

HISTORY AND FUTURE OF “SYSTEMS”

E --> SE --> GUTSE --> ES

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What I believe:

- Both Systems Engineering and Engineering Systems are evolving**
- The domain of Engineering Systems is broader than presently planned extensions of Systems Engineering**
- Systems Engineering and Engineering Systems must work together symbiotically**

Also:

Language is humanity's most distinctive tool

Mathematics is imbedded within language and

-- covers a far smaller domain, but

-- provides greater rigor and trustworthy generalizability

Evolution of System Engineering's Standard Model

Early 1960's: GJF was "chief of systems engineering" at Northrop

Scope: requirements to subsystem specifications, only

Complaints by the manufacturing world; transition to production

Later, complaints by the maintainability, logistics world

Rebellion of the "-ilities" – the specialties, configuration mgt..etc

Life cycle philosophy taking hold; contracts rarely responded

"Womb to tomb" evolved further to "Lust to dust"

In 1994, GJF's year as INCOSE president, no Risk Mgt in taxonomy

Even in 2004, EIA 632 has risk as lower issue

SE standards, guides, codes, manuals still captured by "processes"

SE education deals with far more language than technology

SE still has not attained the respect of the traditional ME, EE,..

"Lessons learned" have become "lessons forgotten"

As the experience base retired, the expertise was lost!

Yearning for Completeness

Most engineering is applied technology based on scientific research
Science's spirit is to focus on tiny, dimensionally restricted domains
That's a very practical strategy to study basic phenomena and
develop trustworthy models of the world

Many technologists and engineers carry this spirit to their designs
BUT the spirit of systems engineering is to strive for *completeness*

GJF's personal history: ask the *why* of the requirement

As manager of B-2 avionics, drove nav, radar, weapons designs
based on detailed ops analysis and modeling of scenarios

As investor and developer of new technologies and systems,
performed detailed studies of operational environments and
alternative technologies and systems concepts, not merely
responding to "customer requirements"

Beyond SE#1:
Interacting worlds of Energy, Economics, Environment

In early 1950's, GJF worked on a *highly complex* power plant, containing over 10^6 parts: *no problems!* (proven designs)
DWP had no vision of the need or utility of renewable energy
GJF wanted to start a solar power research group, was told:
“as young as you are, you will always see the price of oil to be far less than the R&D and production costs of solar power.”

A needed analysis that goes beyond present systems engineering:

The bare costs of oil in \$/barrel are readily measured

What about assessments of the additional costs of oil:

- costs of protecting the supply, including at least:
- costs of Gulf War I and II, 9/11, Homeland Security, Afghanistan
- costs of environmental and health hazards
- costs of economic disruption when demand approaches supply
- economic stimulus of new technologies and *exporting* energy

Beyond SE#2

Planetary Defense Against Comets and Asteroids

In the mid-1990's, GJF chaired AIAA's planetary defense committee

The science was superb: Astronomers, Geologists, Paleontologists and Atmospheric physicists working a new *interdisciplinary* area.
A quantitative conclusion: prob(billion casualty strike)~ 10^{-6} /year
Spacewatch program: 5% to 55% detection of NEOs in a decade

However, the systems engineering was awful:

Premature decomposition into detection and intercept teams

Arguments regarding the size of the NEO, Comets vs Asteroids

Arguments regarding accuracy and time-to-go (detect to strike)

-Intercept folks: the detection folks will provide p(hit)

-Detection folks: the intercept folks will provide system in time

Investment priority: >100:1 in favor of detection

Who's in charge (of research, planning, command and control...)?

Beyond SE#3; Overarching Strategies

Constitutional Philosophy:

Democratic, Free Enterprise

worked!

World War II

Massive conversion of auto and shipbuilding industries

Low technology (except for one)/ high volume

High taxes/ shared sacrifice

worked!

Cold War

High Technology

(GJF sent to von Braun at ABMA, not to Korea)*

Mutually Assured Destruction (MAD)

Competitive Strategies (don't just respond, stress them), worked!

Third-World Wars

Lack of understanding: capabilities, intentions, values, problems

Cognitive Impedences

KISS: Manage complexity by avoiding it

Circuit Phobia: Force tree structure into concepts, no matter what

Specification trees: many good ideas skipped

Organizational Charts: IPT's not possible, no horiz collaboration

Data Base Taxonomy

Computational Flow Graphs

Decision diagrams

Multidimensionality:

Complete modeling requires 1000's of variables, not 7(+/-)1

Looking for the “bottom lines”, the right “angles”

Criteria-free debates:

Won not by logic and facts, but by force of personality

Research Directions

Engineering Systems considers “technologically enabled” complex systems. What drives modern complexity more than the enabling technologies of computer science and software? Why not employ them as a tool to *manage* complexity as well?

