Human Systems Integration (HSI)

"Plants, Tombs, Bulldozers, Bits & Brains"

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Good Evening! The goal of tonight's talk is to look at HSI from some different perspectives, have some fun and end up in a discussion.

One approach I considered for this evenings talk was to develop a future vision and discuss what technology is needed to realize that vision. For example, we might look at the HSI on the bridge of the star trek "Enterprise". "Spock" could have a "natural language" conversation with a knowledge base computer. However, instead of that approach, I have chosen to first look back into the past to obtain a different framework to look at the evolution of complex systems and explore how humans were integrated with these systems, second I have looked back on my past 30 plus career in submarine and undersea warfare systems research, development, and test evaluation and make six (6) HSI observation and third I will ask some of you to present your vision for future systems and HSI.

After writing the following section on the history of systems evolution I rewrote my definition for a system.

First PowerPoint slide please!

HUMAN SYSTEM INTEGRATION
"PLANTS, TOMBS, BULLDOZERS, BITS & BRAINS"
SYSTEM DEFINITION*

A SYSTEM OPERATES ON A SET OF INPUTS TO PRODUCE A SET OF OUTPUTS THAT ACCOMPLISH A SPECIFIC PURPOSE AND A SET OF OBJECTIVES.

IT HAS A SPECIFIED BOUNDARY AND ACCOMPLISHES ITS OPERATION WITH A SET OF LOGICAL AND PHYSICAL COMPONENTS

- **ORGANIATIONAL STRUCTURE AND ARCHITECTURE**
- **PROCEDURES, PROTOCOLS AND RULES**
- **MACHINES AND TOOLS**
- **HUMANS**
- **KNOWLEDGE BASE**
  - **DATA AND CONTEXT**
  - **MODELS AND DESIGNS**
  - **ASSUMPTIONS**

OPERATING IN A LOGICAL AND PHYSICAL BACKGROUND ENVIRONMENT

***HUMAN DEVELOPED SYSTEM**

Slide / Figure 1.

Please quickly read through the definition. Does anyone see anything they want to comment on? **COMMENTS/QUESTIONS**

I would like to make a few additional points (**if they have not already been made):**

- How one defines the boundary of the system is important.
  - What is part of the system?
  - What is part of the external environment?

- I have included humans, both operators and decision makers, as part of the system.

- Every System has a purpose and set of specific objectives, whether written down or not. Communicating the purpose and objectives is critical to the successful project development.
- Try to visualize the components of the systems as in we discuss the evolution of systems over the next few minutes.

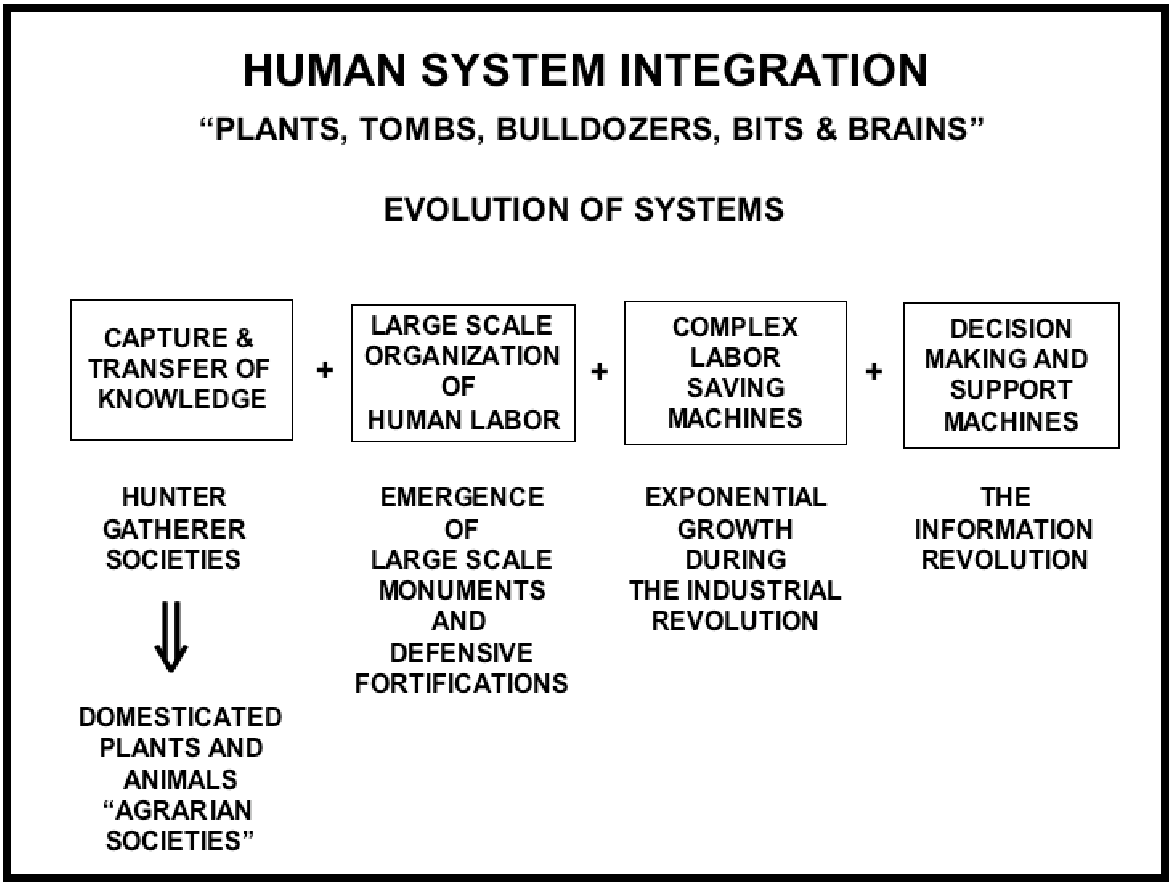
Please extinguish the first PowerPoint chart (figure 1).

