30th Annual INCOSE international symposium
Cape Town, South Africa
July 18 - 23, 2020

Systems Engineering Evidence in Commercial Kitchens

James R. Armstrong
Stevens Institute of Technology
400 Wildberry Court
Millersville, MD 21108
410 987-1267
jimarmstrong29@aol.com

Abstract. INCOSE has expressed interest in the application of systems engineering principles and practices in industries outside of the classic aerospace, communications, and other large system developments commonly related to the discipline. In this case, a visit to the kitchen at the Inn at Little Washington triggered thinking about how and why it was so different from other commercial kitchens. The resulting analysis of how systems engineering has significant relationship to the design of a wide variety of commercial kitchens is provided in this paper. The objective is to learn how we can see systems engineering in places it isn't normally found to both find other ways it can be applied and to help others improve their results by using systems engineering discipline.

The Trigger

The development of this topic begins with a gift certificate to the Inn at Little Washington in Washington, Virginia. The Inn's restaurant had just received its third Michelin star. As one would expect, the meal was outstanding. However, for a long time systems engineer, the highlight was a visit to the kitchen. It should be noted that the Inn has an option to eat at one of two tables in the kitchen. Having seen or visited more than a few commercial kitchens including earned a large part of college tuition in one, this option didn't seem very appealing. However, the actual facility, Figure 1, is quite different from other restaurant kitchens. Not only the visual difference were interesting, but also the efficiency of the layout and how it was specific to this particular situation initiated some thought about how the design reflected several of the practices that we consider basic to systems engineering. This, in turn, raised the question of how they might be applied to other commercial kitchens. Indeed, they appear to do so. This connection should help with the general desire of INCOSE to see how systems engineering applies to industries other than those considered the historic home of the discipline

Figure 1. Inn at Little Washington Kitchen (The Inn at Little Washington, 2019)

The Basics Applied

Systems engineering activities and thought processes definitely have their place in this arena. Although the designers do not use the specific vocabulary or necessarily have the defined process spelled out in the INCOSE Systems Engineering Handbook (Haskins, C, 2007), they have the same concerns in one form or another. Before addressing specific instances, a short review is presented here of how they apply. Later, several examples of each will be provided as part of the following discussion of various types of kitchens.

Concepts. Each kitchen design must start with the concept of operations which will address the kind of business will it support and several other questions such as the type of food will it prepare. The solution will vary dramatically depending on whether the operational concept is fast food or fine dining. Steak houses are different than vegetarian restaurants. An extensive menu will have a different design from one that is limited or focused on a particular style or ingredient. While we tend to think of truly commercial kitchens in restaurants open to the public, some commercial kitchens serve a specific private clientele. A kitchen may be a standalone operation or be part of a larger system. These are only some of the operational considerations that will influence the ultimate solution.

Functions. The basic functions of the kitchen are obviously food preparation. As with any system, they will vary significantly depending on what the answers are to the operational concept related questions. For instance, a standalone kitchen will take in raw materials and focus on all facets of preparing the meals. On the other hand, if there is some form of central kitchen producing pre-cooked items, the focus may be on storage and reheating.

Requirements. The requirements are driven by all of these plus business factors. Type of food prepared, volume of business, customer preferences, and environment will be among the primary drivers as well. Regulations, particularly health and safety, will be included in the requirements. Cost will definitely be a consideration in the design.

Models. Modeling is often done by drawings of the layout. However, other forms of modeling may be applied for specific considerations such as workflow. In some instances, the modeling is by way of a mental model discussed by the architect and users to identify specific workflow issues related to placement of various work centers.

Architecture and Design. There is a wide spectrum of layouts and design approaches available to the commercial kitchen designer. Several of these will be discussed in the examples that follow. One basic architecture trade of alternatives is whether the layout will focus on work flow, functional zones, or an island configuration, Figure 2. Of course, multiple considerations will be addressed in the final layout, but one or these alternatives may well drive the design.

