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Dynamic "What-if" Modeling Simulation

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Summary

Human machine interaction (HMI) and requirements

High-level guidance

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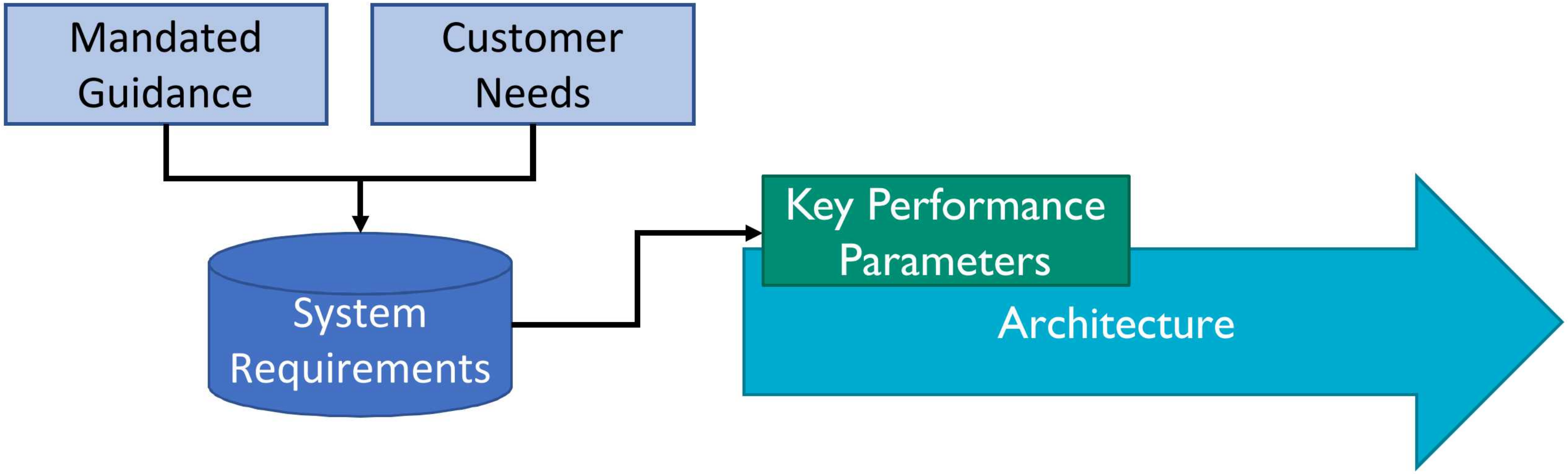
HMI and requirements - creation

The requirement creation process focuses on meeting customers needs regarding the performance of the system from mechanical and electrical aspects

Additionally, the relevant industry often demands certain mandates be observed in these requirements

The most important of these requirements focus on achieving critical performance levels for key aspects of the system (key performance parameters)

These early requirements drive the architecture and are critical to get as right as possible as early as possible



HMI and requirements - problems

It's difficult to objectively assess the role the human may play in the system at early stages for the sake of requirements and architecture determination

While important elements of the system that require HMI should be assessed as early as possible, critical system design elements can only be guessed at for these interactions

Additionally, many engineers prefer not to analyze human-in-the-loop design elements early, since these elements could be more nondeterministic than their mechanical counterparts

This can be problematic and can sometimes lead to delays in performing hazard analyses, which could lead to late-arriving design decisions

Is there a way we can actually provide guidance concerning HMI design decisions and subsequently requirements early in the design process?

High-level guidance – mandated HMI requirements

A legacy method for injecting HMI design guidance early in the system design process is to accept pre-generated, mandated HMI requirements

These requirements can come from many industry-accepted sources

- DOD MIL-STD-1472
- DOD MIL-STD-882E
- DEF-STAN 00-251
- OSHA Reg. 29 CFR 1910

A selected set of these mandated requirements are a good start, and provide a basis upon which early design decisions can be made

However, it isn't easy to understand the full impact mandated requirements can make on a system during the early design process, especially if those requirements involve human performance without some form of reference

Predicting worker-level activities – functions to tasks

Every designed system is envisioned to accomplish a mission need

To achieve this need, functions are determined and allocated to either a component of the system or the human

From the list of human-performed functions, system designers generate tasks and order them in sequential groupings to create task flows