Humans ------ that is Homo Sapiens------- have had our modern level of intelligence for more than 40 thousand years. Research, in the 1950's, on some of the last stone age tribes in New Guinea showed that a stone age adult could identify 1,500 different plant species and know their food value, medical value and toxic properties of each plant. Over the years these "hunter gather" tribes had developed a stable system of knowledge capture, and knowledge transfer from generation to generation.

Roughly 11,000 years ago in the Fertile Crescent, the first plants and animals were domesticated and "agrarian societies" were born. As these domesticated food packagers propagated further away from the equator calendars were developed that aided in planting seeds at the proper time.

Agrarian societies allowed humans to settle at one location, develop town and cities, accumulate significant wealth developed significant organizational structures and become builders of large monuments and defensive fortifications. The first department of defense (DoD) was then established.

Could we please have the next PowerPoint slide (figure 2)!



Slide / Figure 2.

The construction of the Egyptian Pyramids was started in the 27th century BC, that is roughly 4700 years ago. They provide an example of humans developing a complex system comprised of: design processes, work processes and procedures, a multi-level hierarchical organizational structure and logistics to support the large work force required to construct these large monuments. We believe the machines and tools, this integrated work force employed, remained fairly simple.

Today, as we look at the Pyramids of Egypt, and the other great prehistoric monuments around the world we wonder: "How did they ever build these structures?" The answer is: the system that were used to design and build these monuments had complexity in the organizational structures and processes but not in the machines and tools. Speaking of HSI, you might not have wanted to be one of the humans that were integrated into these labor systems.

The next evolution of systems came with the development of complex mechanical machines. These machines saved large amounts of human labor, allowed humans to build "things" at a much lower cost and allowed humans to do "things" that could not be previously accomplished. Mechanical machines flourished during the industrial revolution. The railroad transportation system is an example of a complex mechanical system that allowed humans to accomplish "things" that could not previously be accomplished. Distances were shortened, with respect to time, and large amounts of product could be rapidly moved. These systems again depended on complex organizations, processes and work procedures, and the development, captured and transfer of knowledge bases. However, many of the mechanical machines took on their own identity. Locomotives and steam shovels had names painted on them. Locomotives and steam shovels had names painted on them. The machines were seen as systems in themselves and humans the masters of these machines.

As a footnote, the integration of humans and these mechanical machines has a history of abuse and blood.   This fostered the technical disciplines such as safety engineering and ergonomics. Large human forces were catapulted by the complex systems, such as textile mills, that resulted from the capability to develop complex mechanical machines. Large human forces were captured by complex systems, such as textile mills, that resulted from the capability to develop complex mechanical machines. What kind of pyramids would the Egyptians have built if they had had a fleet of bulldozers?

The emergence of electrical and electronic technology during the late nineteenth century and early twentieth century drove the development of:

- Long range communication systems
- Remote sensing (radar, sonar, etc….) systems
- Digital computing machines

These capabilities formed the core of modern command and control systems and decision making and decision support machines.

The sum of the four punctuated evolutionary steps in complex system development shown in the slide (figure):

- Knowledge development, capture and transfer
- Large scale organization capabilities to focus labor
- Complex mechanical machines to save labor and extend human capabilities
- Complex electrical and electronic machines resulting in decision making and decision support systems.

gives we human's great systems capability. However, with all this, we have less than the desired capability to interact and integrate with these machines. How many of you humans are satisfied with the human system interface on your personal computer? Please, a show of hands!

Nobel Laureate Michio Kaku in his 1997 book "Visions: How Science will Revolutionize the 21st Century" makes the case the airport toilets have more intelligence that your personal computer. His point is that coupling a simple IR sensor and simple processor together allows this device to make a decision to flush the toilet where your computer just sits on your desk unless you, or some other human, take action.

This brings us to a key point of discussion about HSI: The point is automation!

In designing systems a key decision is, what functions do we allocate to machines and what functions do we allocate to humans. We will discuss this in the next section of this talk.

Next PowerPoint slide (figure 3), please.