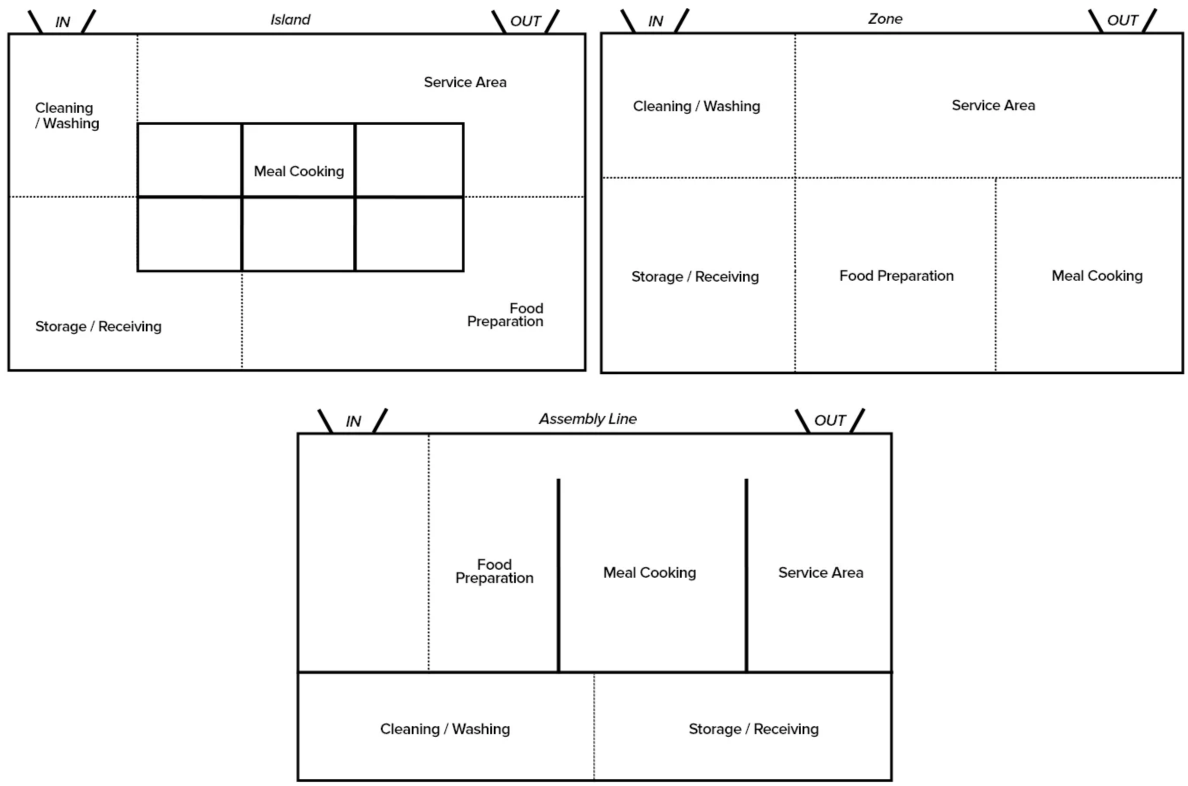

Figure 2, Island, Zone, or Assembly Line architecture alternatives (WebstaurantStore, 2019)

Integration. Integration exists not only among the internal components but with external factors such as the wait staff, supply chain, maintenance, and the overall environment. Human interfaces with the staff are also very important in these environments. As with any facility, the integration of various disciplines such as mechanical, electrical, heating and cooling, lighting, etc. need attention.

Verification. Part of verification is meeting the requirements of the construction contract as well as the various regulatory inspections that may be required. Of course, the ability of the kitchen to produce the quality of food the owner or chef intends to offer is often a critical factor that the owner and customer will verify through usage.

Validation. One might consider validation, particularly final validation, is performed by the customer in most commercial situations. Are they happy with the product and is the facility profitable.

