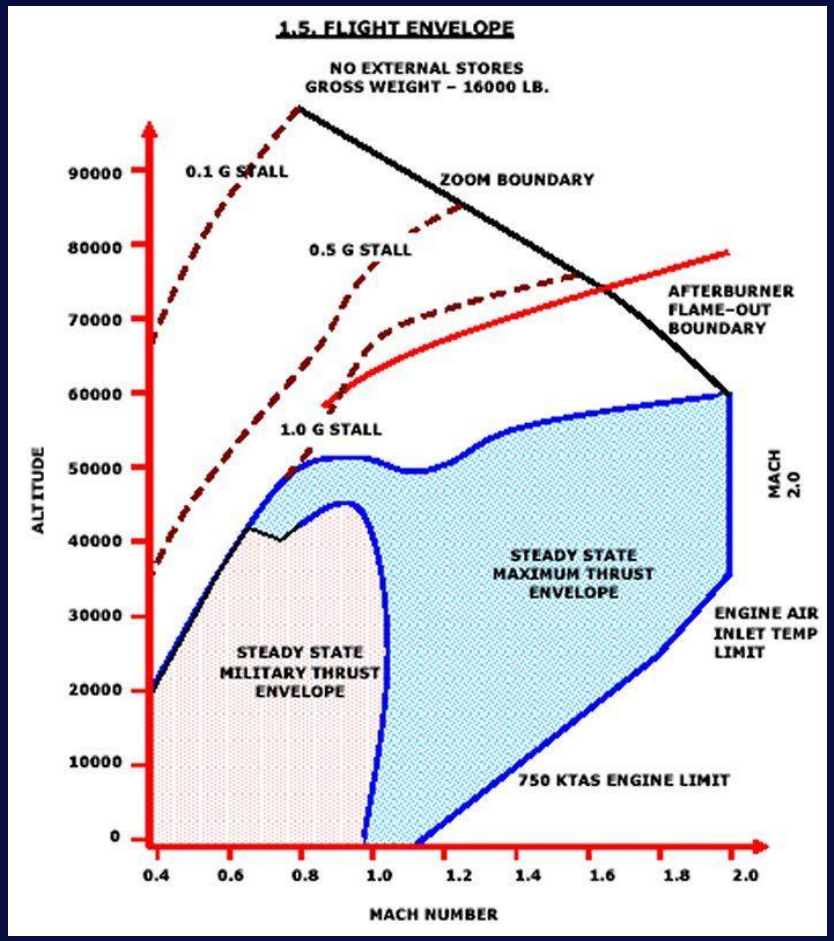


Every SYSTEM Has a Multidimensional PCE

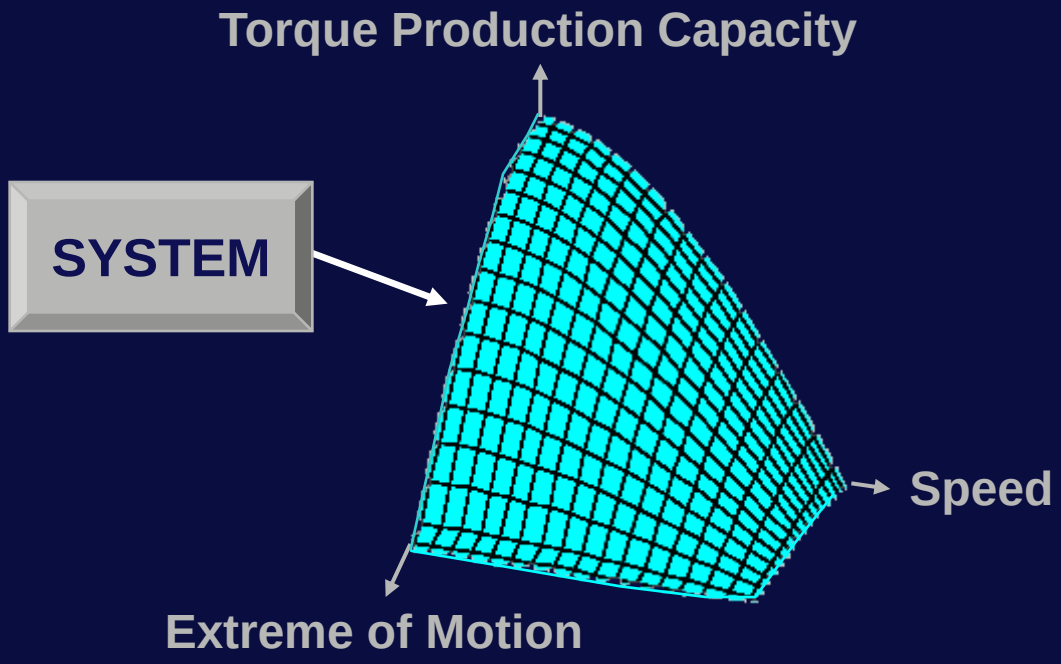
PERFORMANCE ENVELOPE: History..