This process, from functional allocation to the generation of task flows, is called task analysis

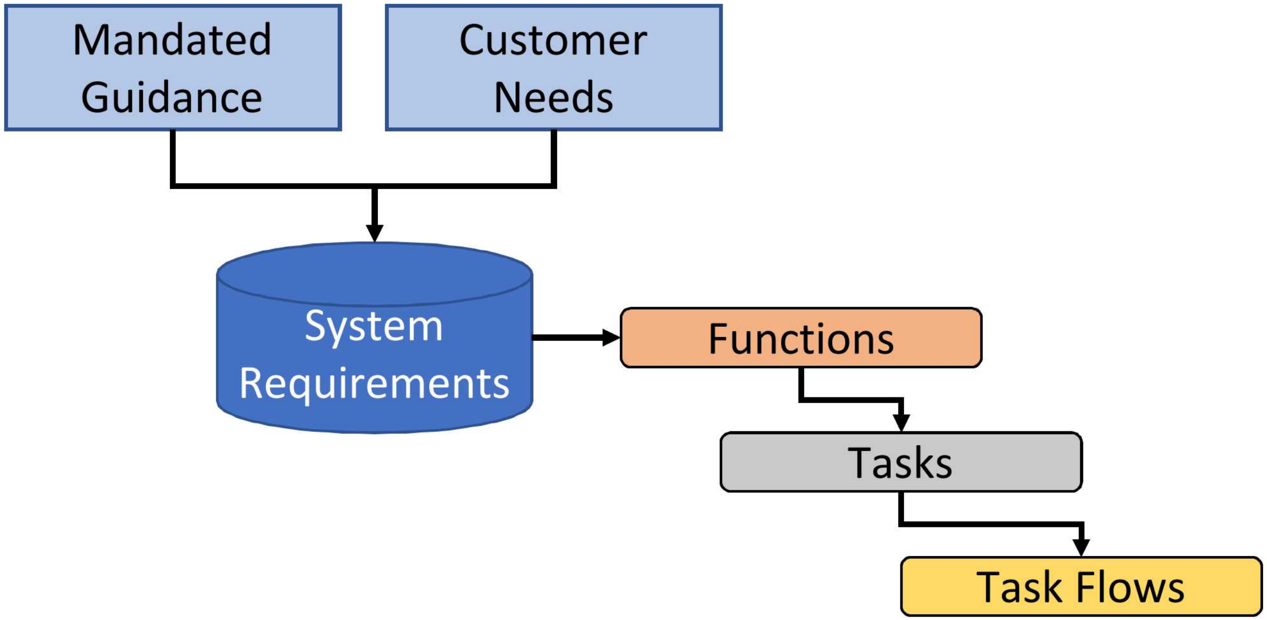
A task analysis seeks to understand all activities that occur on the part of a discrete individual or team employing a defined set of tools or methods, surrounding the accomplishment of a specific goal (Kirwan & Ainsworth, 1992)

Early in the system design, tasks can be extrapolated from legacy systems and domain SMEs

Predicting worker-level activities – what next?

Below we see the relationship of worker-level activities (tasks) to high-level mandated guidance

Now that we've established a set of human tasks for our system, how then can we extrapolate human performance out of them early in our system design process?



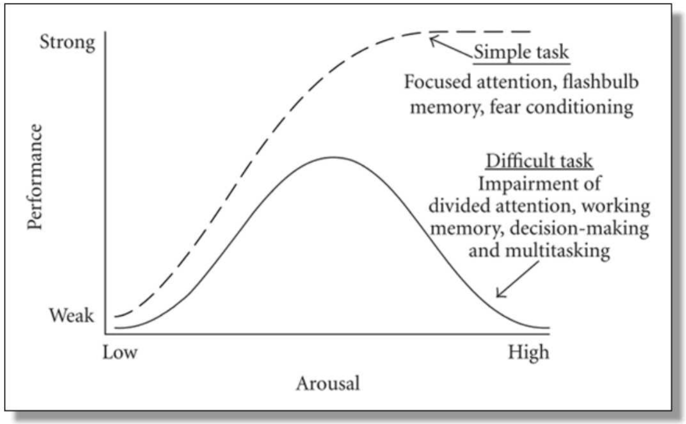
Workload and human performance

Workload refers to "… a mental construct that reflects the mental strain resulting from performing a task under specific environmental and operational conditions, coupled with the capability of the operator to respond to those demands." (Cain, 2007, p. 4-3)