To provide more specific relationships, we will look at a variety of different kitchen applications and discuss some examples of how they relate to systems engineering.

The Inn at Little Washington

The Inn at Little Washington *A Magnificent Obsession* (O'Connell, 2015) chronicles the history of the hotel and restaurant. The restaurant started in 1978 in what had been an auto repair garage with a dance hall above it. Over the years, it has been completely modified to add lodging and significant interior design changes to become the present establishment.

Figure 3. Evans designed dining area and guest room (The Inn at Little Washington, 2019)

One of the critical points in this history is the collaboration with the London-based interior designer Joyce Conway Evans. Her concepts have given the Inn a distinct feel that provides an excellent atmosphere for the dining experience, Figure 3.

There are those who believe that operational concepts are written in stone and do not change. While that isn't really the case in most systems, it isn't here either. Over the years, the Inn has gone from just being a restaurant to having guest rooms and acquiring additional properties for accommodations, ballroom, garden, and gift shop. The dining operations have evolved to the current focus on gourmet dining. The customer has three multi-course menu options to choose from including one vegetarian menu and can switch from one to another as the courses proceed, Figure 4. While the selections are limited relative to most restaurants, the focus is on having something expertly prepared that you probably won't have at home. Located 70 miles from the center of Washington, DC, The food and service has to be excellent to attract customers.

THE GASTRONAUT'S MENU

Amuse-Bouche

A Tin of Sin:
*Imperial Osetra Caviar
with Peekytoe Crab and Cucumber Rillette
L. Aubrey Fils, 1er Cru, *Jouy-les-Reims, Champagne, France (N.V.)*

*Carpaccio of Herb-Crusted Elysian Fields Baby Lamb Loin
with Caesar Salad Ice Cream
Domaine Maubernard, Rosè, Bandol, France (2018)

Seafood Sausage with Tomato-Tarragon Butter
La Vizcaína, La Del Vivo, Bierzo, Spain (2016)

*Blackened Heart of Wagyu Ribeye
with Grilled Romaine and Bone Marrow Custard
Avennia, Syrah, Arnaut, Bouchey Vineyard, Yakima Valley Washington (2016)

•••

A Lilliputian Mandarin and Vanilla Dreamsicle

Our Chocolate-Hazelnut Mousse Napoleon
Toro Albala, Pedro Ximénez, Don PX, Gran Reserva Montilla-Moriles, Spain (1990)

-or-

A selection of cheese from Cameron, our "Cheese Whiz"

THE GOOD EARTH
OUR VEGETARIAN CREATIONS

Amuse-Bouche

Sweet Pea Panna Cotta with Baby Radishes, Snow Peas
and Chilled Pea Flower Consommé
Alfred Merkelbach, Riesling, Auslese, Ürziger Würzgarten, Mosel Germany (2016)

Our Garden Green Bean Tartare with Tomato Vinaigrette
Alzinger, Riesling, Hollerin, Smaragd, Wachau, Austria (2016)

Summer Vegetable Raviolis
with Roasted Sweet Corn and Chanterelle Mushrooms
Pahlmeyer, Chardonnay, Napa Valley, California (2017)

A Filet of Beet with Creamed Spinach, Pomme Soufflé
and Beurre Rouge
G.D. Vajra, Dolcetto d'Alba, Coste & Fossati, Piedmont, Italy (2017,

•••

Global Warming

A Lemon Tart Reincarnated
Domaine des Baumard, Quarts-de-Chaume Loire Valley, France (2012)

-or-

A selection of cheese from Cameron, our "Cheese Whiz"

Figure 4, Sample menus (The Inn at Little Washington, 2019)

The Kitchen. The overall story of the Inn is quite interesting and includes several systems engineering related activities such as the tradeoff of various approaches to adding a foundation to the original building after modifications had already been made to turn it into the inn. However, the focus of this paper is the kitchen.