GJF’s research agenda:

Graph Theory for managing multidimensional math models

Decision Theory for quantitative risk management

Portfolio Theory for new technology investments

---> leading to “GUTSE”: Grand Unified Theory of SE

The quest for unification is centuries old:

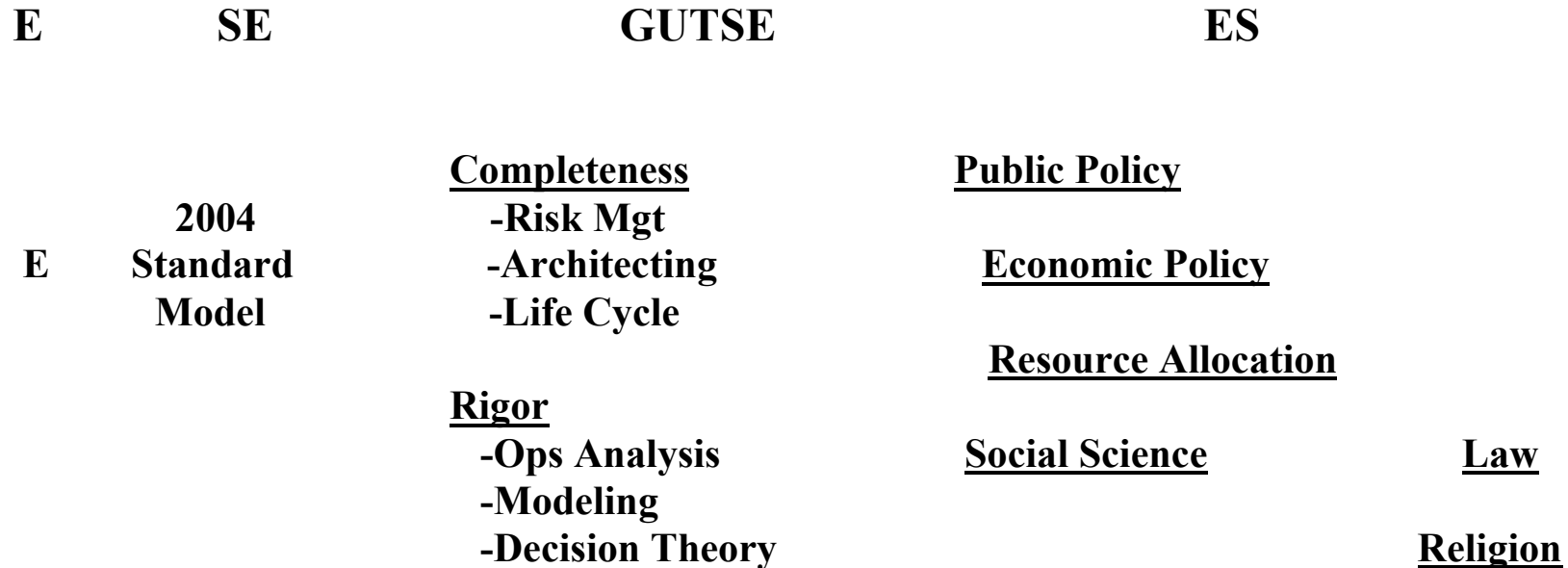
Newton: laws of motion and gravity the same in heavens as on earth

Descartes: unification of the left and right brain mathematics

Maxwell: unification of electricity and magnetism

Einstein: unification of matter, energy, space, time and gravity

DYNAMIC SYSTEMS VENN DIAGRAM



DEFINITIONS:

- E:** Traditional engineering disciplines of ME, EE, etc
- SE:** Systems Engineering Standard Model in 2004: INCOSE, EIA 632, etc
- GUTSE:** Grand Unified Theory of Engineering: SE + ops + modeling + decision theory, etc
(Expands SE into domain where math methods and computer science apply)
- ES:** Further expands SE and GUTSE into all domains and disciplines influencing the system

Conclusions

The domain of Engineering Systems is broader than that of Systems Engineering – extended, and is necessary to manage present and future problems in complexity.

SE and SE-extended, working symbiotically, can become more rigorous, providing more trustworthy results and greater acceptance by industry, government and academia.

The outer boundaries of ES represent disciplines which are embedded in language, rather than mathematics or logic. A concern is that, as the domain expands, it will become more dilute and difficult to generalize effectively.

Disciplines of SE—extended, such as GUTSE, can offer a stabilizing intermediate step towards the broad acceptance of these methods.