There is a relationship between workload and stress that is the basis for predicting human performance for a set of tasks (Pass, 1992)

Workload overload and underload can both affect human performance for a system and should be understood to ensure an efficient and acceptable system design

Measuring workload allows for better understanding of the performance demands of given tasks, which improves prediction of operator and system performance (Cain, 2007)



Yerkes and Dodson (1908) Arousal/Engagement/Stress Curve

Workload modeling and "what-if" scenarios

Workload models can be constructed and analyzed in many ways, however, certain popular workload theories lend themselves to discrete event simulation models

Most modelled workload measures are based on the VACP (visual, auditory, cognitive, and psychomotor) (McCracken & Aldrich, 1984) theory and the Multiple Resource Theory (MRT) of workload (Wickens and Yeh, 1986)

These theories postulate that individuals possess channels of capacity from which tasks draw resources. This concept formulates a measure of the difficulty of the task in question, with more difficult tasks drawing more resources from more channels

Rating scales have been developed that capture common scores for different types of activities (Szabo and Bierbaum, 1986)

Cognitive Channel Workload Ratings

Workload Score	Activity Type
0.0	No Cognitive Activity
1.0	Automatic (simple association)
1.2	Alternative Selection
3.7	Sign/Signal Recognition
4.6	Evaluation/Judgment (consider single aspect)
5.3	Encoding/Decoding, Recall
6.8	Evaluation/Judgment (consider several aspects)
7.0	Estimation, Calculation, Conversion

Workload modeling and "what-if" scenarios

The core of the model revolves around the resource cost values assigned to tasks and whether an individual's resource allocation exceeds an established threshold at any given time (Wickens and Yeh, 1986)

This threshold is used as an indicator that an individual could be overloaded

Workload overload could point to required task flow changes, alternative system designs or crew task reassignments to avoid performance decrements

Additionally, task performance times can also be predicted and incorporated into the model by leveraging research-based human performance time estimates (Miller & Licklider, 1950; Welford, 1968; Card et al., 1983; Houtmans & Sanders, 1984)

These estimates are used to generate models of human performance times for task flow activities, which are then compiled to compute overall task-performance times

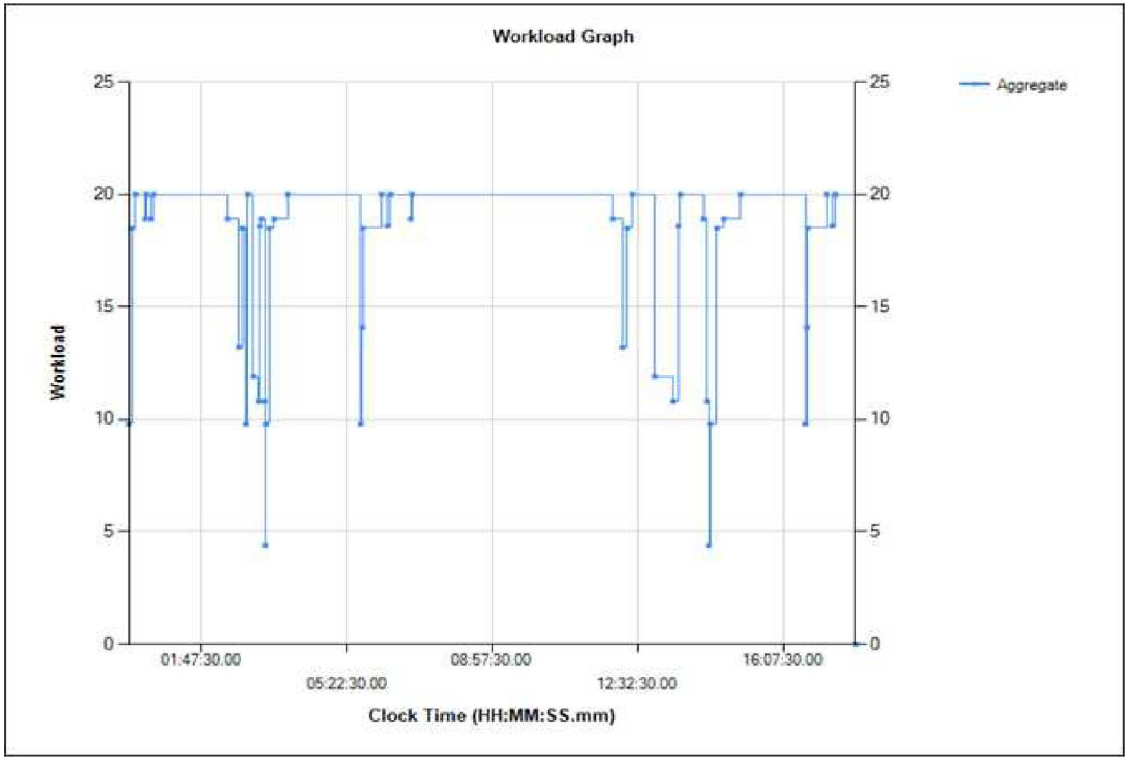
<u>Choice reaction time</u> (Card et al., 1983) – model used to represent an individual's selection of a correct option as a function of the number of alternatives options available. P1 = Number of possible alternatives.