Concepts. The basic concepts of restaurant operations apply to the Inn. The principal differences relate to the focus on providing a gourmet dining experience. Additionally, the kitchen needs to support the operations of the Inn and be open 24/7. While the main gourmet dinner menu is limited, other uses expand the needed capabilities of the kitchen. And, there is the additional use as a seating area as well as tours for others dining at the restaurant. The latter activities place the visual image front and center and had a strong influence on the system design.

Requirements. The operational concepts and business intent drive the requirements for a project of this type. As with any commercial kitchen, there are numerous regulatory requirements such as fire prevention and sanitation that must be addressed. In this instance, the quality of the cuisine is a significant factor. However, the actual appearance of the kitchen and the need to integrate with the rest of the facility and the overall look and feel associated with the business was the factor most obvious to the observer. While costs are always a consideration, the market the Inn is serving provides more flexibility to spend more on a kitchen design that might be above the budget of other restaurants.

Functions. Most of the basic functionality was addressed under operations. In development of the final architecture, the cooking and preparation activities were decomposed into specific activities that are accounted for in the architecture that follows.

Modeling. The use of drawings and mental models are the closest activities to the concept of modeling in this instance. While there may have been some physical models built, a common practice in facilities architecture, there is no specific reference in the source material.

Architecture. On the functional side of the architecture, the kitchen has been designed in consideration of the functional decomposition of the overall need.

"The kitchen's workspaces are very clearly defined: One side of the range is used for hot first courses, while the other side is for main courses. There is a separate area dedicated to cold first course, and another to pastry and dessert." (O'Connell, 2015, pg. 118)

The range mentioned is a specially designed dual-sided range that sits under the canopy in the center of the kitchen. The rest of the kitchen areas sit around it and provide a flow that supports efficient operations of this particular kitchen.

On the artistic side of the design, the problem was that the usual designs were either sterile or more modern and glitzy as shown in Figure 5. These would not integrate well with the overall look and feel of the Inn. As a result, the design and interior decorations are quite different from what might normally be expected.

Figure 5. Commercial kitchen designs – typical (Jeans Restaurant Design, 2019) or for show (Fabris, 2019)

Evans' imagination differentiates this kitchen from the stainless steel appearance of most commercial kitchens. The brass and copper canopy over the range has a medieval fest appearance and the decorative treatment of the room provides a truly unique atmosphere for a commercial kitchen.

Figure 6. The view from and of the kitchen dining tables (The Inn at Little Washington, 2019)

In Figure 6, the kitchen décor can be seen from the guest dining tables which are very popular with the guests. This kitchen dining area is also in keeping with the rest of the facility and is designed to have the feel of the Windsor Castle dairy room (Nania, 2015).

An additional feature is the north side of the room which has a large window that provides light to the room rather than the closed in feeling as would be the case with a wall. Being the north side, it provides the type of light that artists seek.

Integration. As mentioned earlier, the integration into the overall design of the Inn facilities was a critical part of this design and the factor that makes it different from other commercial kitchens. The most basic integration is among the various components of the kitchen – the stove, work areas, lighting, cooling, electrical, plumbing, etc. At the next level is how the various functional areas work together including the two tables where customers dine in the kitchen. Also, the kitchen has to work well with the wait staff entering orders and delivering the product. At all levels, the human interfaces with the chefs, wait staffs, customers, and management must work well. At a more abstract level, the kitchen has to integrate with the supply chain including locally grown ingredients from the Inn's vegetable garden. This interface is also an operational concern due to the lead time should a new ingredient be desired. All of these integration concerns seem to have been appropriately addressed and successfully executed.

Verification and Validation. The real verification and validation of the kitchen is its success in producing the high quality product intended. It received high praise from the owner and most that have been able to visit it. The kitchen dining tables have become a best seller and have a dedicated clientele. While the sources haven't provided specifics on verification and validation, the success of the restaurant and its new Michelin third star are evidence of success.

