From the Complex Systems Engineering Series:

A Brief History of Systems Engineering

(or, how in the heck did we get here?)

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In the Beginning…….

- The origin of systems engineering is disputed, but it surely evolved out of necessity.
  - *The complexity of the entities and projects increased*
  - *The technical depth and necessary specialty know-how increased*
  - *The breadth of types of technical know-how widened*
  - *The need to communicate and coordinate amongst a wide variety of people (no one person had sufficient knowledge)*
- The term, “Systems Engineering”, is relatively new (since the 1940’s [1] [2]), even though the art of systems engineering is much older.
- The discipline and science of systems engineering as we know it today is relatively recent (1990’s), and owes a lot to NCOSE/INCOSE [2].

Modern Systems Engineering

- Several aspects made the discipline and science of modern systems engineering possible.
  - *A well-defined, common vocabulary*
  - *Documented standards and guidelines*
  - *A coherent set of processes that are documented*
  - *Tools and methods able to implement those processes*
  - *The use of models to develop, test, and communicate system concepts*
  - *An educational program in various institutions that offers a specialty in systems engineering*
  - *A method to certify or qualify systems engineering professionals*
- INCOSE has been instrumental in all of these, and they have been in place only in the last few years. [1] [3]

The Rapid Evolution of SE: 1940 to 1995

- Driven by the need to develop and field complex, highly technical systems.
  - *Manhattan Project*
  - *Military systems (large ships, aircraft, missiles)*
  - *Space systems*
  - *Computer hardware and software*

- Talented individuals, enlightened companies, and even the government forged their way through the complexity. They invented *ad hoc* standards, methods, and tools as they went.
  - *Discipline and repeatability were a problem*
  - *Education and written processes were lacking*
  - *Varied considerably across the country, and the world*

The Rapid Evolution of SE: 1940 to 1995 (cont.)

- The term “systems engineering” dates back to Bell Telephone Laboratories in the early 1940s [2] [4]
- WWII was a major driving force behind the need for “systems engineering”.
- Hall [1962] asserts that the first attempt to teach systems engineering as we know it today came in 1950 at MIT by Mr. Gilman, Director of Systems Engineering at Bell. [5]
- TRW (now a part of Northrop Grumman) claims to have “invented” systems engineering in the late 1950’s to support work with ballistic missiles. [6]

The Rapid Evolution of SE: 1940 to 1995 (cont.)

- In 1990, a professional society for systems engineering, the *National Council on Systems Engineering* (NCOSE), was founded by representatives from a number of U.S. corporations and organizations.[1] [2]
- As a result of growing involvement from systems engineers outside of the U.S., the name of the organization was changed to the International Council on Systems Engineering (INCOSE) in 1995. [1] [2]
- In the 1970's/1980's, the energy crisis and competition from Japan forced the automotive industry to develop cars as highly complex systems.

The Rapid Evolution of SE: since 1995

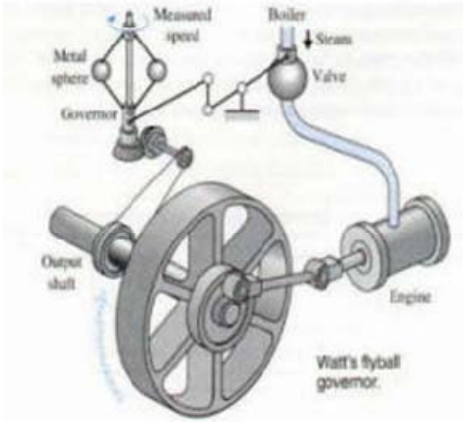
- In the last 16 years, most all commercial systems have become more complex, and technology more diverse, such that systems engineering is now essential in virtually all fields.
- More recently, medical, biomedical, and medical devices have become sufficiently complex, as well as safety-critical, that a disciplined systems engineering approach has become essential (hence the theme of this Mini-Conference).

Origins of Systems Engineering in Control Theory

- But wait! Some (including myself) would argue that systems engineering really started with control theory.
  - *It is feedback and control that makes a system a "system".*
  - *Feedback causes complexity, and leads to emergent behavior.*
  - *Scientists and engineers have been working with control theory since the 1800's (even though the terminology was different)*

Brief history of Automatic Control (through Years)

- *1868 first article of control 'on governor's' –by Maxwell*
- *1877 Routh stability criterien*
- *1892 Liapunov stability condition*
- *1895 Hurwitz stability condition*
- *1932 Nyquist*
- *1945 Bode*
- *1947 Nichols*
- *1948 Root locus*
- *1949 Wiener optimal control research*
- *1955 Kalman filter and controllability observability analysis*
- *1956 Artificial Intelligence*
- *1957 Bellman optimal and adaptive control*
- *1962 Pontryagin optimal control*
- *1965 Fuzzy Set Theory; Fuzzy Control*
- *1972 Vidyasagar multi-variable optimal control and Robust control*
- *1981 Doyle Robust control theory*
- *1990 Neuro-Fuzzy*



Buddha was the First Systems Engineer

- But wait! The origin of systems engineering can be traced to Buddha.

