Expanding GOMS-HRA from Analog to Digital Human-Machine Interfaces

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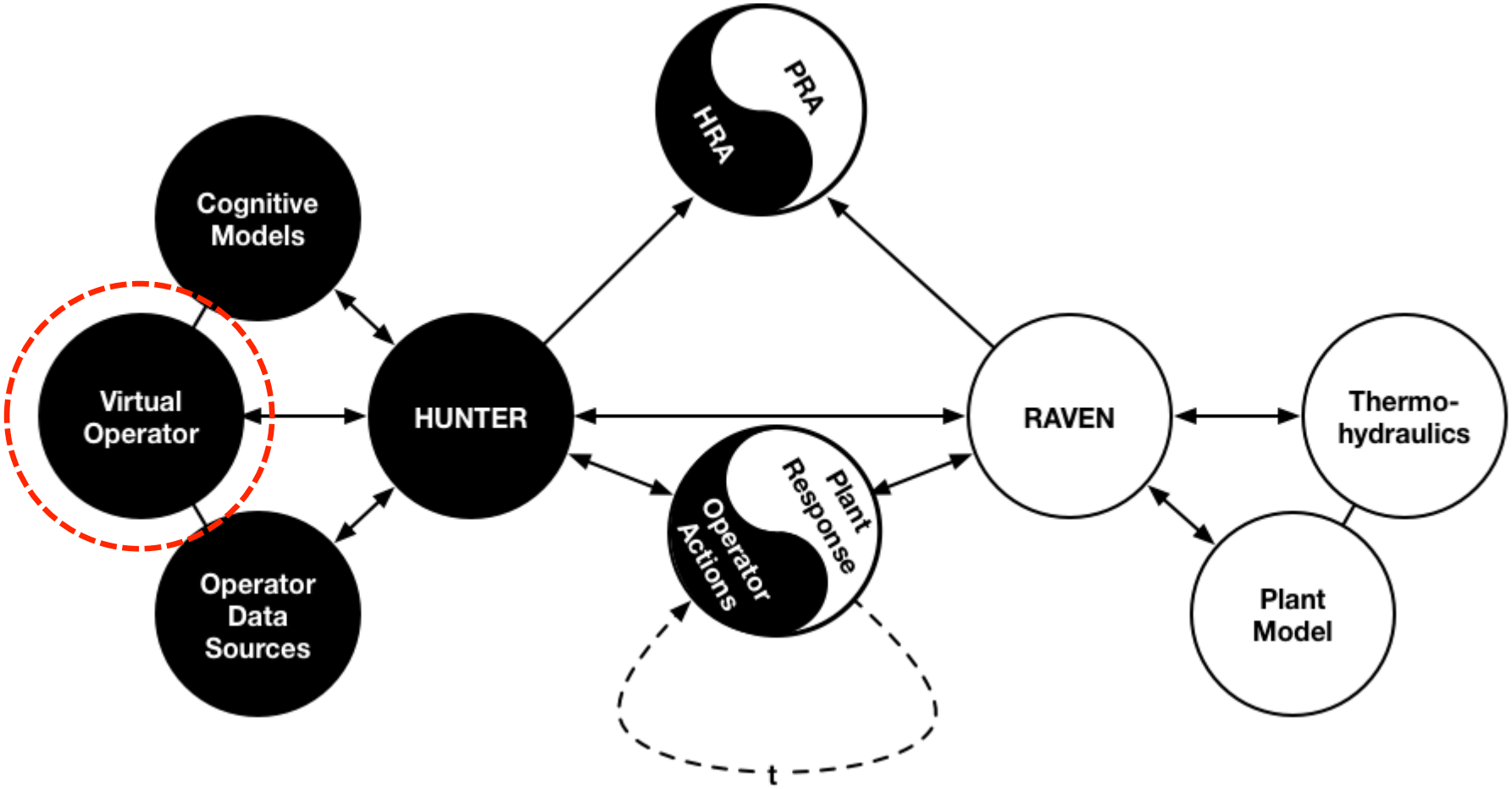
Our Framework

- HUNTER: Human Unimodel for Nuclear Technology to Enhance Reliability
  - A unimodel is a cognitive framework that favors simplified decision models
  - This yields the MOOSE-HUNTER or RAVEN-HUNTER system
  - (We're looking for a friendlier mascot, as we do not want to kill any of these code animals)

HUNTER Framework



Computation-Based HRA (CoBHRA)

Use of a computational techniques like simulation to integrate virtual operator models into virtual plant models

- Static HRA uses experts and fixed models to judge effects of human operators on overall risk of system
- Dynamic HRA or CoBHRA uses virtual operators and auto-calculates what the human will do
  - What decisions are made
  - What actions are taken
- Dynamic simulation changes course as a result of these
  - Not predefined event trees
  - Possible to model errors of commission and their consequences—a challenge historically for HRA
  - Possible to model unexampled events
- Finer (more detailed) level of modeling resolution than in static HRA

Most Static HRA Models at the Human Failure Event (HFE) Level, but Dynamic HRA Needs the Subtask Level

Can't model decisions and actions at the HFE level!

What HRA methods give us subtask modeling?