While the term systems engineering would probably need to be explained to the team that created this kitchen, the concepts and thought processes were definitely present.

Other Kitchens

While the Inn stimulated interest and thought in the application of systems engineering in this area, the thinking soon progressed to variations on the theme. There are many other types of commercial kitchens that provide some examples of how systems engineering thinking may be applied. Even where the use of systems engineering may not be evident in the development, there are factors that relate to systems concepts that can be observed and used to describe the differences. Several of them are discussed below.

Fast Food. Kitchens for fast food restaurants have a significantly different concept of operations resulting in a very different design. Speed, price, quality, quantity of stores and volume of sales present a different requirements. Mc Donald's has put a lot of effort into defining a fast, repeatable process that will produce a consistent product for the customer. Early in the company's history, Ray Kroc did a form of modeling (film/book) by setting up a mock kitchen and working through various ways of performing the tasks to minimize the time spent fulfilling an order.

The initial concept, and one still often used, is to place an order and have the product quickly prepared. One variation is to prepare food ahead, particularly during very busy periods where sales are reasonably predicted. Other variations, such as observed at a Burger King on the NJ turnpike is a change in function sequence where the food is prepared and placed on selves for the customer to pick up with payment following in more of cafeteria style. While the design of the kitchen is not significantly different, the surrounding environment does change as space must be made for the racks. Also, the functionality of the kitchen staff changes since they must be aware of shortages and respond directly rather than just reacting to orders.

What's cooking? Of course, the food on the menu will dictate design. A pizzeria will have an oven specifically designed for cooking pizza oven or even a wood burning oven. Octopus is a common menu item in the Mediterranean. The octopus needs to be tenderized. This can be done by pounding it many times. Some restaurants in Greece have solved this by placing a washing machine in the kitchen and running the octopus through a rinse cycle (Papantoniou, 2019). The Din Tai Fung restaurant that many of the INCOSE International Symposium attendees in 2015 visited has a section of the kitchen at the front of the restaurant where the dumplings are prepared. This area is visible through large picture windows to people passing by and customers waiting for a seat.

Bern's Steak House in Tampa, Florida provides a slightly different example of the impact of menu on kitchen design. As the name would imply, their emphasis is on excellent steaks of various types that are "perfectly aged" (Bern's Steak House, 2019). The menu includes a matrix showing for a different steaks what you can expect if you order rare, medium rare, well done, etc. As a result of this emphasis, the kitchen is structured to provide the correct means for cooking different cuts of meat and refrigerators for meat storage receive a lot more attention than in most kitchens.

Figure 7. Bern's Steak House Specialty (Bern's Steak House, 2019)

Another difference at Bern's is the desert menu. A quick count comes to sixty-one choices, not including options for number of scoops for ice cream. Also, should you wish to imbibe in the deserts, this functionality is allocated to a separate part in the restaurant and you will be graciously moved. Between supporting the extensive selections and the difference in location, this also has an impact on the design of the kitchen.

Sandwich shops. Kitchens at places such as Subway, Quisnos, or other sandwich shops have a different allocation of functionality. The customer is more involved in the actual preparation of the order and participates in design decisions as the sandwich is assembled. In order to do this, the kitchen is moved out to the public area and uses assembly line architecture with the staff on one side and the customer on the other. There is still a prep area in the back where the ingredients are stored and prepared as well as a clean-up area. One class assignment to rethink this design (in SlideShare, viewed Nov 2019) included several potential changes to the functional architecture by both moving payment from the end to the start as some do and a larger change of allocating much of the sandwich assembly other than meats to the customer. The impact on the design is shown in Figure 8. While there are some issues with the work flow, it does show how use of functional considerations can be used in this arena and is the basis for a potential trade study.