MILITARY AIRCRAFT

- ***Speed***
- ***Altitude***
- ***Range***



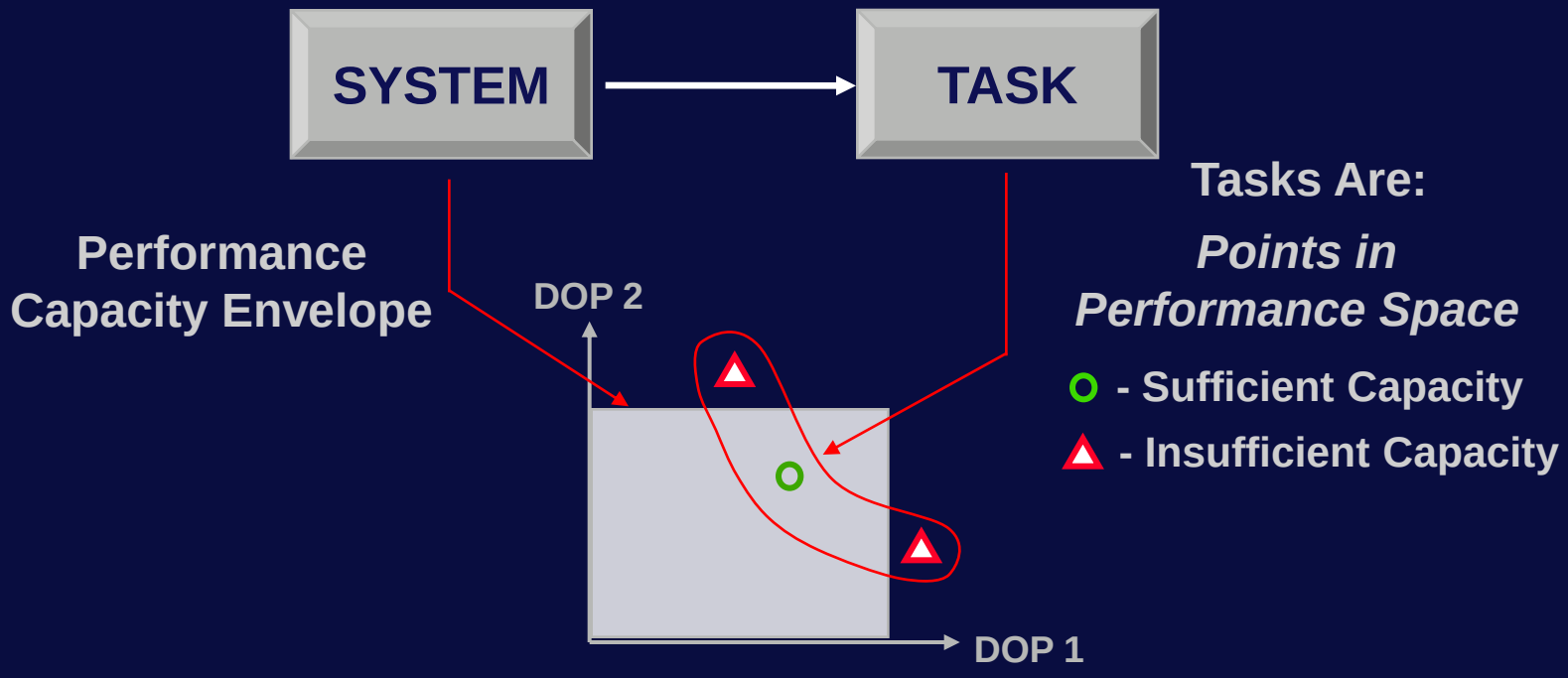
GSPT:
PERFORMANCE CAPACITY ENVELOPE (PCE)



You only obtain a PCE IF:

1) each dimension represents a performance resource, and
2) each measure is defined so that a larger numerical value reflects "more" of that resource.

PERFORMANCE CAPACITY ENVELOPES:
Relation to Tasks



LAWS of the SYSTEM-TASK INTERFACE

For "Success" of a Given System in a Given Task,

Performance Resource <u>Availability</u>

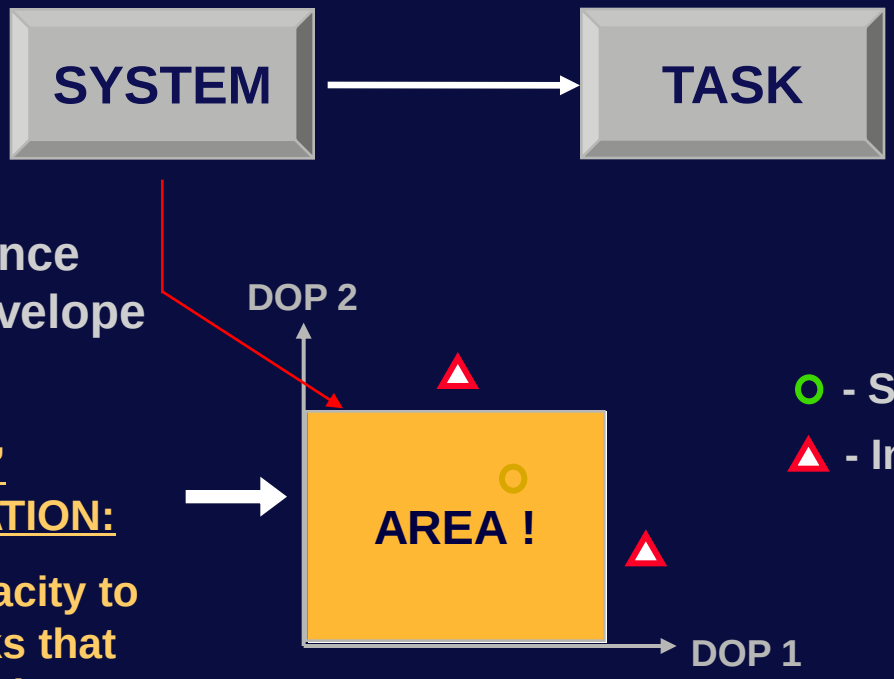
<u>Must</u> <u>Exceed</u> Performance Resource <u>Demand</u> ($R_A \geq R_D$).

Resource Economic Principles
***Govern* System-Task Interfaces**

A GENERAL "Rule for Success" (system in a task):

<u>If</u> $R_{A_1} \geq R_{D_1}$ <u>AND</u> $R_{A_2} \geq R_{D_2}$ <u>AND</u> … $R_{A_n} \geq R_{D_n}$,
<u>Then</u> "SUCCESS" (Else "FAILURE")

PERFORMANCE CAPACITY ENVELOPES:
Interpretation of Area (n-dimensional Volume)



"AREA" INTERPRETATION:

System's Capacity to Execute Tasks that Make Demands on Performance Resources Forming the "Performance Space "

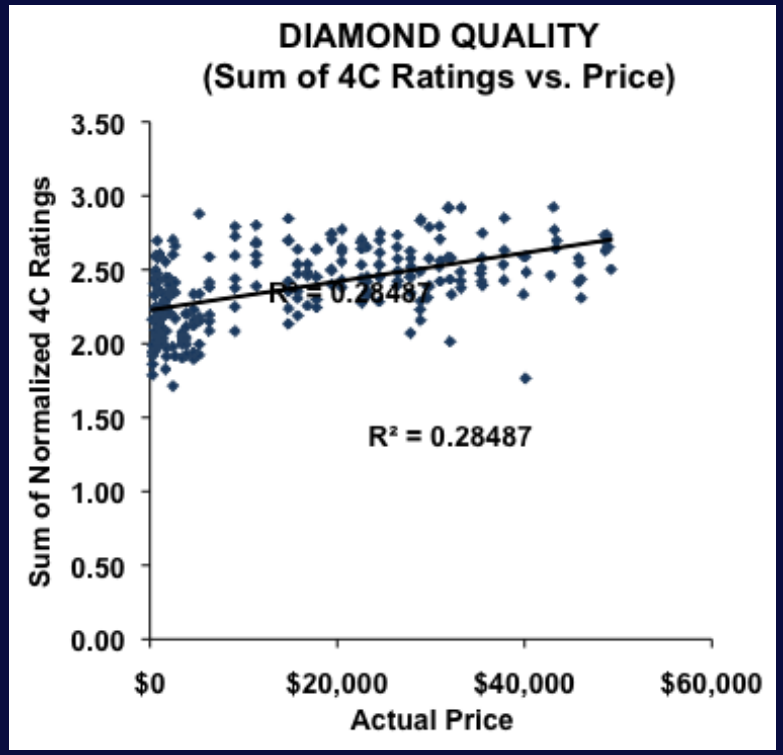
Consider Joint Probability Interpretation..