$$.15*\log2(P1+1) \quad \text{Eq(1)}$$

Workload modeling and "what-if" scenarios

The model output displayed below, provides aggregated workload values, over time, for all utilized channels from the VACP theory, while also incorporating the concept of channel interference as postulated by MRT

These values can be directly compared across models to determine differences



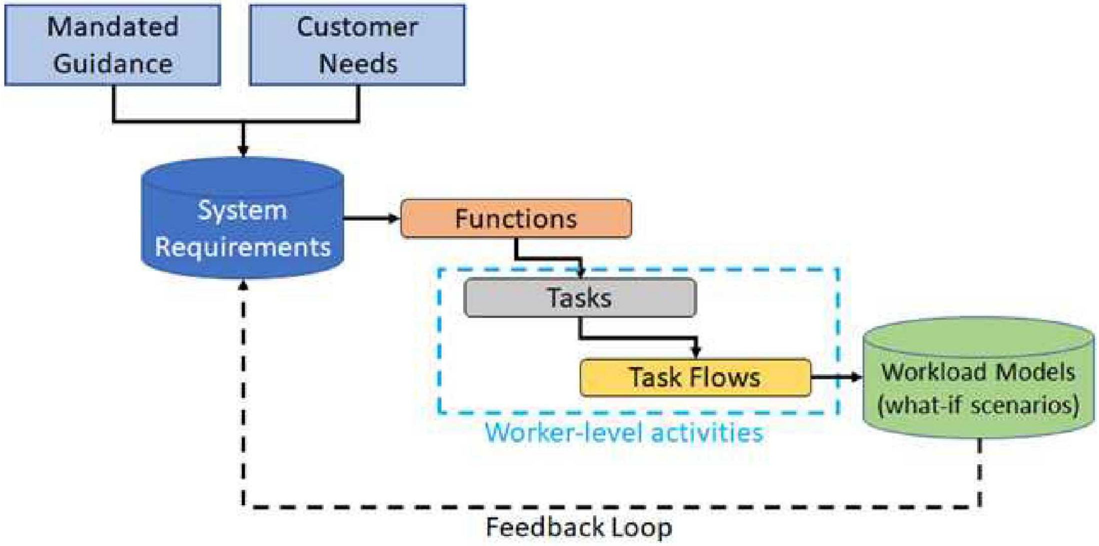
Workload modeling and "what-if" scenarios

This process can be repeated over multiple instances, in "what-if" types of analyses, where design parameters or even mechanical and physical elements can be changed

These models provide a glimpse into how these changes might affect HMI performance without the need for physical mock-ups or test-beds

Effects can be used to alter requirements or design constraints to accommodate human performance concerns

Workload models can become integrated in the end-to-end system analysis with results providing a feedback loop to requirements and design changes



Conclusion

By modeling worker-level activities through this method, a better picture of human-in-the-loop activities can be constructed early in the design cycle, and traced back to high-level requirements

It is not conclusive that instances of high workload correlate with higher incidents of human performance failures (Hancock & Warm, 1989),

However, designing systems with the goal of streamlining the HMI would pose little doubt to minimizing situations where the human user would be subjected to high-workload conditions for which many would argue are more "stressing" for the individual than low or moderate workload conditions (Paas, 1992)