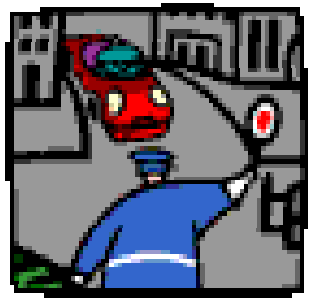
- The historical Buddha lived from 563 to 483 BC (this is actually uncertain, since this was pre-historic times).

Buddha was the First Systems Engineer (cont.)

- Anil Rajvanshi makes a case for the very first philosophical awakening to systems engineering. [7]
  - *"Does an enlightened individual need to remain caged in the body? Why not get liberated from the physical? For seven days, the Buddha grappled with this dilemma. In the end, he decided that* ***there was nothing personal about enlightenment*** *- the knowledge should be shared with all for the benefit of humankind. He spent the next 50 years doing just that, and all those who listened to him benefited greatly."*
  - *"It is necessary for all of us to discover truth (understand the system, build a model of the system, define interfaces, and interactions with other systems), but once we find it, it should be shared freely with others (specs flowed down, ICDs generated, share with others an understanding of how the system should work). This will not only provide more insight, but also foster peace and happiness (successful and effective systems). The desire to share our discoveries with the world is normally fuelled by greed (ego) for either fame or money. Very few are selfless enough to share their discoveries freely for common benefit (but this comes as second nature to a systems engineer)."*
  - ***Buddhist Proverb: "When someone shares something of value with you, and you benefit from it, you have a moral obligation to share it with others."***
- And thus "systems engineering" was born!

Buddha was the First Systems Engineer (cont.)

- The detailed specialists (mechanical engineers, electronics engineers, software engineers, etc.) attain inspiration and enlightenment, but…….
  - *It's a unique in-body experience that specialists tend to internalize*
  - *Can produce very good designs, but not necessarily good systems*
  - *Typically not communicated to, and not coordinated with, others*
  - *Has not worked well on complex systems, unless the detailed specialists are managed and coordinated by a systems engineer*
- Systems engineering is all about sharing, communicating, coordinating, and optimizing (all out-of-body)



Buddha was the First Systems Engineer (cont.)

- The key points here are:
  - *The universality of enlightenment, and the problems of keeping it within you*
  - *The concept that great improvement and success can be obtained by many people openly sharing their "enlightenment"*
  - *The systems engineer's intrinsic need to communicate and coordinate his own "enlightenment", as well as that of others, for the overall success of the system*
  - *"Greed" (ego) is an impediment to successful systems*

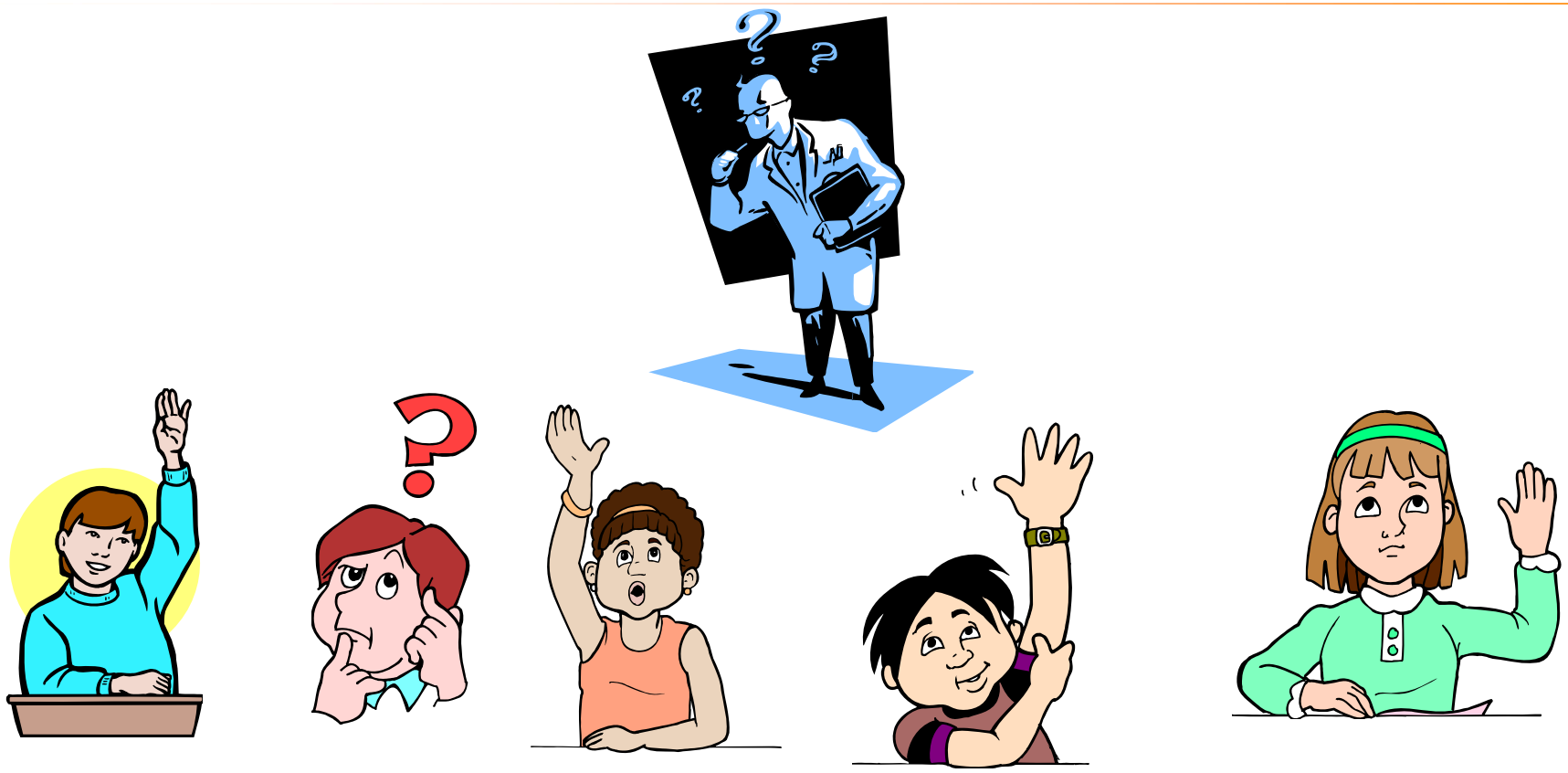
Buddha was the First Systems Engineer (cont.)