EXAMPLE – DIAMOND QUALITY

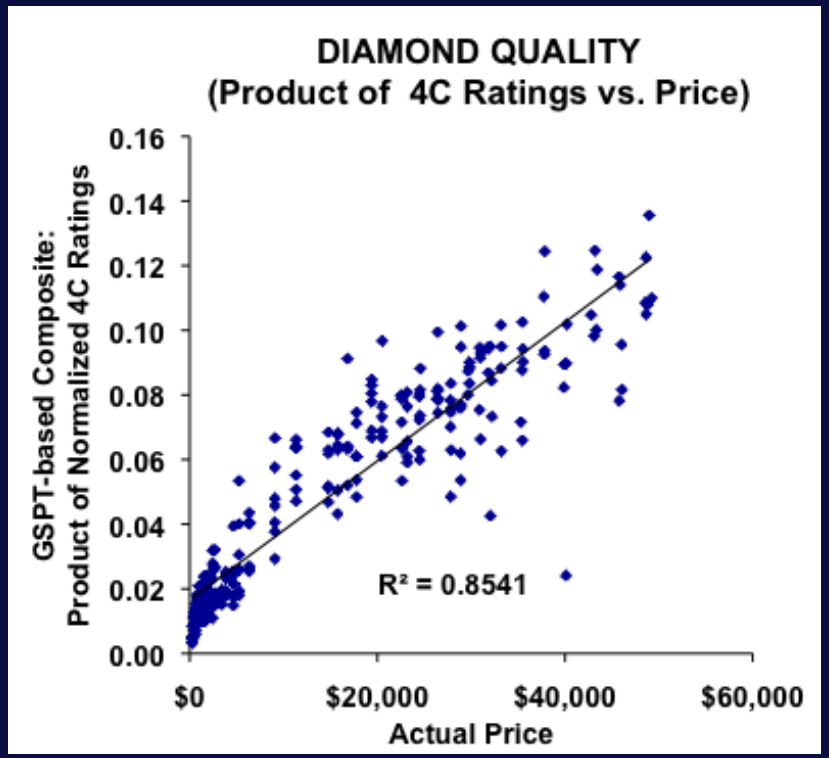
- How Can We Combine Measures of the 4C's to Obtain a Single Number Measure of Quality?
- Online Database of Diamonds (4Cs, price)!
- Computed Normalized (not weighted) Measures for Each of the 4C Items
- Formed Additive and Multiplicative "Composites" Resulting In..

EXAMPLE – DIAMOND QUALITY

Additive

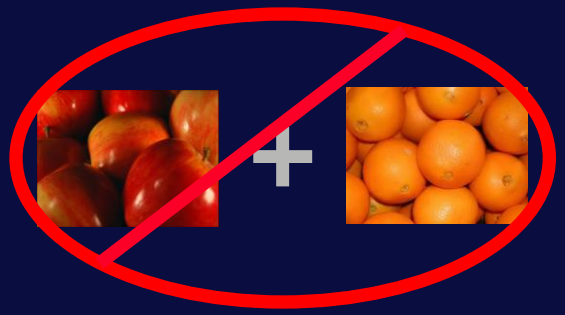


GSPT => Multiplicative



REMEMBER THIS?

SATs, GREs **=> Overall Score = Math (Skill) + Verbal (Skill)**



Countless Human Performance (and Other System Performance) "Rating Scales" Where..

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Also, Linear Regression Predictive Models..

(e.g., ADD Strength to Memory Capacity, etc.

Many Implications! Beyond Scope of This Presentation.

RECALL the "MATH" of CHEMISTRY..

$$12CO_2 + 11H_2O \Rightarrow C_{12}H_{22}O_{11} + 12O_2$$

NOT "Mathematical Addition", but means "Combine"!

"Limiting Reagent" Concept => Limiting Performance Resource

The *Math of Performance* is the *Math of Chemistry*!

GSPT PROVIDES FUNDAMENTAL INSIGHTS..

BACK TO THE HUMAN SYSTEM:
Organize the Complexity and Apply GSPT

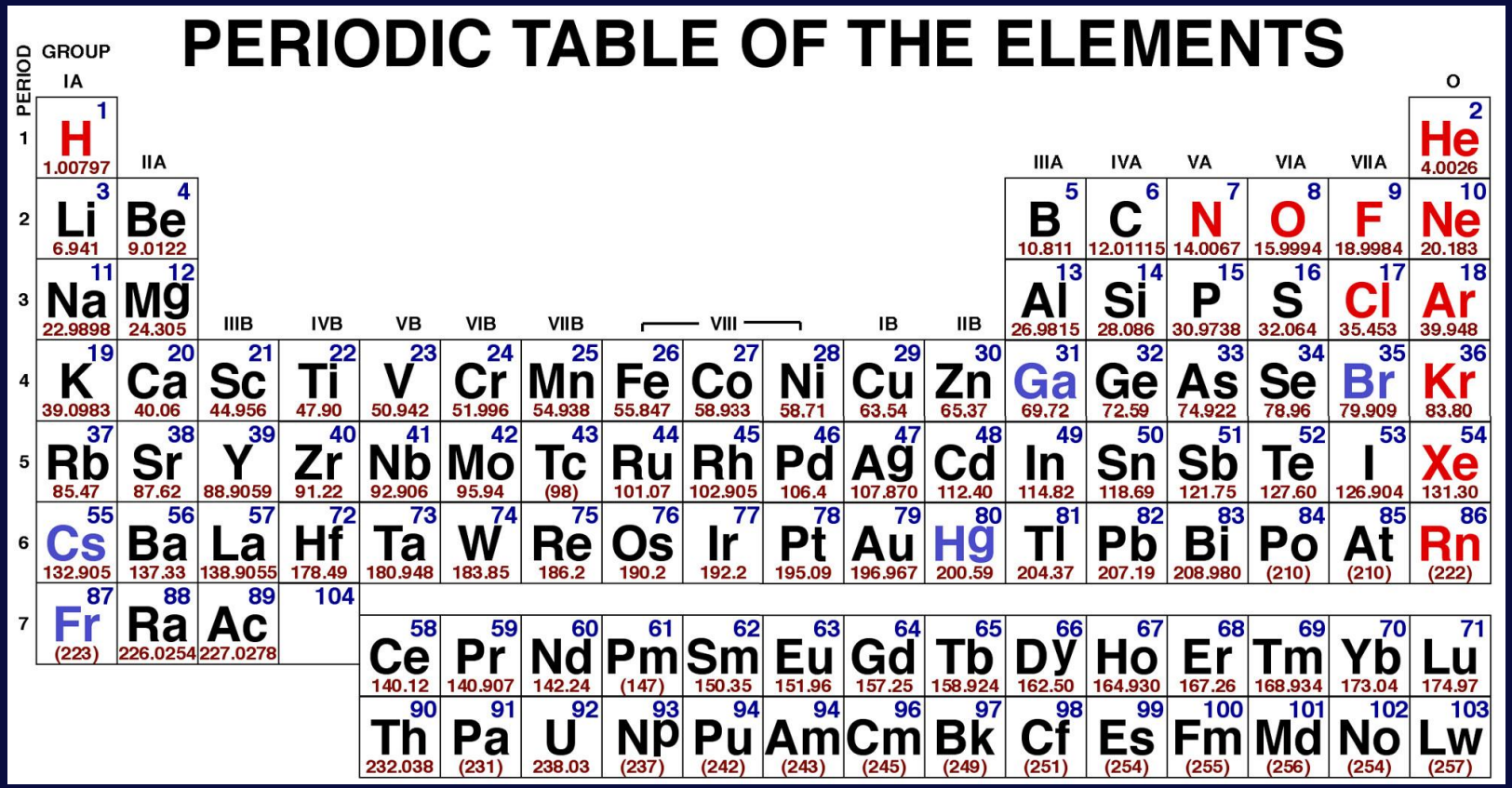
- Use Hierarchical Concepts
- Group Subsystems by Type
- Monadology (Leibniz 1714)