HUMAN SYSTEM INTEGRATION
LESSONS LEARNED

- DEFINE AND SPECIFY HUMANS AS PART OF THE SYSTEM
- SPECIFY, DESIGN AND TEST THE SYSTEM WITH A TEAM OF HUMAN USERS/ENGINEERS/COGNITIVE PSYCHOLOGISTS
- DEVELOP A FULL UNDERSTANDING OF THE ENVIRONMENT IN WHICH THE SYSTEM OPERATES. ITS PHYSICAL AND LOGICAL (TEMPORAL & SPATIAL)
  - COMPLEXITY
  - VARIABILITY
  - UNCERTAINTY
- DEVELOP A FULL UNDERSTANDING OF THE OBSERVABILITY OF THE KEY SYSTEM PARAMETERS.
- DEVELOP A FULL UNDERSTANDING OF THE EMBEDDED ASSUMPTIONS
  - MODELS
  - AUTOMATION
  - DECISION PROCESSES
  - TRAINING
  - OPERATOR PROFICIENCY
- TEST THE SYSTEM OVER THE FULL SPECTRUM OF OPERATIONAL SCENARIOS, ENVIRONMENTS AND HUMAN BEHAVIORS.

Slide / Figure 3.

These six points summarize the top level lessons learned from my 30 plus year career in submarine and undersea warfare sensor, combat control and weapon system development and evaluation.

The first point has been already discussed to a degree. During the conceptual phase, of a system development, it is important to specify not only what functions and tasks will be performed by humans, but also the educational level, training level and proficiency level required by both the machine operators and the decision makers, who are part of the system.

The second lesson points to the need to appropriately include users in the engineering design team. Although this may seem obvious to most of you today, twenty five years ago many of us were learning this lesson the hard way. I also find that this point is not always followed today. I also point out the need to include a cognitive physiologist on the design and test teams as we many times do not rigorously test the effectiveness and efficiency of the human machine interfaces.

Embedded in the third, fourth and fifth statements are lessons learned from successes and failures with attempts at automating decision functions that previously were accomplished by humans.

Today, humans make better quality decisions than machines, on a regular basis, when the decisions are based on incomplete and uncertain data. A little data, some "indicators," a little statistics and the human brains patterns recognition capability allows some humans to make very high quality decision with a minimal of data. Some humans are better at this than others.

Carnegie Mellon, Professor and Nobel Laureate, Herbert Simon did research on "what makes Chess Masters." He found Chess Masters had no greater average intelligence or memory than the average human on the street. However, he found that they could just glance at a chess board setup and recognize and remember the board's setup. The human off the street could not accomplish this with just a glance are the board. If the chess board was set up in a nonsense manner, the Chess Masters were on better than the human off the street. Simon attributed this to the human's brain pattern recognition capability. He also found that Chess Masters became Masters after roughly 10,000 hours of actually playing chess. He found similar situations in other areas where "experts exist." I have been able to use these results in digitizing (is that the word you wanted? I could not read it.) sonar operator performance. We need not design human machine interfaces that work well for "experts" but are not efficient and effective for the "trained operators."

Key to successful automation is an understanding of:

- The complexity, variability and uncertainty of the environment the system will operate in,
- The observability of key system parameters, and
- The explicit and implicit assumptions embedded in the system.

Recently I was reviewing some automation work where the developers were trying to provide a key result for the decision makers. The algorithm was estimating a weakly observable parameter. In order to get a good "result", the developers constrained the range of the weakly observable parameter in their algorithm to fit their development dataset. When the algorithm was tested with a new data set, the algorithm bounced all over because the data had a real world parameter value far outside the algorithm constraint. The algorithm failed the test. The developer had an algorithm the produced the desired picture for the human decision maker but was not robust over the full operating domain.

This brings us to the last point that emphasizes the importance of testing over the full spectrum of:

- Operational scenarios
- Environment, and
- Human behaviors

Lately I have seen a trend to "save money" and be more efficient by cutting out stress testing of the system. A case I recently reviewed resulted in system problem getting into the Fleet requiring rework and retest. Rework and retest doe not save money!

Finally we are seeing the rate of technology being absorbed by society, grow at an expediential rate.

- "Moore's Law" implemented by the semi-conductor industry gives us more and more affordable computing power.
- Display technology gives us almost unbounded rendering ability.
- Low cost sensors are becoming more prevalent in many systems
- Research is being conducted on self organizing systems
- Brain activity imaging technology provide us new understanding of how the human brain works.

Given the rapid pace of technology growth and absorption into society, given the papers presented and discussions you have had during this conference, given that most of us are not satisfied with how we interact with machines, what is the HSI vision for the future?

I expect there are many valid visions, that to some degree depend on what problem area you are working on.

Who wants to present his or her HSI vision?

As a post note, three key points or themes came out of the discussion of "Visions."

- We are making evolutionary improvements in the human machine interface. For example, there are tablets/pads that allow humans to write cursively and the computer recognizes the writing with a fairly low error rate.
- Research into direct brain-computer interaction could lead to a revolutionary change in the human-computer interface.

- What will be the fifth (5th) box in the second PowerPoint chart (figure 2), "Evolution of Systems?" Engineering biological systems? Weather control systems? Complex automation and robotic systems?…