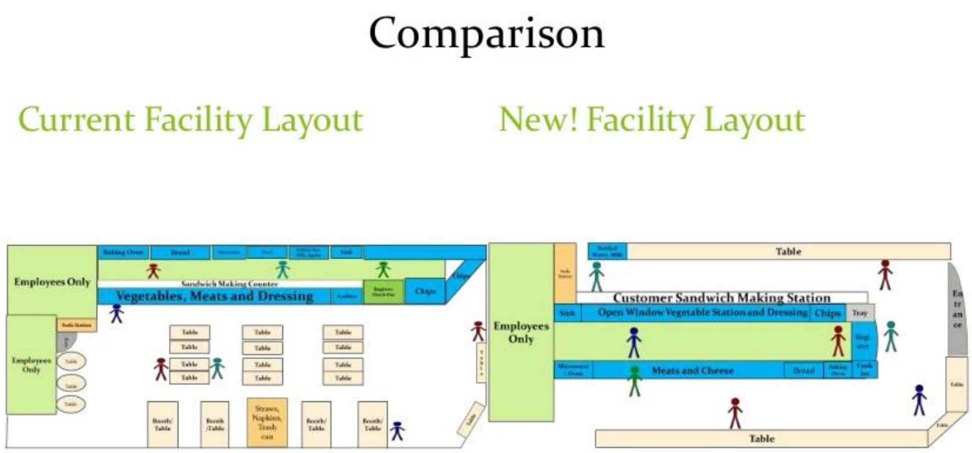

Figure 8. Subway Redesign Student Study (in SlideShare, viewed Nov 2019)

Cafeterias. Kitchens for cafeterias will be focused on preparation of food that can be presented in volume and kept warm on a serving line. The flow of activities from storage to preparation to the serving line will be of concern to the staff and influence the architecture.

Schools. School cafeterias are a special case. Factors that affect their design are whether they prepare food from scratch or there is a central kitchen that prepares some or most of the food and the local function is limited to storage and heating. The requirements for school cafeterias can vary from high level identification of functional areas and space allocations (Brailsford & Dunlavy, 2017) to specific listing of the equipment to be provided (Board of Education, October 14, 1999). The difference in these two is how much of the analysis has been done by the customer and how much is left to the architect with regard to the transition from functional to design requirements and what the scope of the trades will be. In either case, high levels of user involvement are commonly involved in such designs. For public schools, the public will also be involved either through school boards or other means. Modeling is primarily through via drawings and mental models. As with cafeterias in general, flow for both the customers and staff will be a topic of discussion as the design evolves. In one recent design, the interactions between the architect, school system managers and school staff resulted in the selection of a more square design with the preparation area centrally located between various storage areas and the serving area instead of a longer rectangular approach. This was done with both the staff and student customer experience being considered. Such interaction is a good example of the concepts embodied in validation to both clarify the stated requirements and address the impact of design options.

Hotels. There is a wide variation in hotel kitchens. Some are designed to be just large enough to prepare a light breakfast and expect the guests to find other meals elsewhere. At the other extreme are those that have to a large banquet. In between are various sizes of restaurants from small bistros to high end and most everywhere in between. Key drivers are the volume of traffic expected and the expectations of the patrons. Several hotels where guests are extended stay workers provide features such as light meals that are included in the room charge and this may be a barbeque on an outside grill.

Kitchens in motion. Going mobile on the ground, the requirements for food trucks have many of the same requirements and challenges of fixed kitchens, but also face several differences. These similarities and differences can be seen in the following suggested considerations for food truck kitchen design follows:

General design considerations:

- "Durable, non-slip, inflammable floors like commercial grade laminate or vinyl
- Proper ventilation in the form of a hood fan and roof vent, with additional windows if you can swing it
- Room for staff to move around freely while carrying hot pots and pans
- Easy access to inventory and ease of transition between workstations
- Emergency exits" (Regaudie, 2019?)

Kitchen specific needs:

- "Refrigeration and dry storage
- Food preparation area
- Grills, deep fryers, ovens, and stove tops
- Plating area
- Serving area
- Clean up station
- Handwashing station as per your local regulations" (Regaudie, 2019?)