Resulting In:

The Elemental Resource Model (ERM)
for Human Performance

MONADOLOGY and CHEMISTRY:

"Finite Set of Basic Elements" *not*
"Infinite Number of Unique Substances"



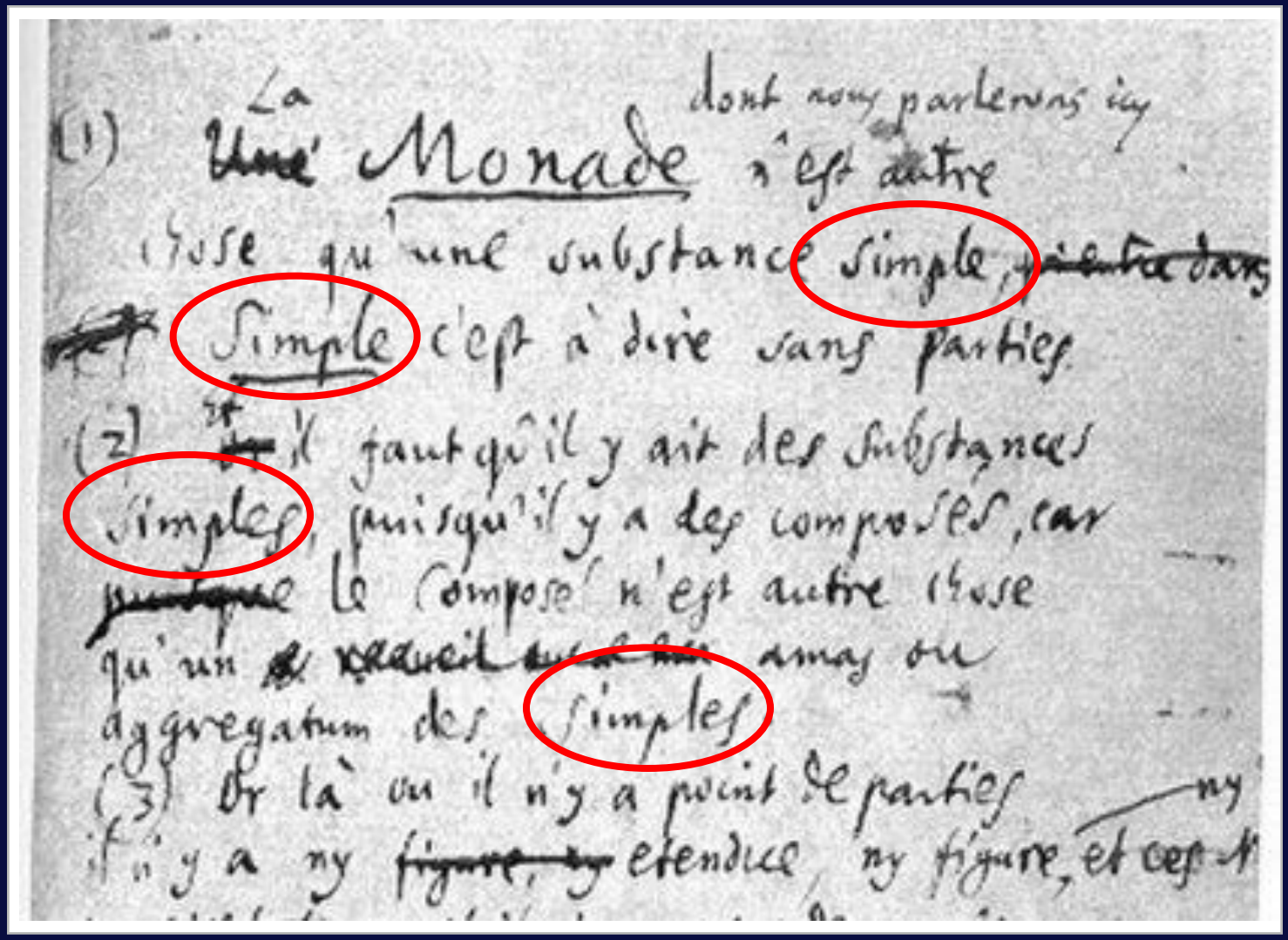
MONADOLOGY

"Considering matters accurately, it must be said that there is nothing in things except simple substances..."