- Halverson's First Axiom on Systems Engineering:
  - *"If the detailed specialists could see the big picture, and were able to communicate perfectly, there would be no need for systems engineers."*
- Halverson's Second Axiom on Systems Engineering:
  - *"Except for Buddha, all people are born as either detailed specialists (an inch wide, but a mile deep), or as systems engineers (a mile wide, but an inch deep)."*
- Halverson's Third Axiom on Systems Engineering:
  - *"You can't train a detailed specialist to become a systems engineer, and vice versa. These are intrinsic traits you are born with."*

Conclusions

- The real novelty here, and the point of this whole presentation, can be summarized as follows:
  - *There has always been a need for systems engineering*
  - *Complexity, technical diversity, and the need to involve many experts leads to the need for systems engineering*
  - *It is only recently that we have had a name for it*
  - *It's all about communication!*
  - *It is the moral thing to do*

Questions?



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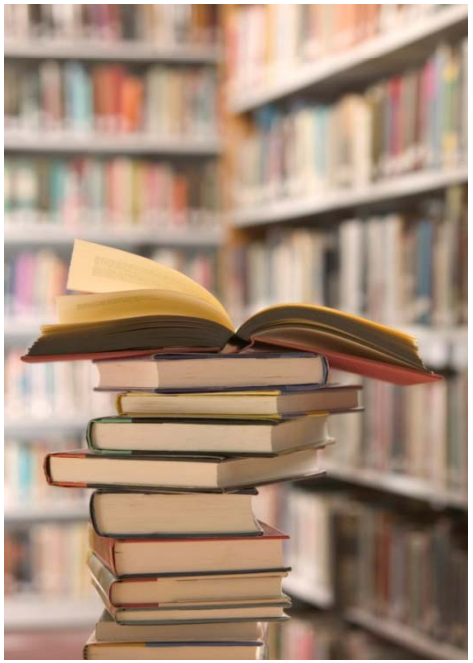

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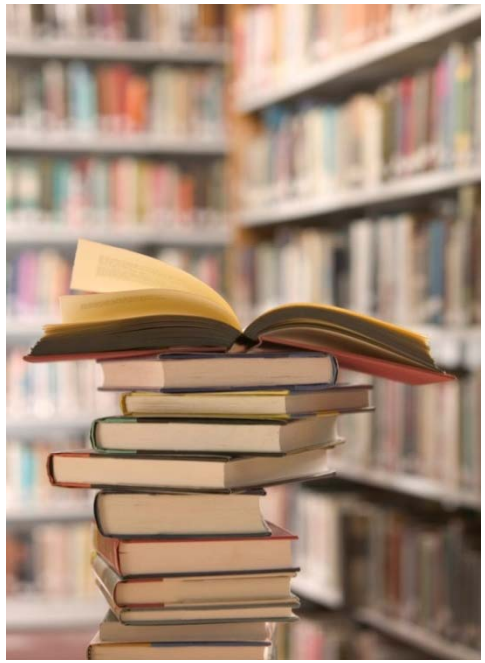

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