Of course, the system must be able to withstand the motion environment as well as either to provide internal power, interface with external power, or both. And, there are various regulations that must be addressed.

Kitchens on the high seas. Cruise ships, naval vessels, or privately owned boats all have their own set of requirements for kitchens that have to operate at sea. The main difference is the addition of significant motion while underway. It was surprising at first to see in a sea trail of the Cole

Aegis destroyer that the maximum, full-speed turn test was scheduled during lunch. On second thought, what an excellent time it is to do it. During operations, this could well happen and how the kitchen handles it would be nice to know before that point.

Galleys on sailing boats have the requirement to remain stable when the boat is heeling. Figure 9 shows a gimbaled stove that is remaining vertical while the boat is heeling. Other design elements have to be added to keep pots and pans stable with regard to more dynamic wave action such as the clamps in the detail picture.

Figure 9. Gimbaled stove on sailboat remains vertical while boat heels. (Burden. 2019)

As with any fuel on a ship or boat, safety is a primary concern. Care has to be taken to prevent fuel from pooling in the hull and catching fire or exploding. A discussion of the alternatives for sail-boats is provided by Burden (2019) that explains the factors that should be included in a trade decision.

Any kitchen design needs to address storage. WWII submarines faced an environment with very limited space. As a result, the stored food everywhere, including hallways engine rooms, and showers (San Francisco Maritime National Park Association, Mar 2017).

In the air. Another mobile galley that most travelers are familiar with is in various passenger aircraft. Certainly additional requirements for safety, as well as space, weight, and power con-sumption would definitely differentiate this application. Since the aircraft manufacturers are part of defense and aerospace, more direct use of systems engineering would be expected.

Summary

This discussion was initiated by observing something quite unexpected and realizing that it had a lot of the earmarks of systems engineering thinking. This turns out to be the case for the specific instance of the Inn at Little Washington kitchen. However, in expanding the question to include commercial kitchens of various types, we find that the core concerns of systems engineering are the principal factors in the variety of applications and designs that exist. When hearing the term commercial kitchen, the stainless steel approach in Figure 5 probably comes to mind along with some nominal set of hardware. However, as we go through the list of types, we find that each design starts with the specific operational concept of what is being prepared, for whom, how much, where, in what environment, and what the business purpose is. These all drive the requirements along with various local restrictions and regulations. The functionality has to be understood and there may be alternatives that will drive the design. There are architectural and design options for trade analysis. Modeling may be more based on drawings and mental models but still exists and actual prototypes and exercises have been used. There is a lot of integration involved with both the internal and external elements and human interfaces are important. The final product must work as advertised and, in the truest sense of validation, must support a successful business. There are several areas where specialty engineering is involved such as safety, reliability, and maintainability. In summary, we see a significant relationship to the classic world of systems engineering even if it doesn't use the same vocabulary.

So what should we gain from this discussion? Its aim is to help systems engineers to recognize the discipline in other places where it is not normally talked about and be able to learn from those applications. Also, it can help in recognizing that we can better tailor our explanation of our best practices for others who could benefit from more discipline in their work. It is up to the systems engineering community to use this discussion to aid such a two-way flow of ideas for the benefit of all.

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Biography

James R. Armstrong. Jim Armstrong has practiced systems engineering for 52 years, performing various roles including configuration management, test, deployment, chief engineer, program manager, and program element monitor. For the last 30 years, he taught, consulted, and appraised systems engineering in industry and government. Also, he was on the author teams for several of the standards and models discussed in this paper. He is also certified in the use of the Meyers-Briggs Type Indicator. He has a BS in Mechanical Engineering from Rensselaer Polytechnic Institute, an MS in Systems Management from the University of Southern California, and a PhD in Systems Engineering from Stevens Institute of Technology. He has an INCOSE Expert Systems Engineering Professional certification.