Leibnitz 1714

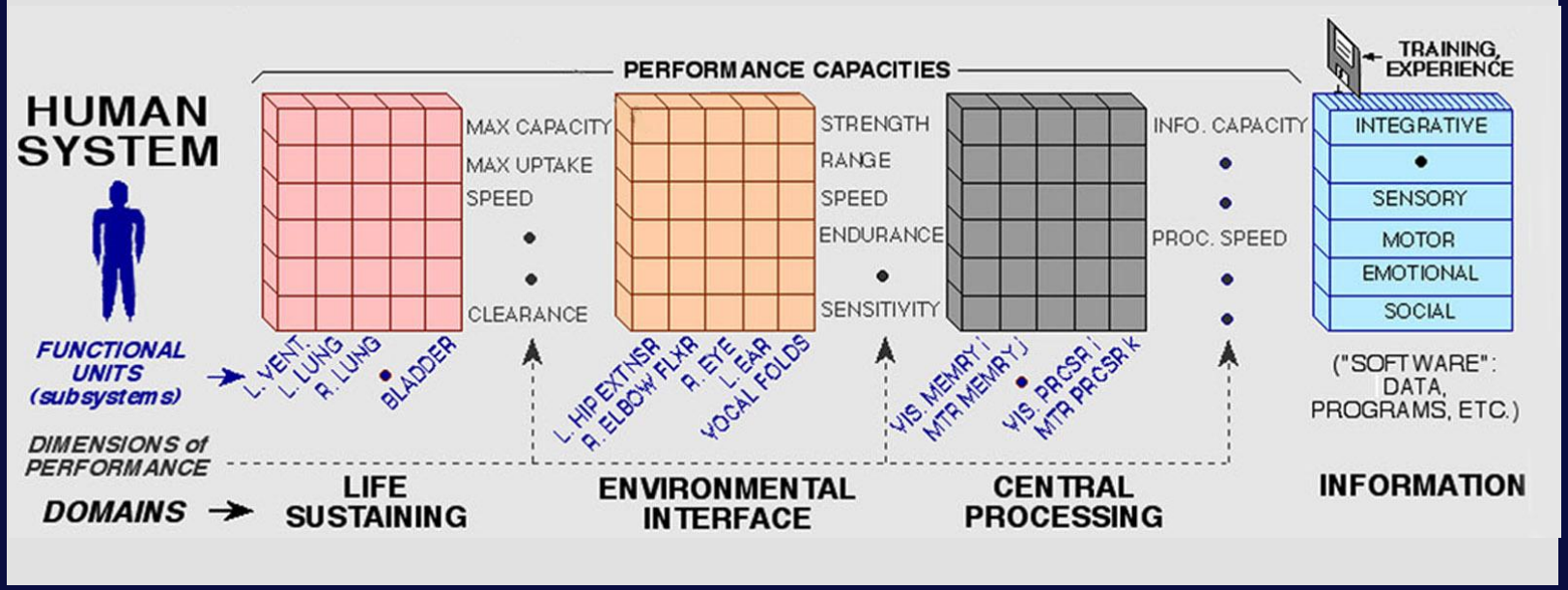
1714 !

MONADOLOGY – *from the Source*

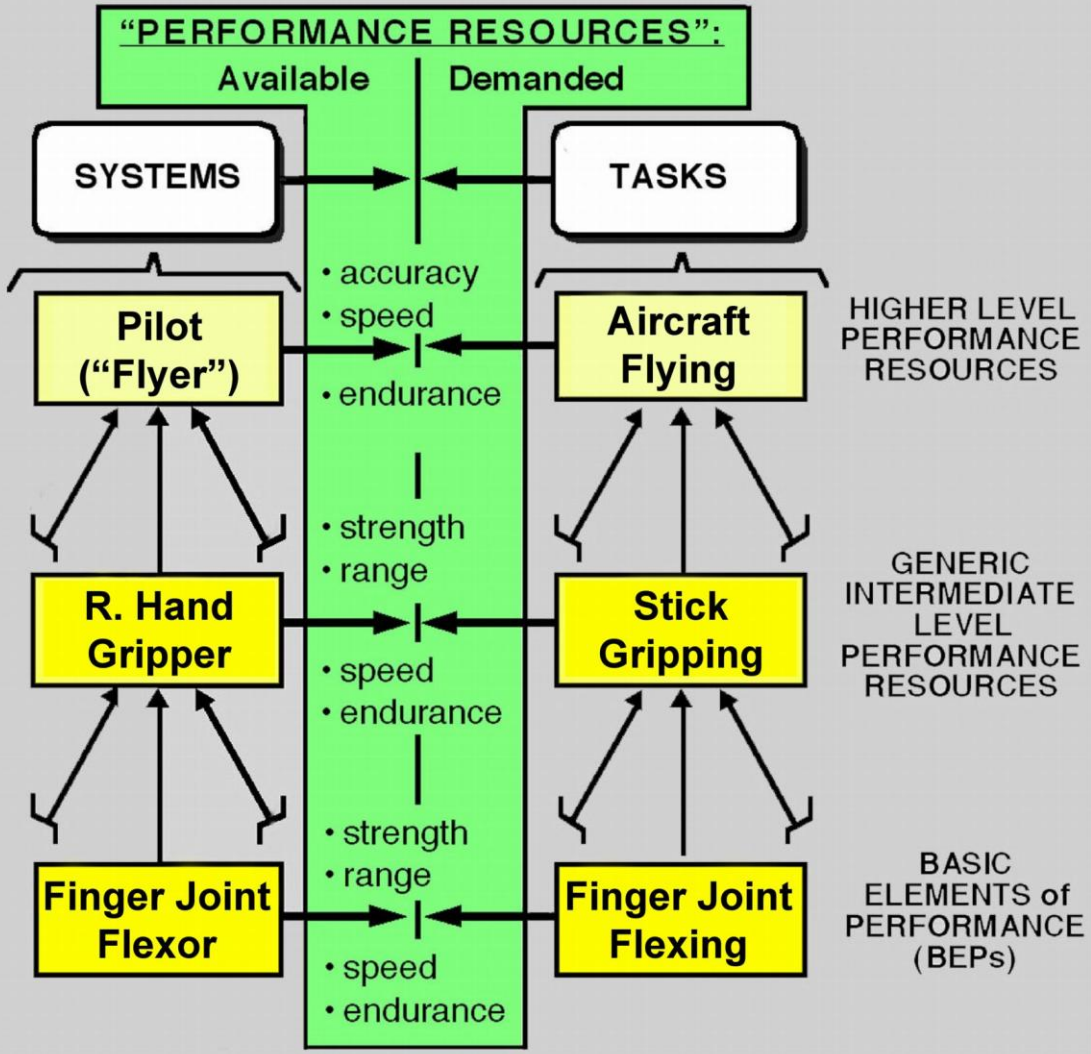


A "CHEMISTRY" for Human Performance: The Elemental Resource Model (ERM)

