**Innovative Conceptual Engineering Design (ICED) - The Seven Themes**

A short list of key ideas or themes which are critical to innovative design were developed and captured as easily recognizable icons which the faculty and lecturers could refer to and help integrate throughout the lectures and sessions to positively reinforce and provide relevant examples of how these themes were/are used in real projects (Fig. 6).

The first theme was borrowed from a colleague and well respected expert in structural dynamics, Dr. Robert Ryan, and changed slightly: “The human mind – use it” speaks to a habit of young inexperienced engineers who may tend to dive into the numerical analysis of a problem without first understanding the physics. Very simple models should be tried first to establish this preliminary understanding and to assess the important or key parameters to ensure the physical understanding, simple model, and observed behavior all agree. The mind’s ability to use experience and judgment to correctly formulate the problem together with realistic assumptions and boundary conditions is critical and will serve to better understand more rigorous and complex representations and to determine if errors exist.

The next theme, “arrogance is the enemy of creativity” was touched upon earlier and one of the most serious impediments to creativity and should be recognized and avoided at all costs. Highly competent teams should avoid crossing the line and becoming arrogant because this will limit acceptance of new ideas, learning, and prevent objective criticism/review of one’s own ideas and those of the team! This is directly related to the next theme: “understand the mechanisms of failure.” Professor Henry Petroski (ref. 15) links good design as one that “obviates failure” by adequately addressing potential failure mechanisms early in the design process. If you understand and can visualize potential failure mechanisms early enough in the design it will open up avenues of new ideas to simply and elegantly address and eliminate these modes of failure from ever occurring. Studying the histories of past failures of similar or analogous systems provides a starting point for this critical analysis.

The next theme is “failure is not an option…it is a requirement.” In contrast to the popularized Mission Operations Directorate (MOD) of the movie “Apollo 13”, while failure cannot be tolerated for operational vehicles, failure is a necessity for research and development. Discovery and innovation go hand-in-hand with failure and failure to permit failure impedes exploration, discovery, and innovation. We learn so much more from our failures and, in fact, success may actually increase the chances for failure. Dr. James Starnes often stressed the importance of understanding all failure modes and of testing to failure to corroborate and verify analysis. An environment must be ensured that allows engineers and scientists to experiment/tinker, fail, and learn. Dr. Jack Matson calls this “intelligent fast failure” (ref. 12).

During the course of the design cycle teams will have to pan out and view the problem in its entirety and at the same time be able to zoom in and rigorously look at critical details to understand key local as well as global failure modes. This ensures that a true “systems” approach is always taken. When working on one detail or component of the whole system, the designer has to step back and assess how the detail changes affect the whole system. It is crucial that a good systems engineer can recognize when highly rigorous, detailed analyses, and experimentation is necessary to ensure the true representation of a complex behavior!

When pondering the problem, it is often necessary to allow time for ideas to incubate, gel, and morph and allow non-linear patterns and cross pollination. The teams were given idea journals to use throughout the course to jot down and sketch any thoughts or ideas.

The final theme is that everyone is creative and has the ability to enhance their creative potential. In addition, the creative quotient of a team can be enhanced. Good groups/teams can become “great groups” (ref. 6).



Figure 6. – Innovative Engineering Design Thematic icons.

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