TABLE of HUMAN BASIC ELEMENTS of PERFORMANCE



ELEMENTAL RESOURCE MODEL
for Human Performance



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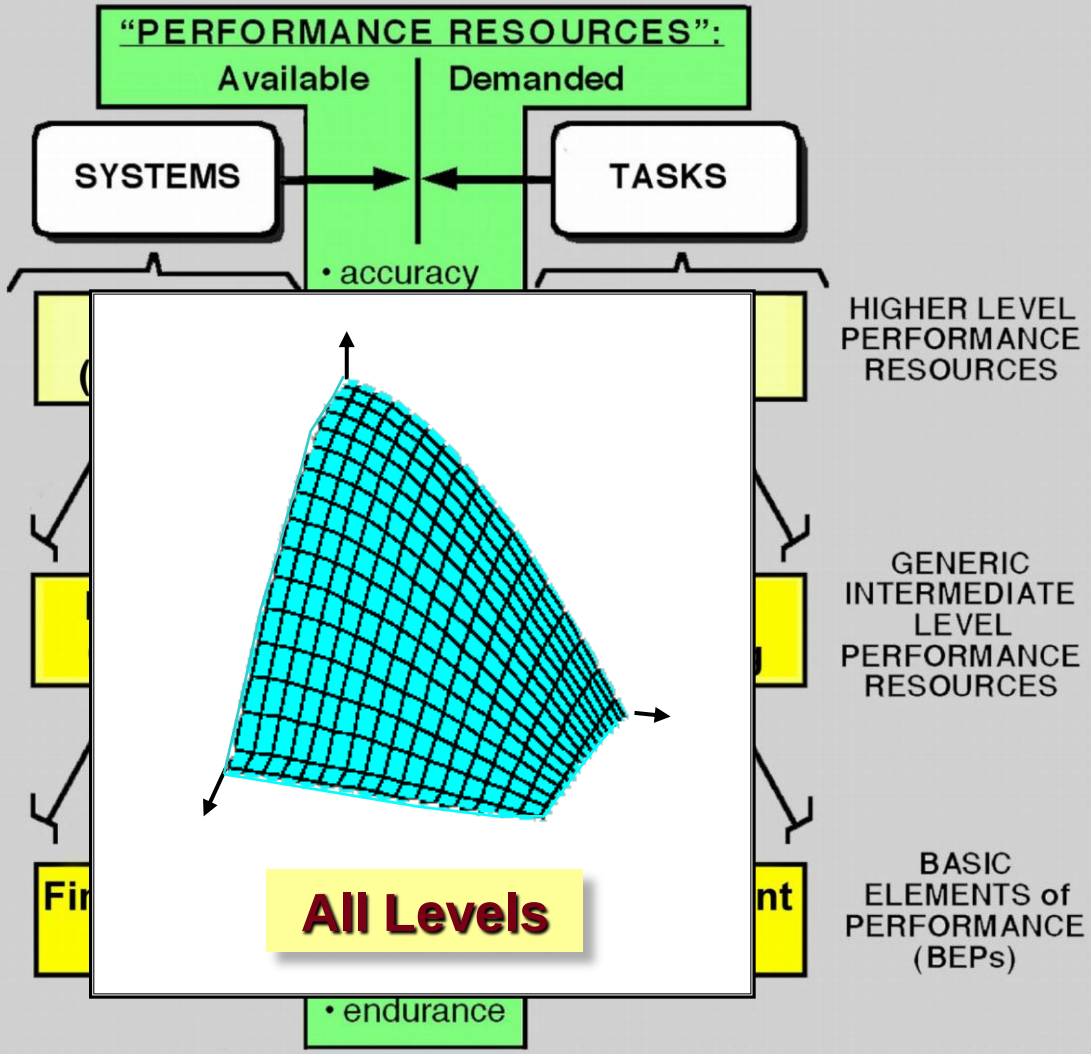
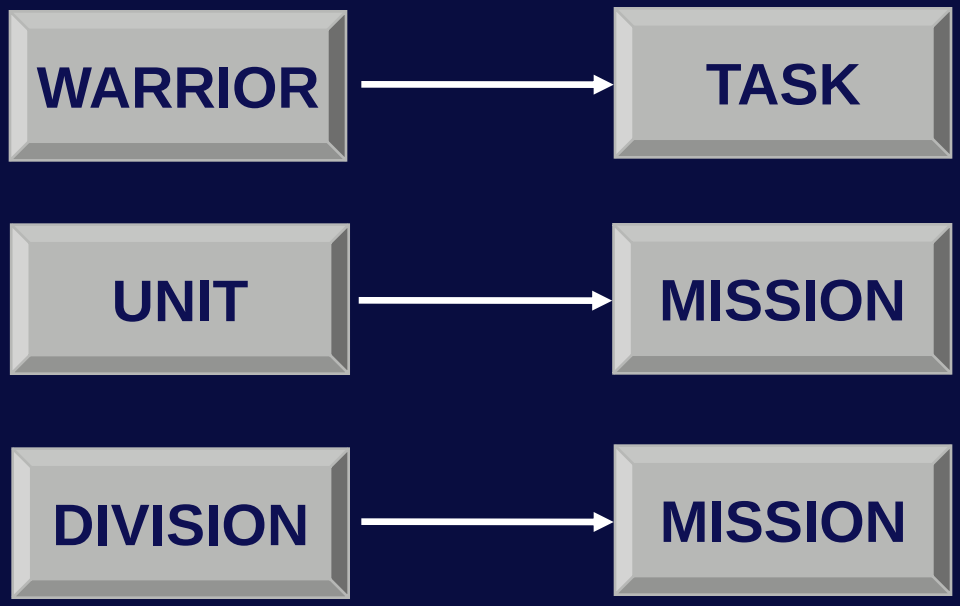


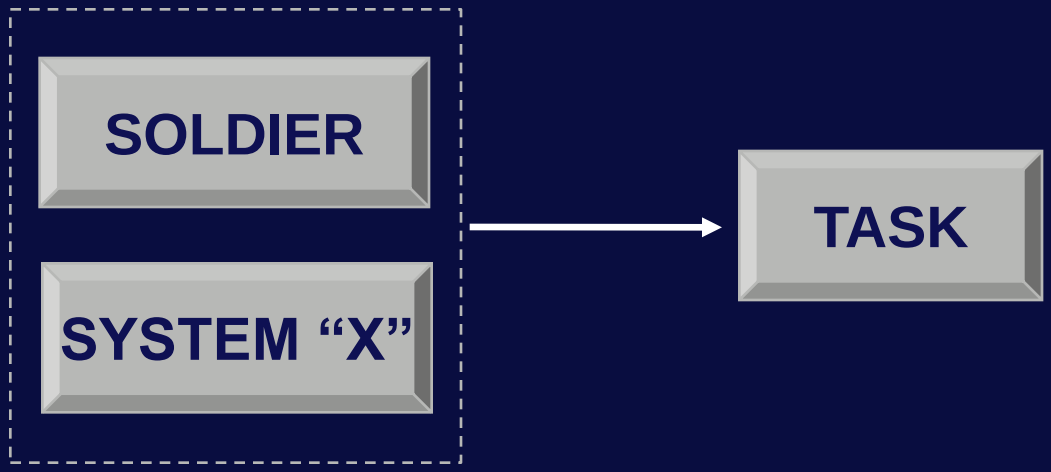
GSPT & PERFORMANCE CAPACITY ENVELOPES:

Applicable to Any Hierarchical Level:

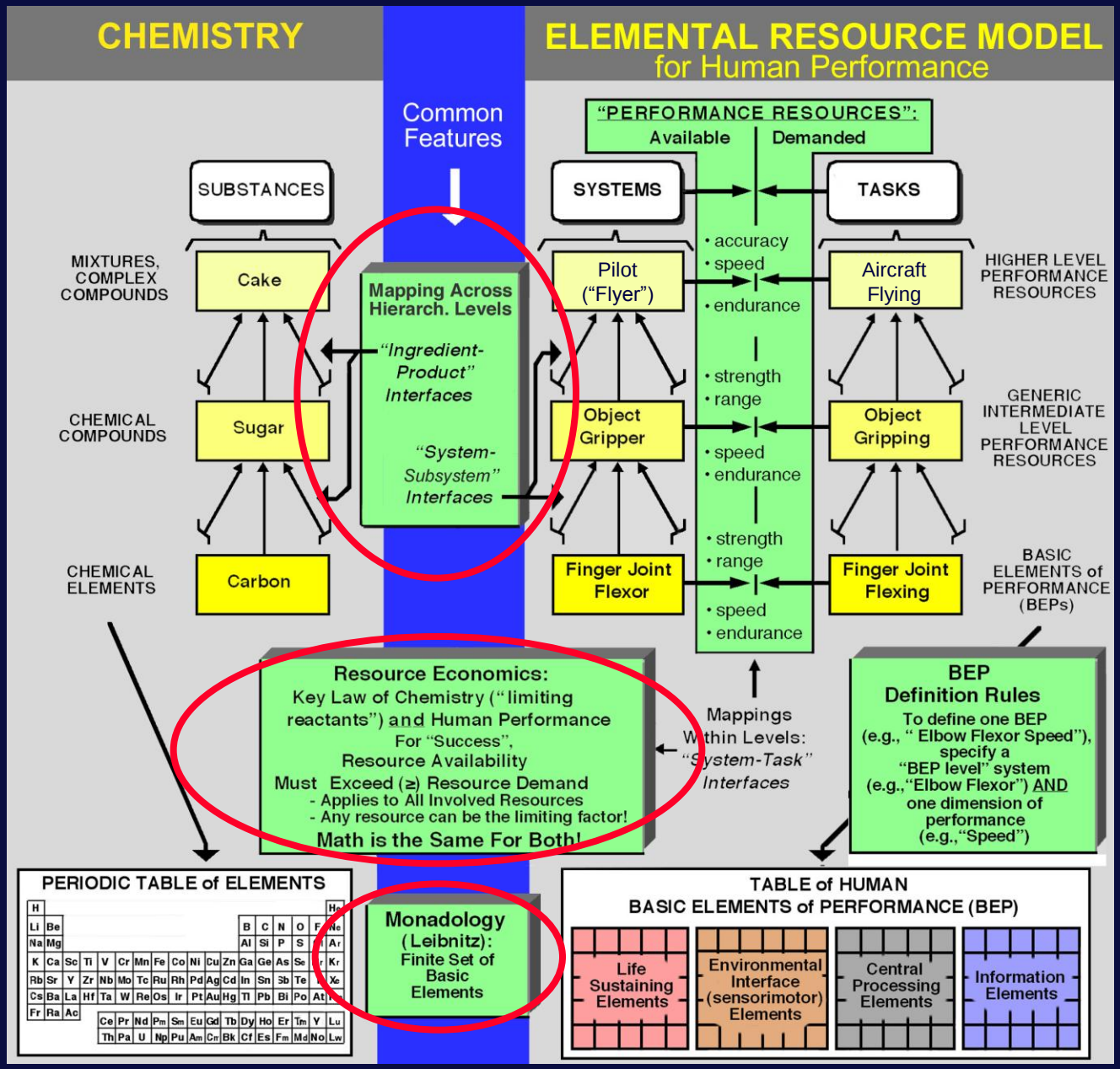


Can Also Combine Human and Artificial Systems (e.g., weapons, transportation, etc.)

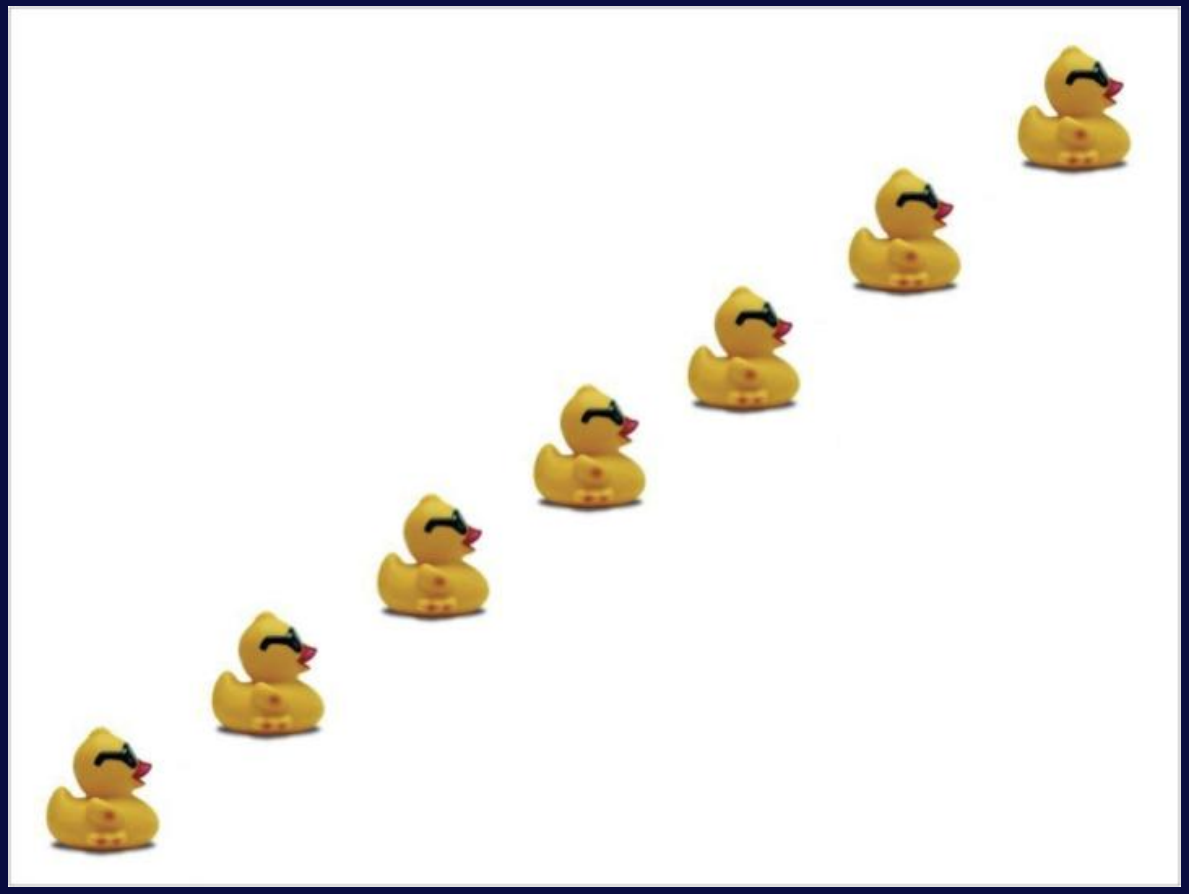
MIXED HUMAN-ARTICIAL SYSTEMS



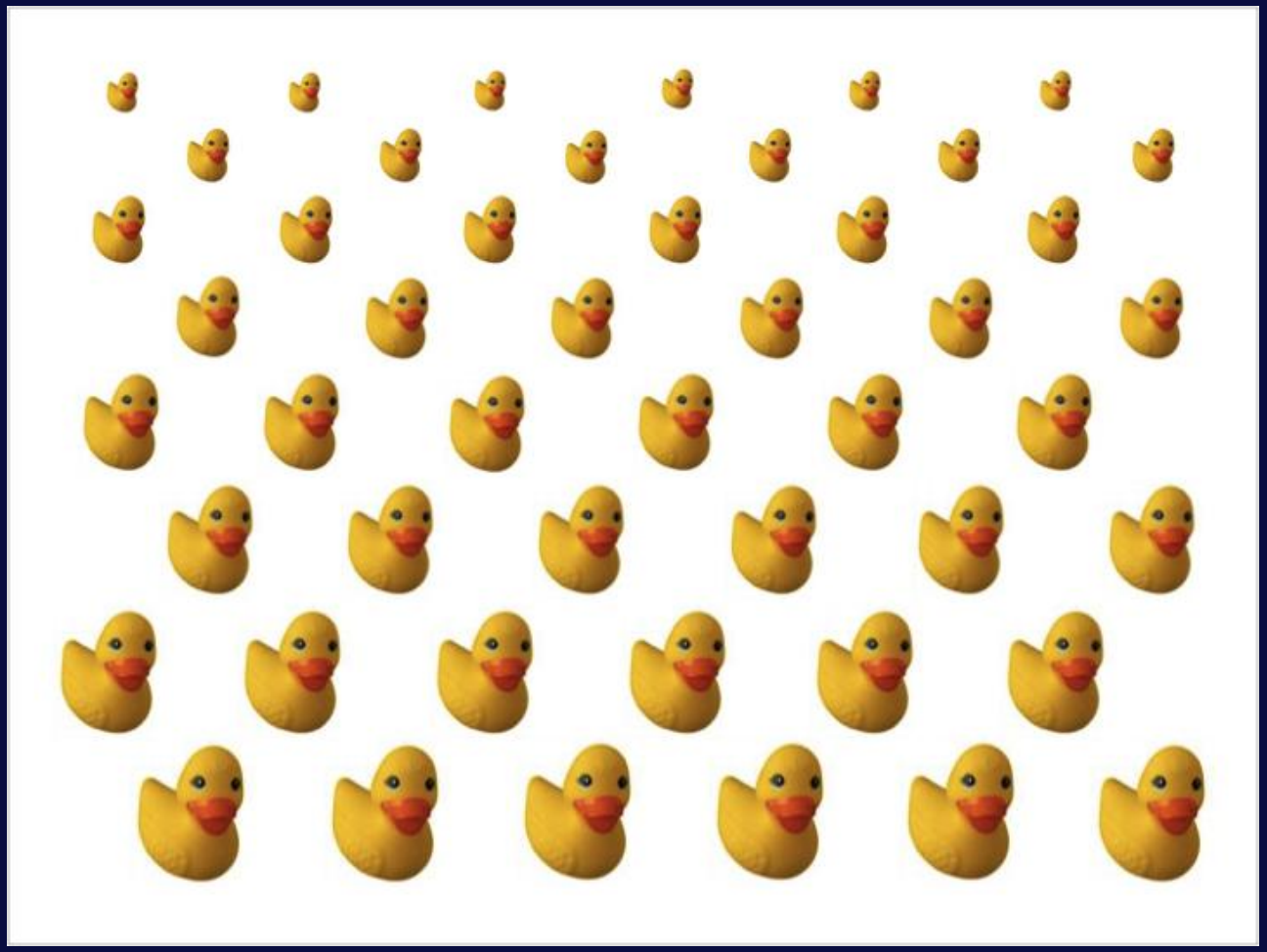
"The TASK" Does Not Care Where Performance Resources Originate!


CHEMISTRY
ELEMENTAL RESOURCE MODEL
for Human Performance
Common Features
"PERFORMANCE RESOURCES":
Available
Demanded
SUBSTANCES
SYSTEMS
TASKS
MIXTURES, COMPLEX COMPOUNDS
Cake
Pilot ("Flyer")
Aircraft Flying
HIGHER LEVEL PERFORMANCE RESOURCES
• accuracy
• speed
• endurance
Mapping Across Hierarch. Levels
"Ingredient-Product" Interfaces
"System-Subsystem" Interfaces
CHEMICAL COMPOUNDS
Sugar
Object Gripper
Object Gripping
GENERIC INTERMEDIATE LEVEL PERFORMANCE RESOURCES
• strength
• range
• speed
• endurance
CHEMICAL ELEMENTS
Carbon
Finger Joint Flexor
Finger Joint Flexing
BASIC ELEMENTS of PERFORMANCE (BEPs)
• strength
• range
• speed
• endurance
Resource Economics:
Key Law of Chemistry ("limiting reactants") and Human Performance
For "Success",
Resource Availability
Must Exceed (≥) Resource Demand
- Applies to All Involved Resources
- Any resource can be the limiting factor!
Math is the Same For Both!
Mappings Within Levels: "System-Task" Interfaces
BEP Definition Rules
To define one BEP (e.g., " Elbow Flexor Speed"), specify a "BEP level" system (e.g.,"Elbow Flexor") AND one dimension of performance (e.g.,"Speed")
PERIODIC TABLE of ELEMENTS
Monadology (Leibnitz): Finite Set of Basic Elements
TABLE of HUMAN BASIC ELEMENTS of PERFORMANCE (BEP)
Life Sustaining Elements
Environmental Interface (sensorimotor) Elements
Central Processing Elements
Information Elements

GSPT & The ERM – New Candidate Frameworks to Facilitate Tough Systems Engineering Processes..



FURTHER PROGRESS REQUIRES ADOPTION of *SOME* UNIFYING FRAMEWORKS..



CONCLUDING COMMENTS

- GSPT & The ERM Provide Powerful, New Constructs for System/Task Characterizations
- Applicable to Many DoD-Related Challenges:
  - System Performance Quantification
  - HSI (Design, Modeling, etc.)
  - DoDAF (Human View as well as *All* Systems)
- No Other Competing Frameworks that Attempt to Address the Same Issues Known to Exist (Any others? Inputs welcomed.)
- Vetted and Endorsed by One Major Group (DSOC HSI Task Force)

Thank You!

SOME REFERENCES

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