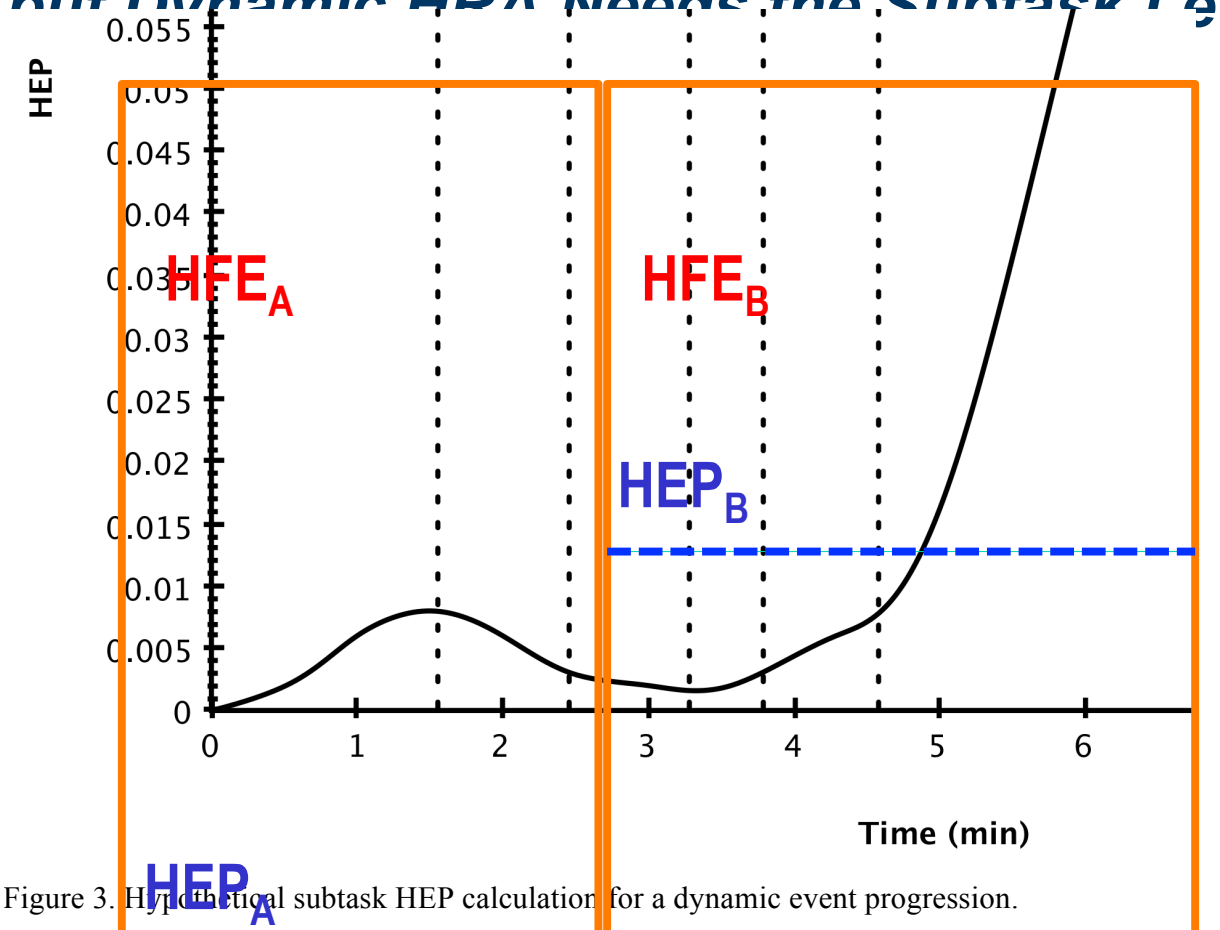
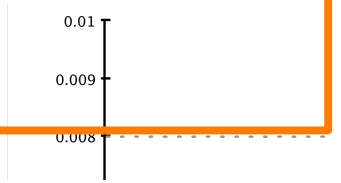


Figure 3. Hypothetical subtask HEP calculation for a dynamic event progression.

subtask will do so differently. As such, it is often convenient to consider the subtasks in terms of windows of time. Hypothetical Tasks A – I are parsed across the timeline in Figure 3. Within each subtask



Requirements for Subtask Modeling

Should model operator activity types

- Subtasks should align with cognitive modeling approaches in use in the research and applied community
- Should include information sufficient to guide that action
  - It is this type of activity, therefore we expect this kind of outcome

Should provide reasonably validated approach

- Don't want to go down the rabbit hole of untested methods

Should lend itself to quantification

- Should be able to tie into existing HRA methods to arrive at human error probabilities (HEPs)

GOMS Task Level Primitives

GOMS

Way of classifying human actions according to Goals, Operators, Methods, and Selection Rules

- Goals: Tasks to be achieved
- Operators: Elementary perceptual, motor, or cognitive acts
- Methods: Procedure for accomplishing a goal
- Selection rules: Way to chose between competing methods

Developed by Card, Moran, and Newell and considered one of the seminal approaches to human-computer interaction

- Variants like Keystroke Level Model (KLM—*not the airline!*) used extensively to provide timing data to human activities

GOMS-HRA

Took the idea of GOMS and extended it with SHERPA-like error taxonomy

- Operators for use as subtask primitives in HRA

Mapped the GOMS-HRA operators to subtask HEPs in THERP

- Created a nominal HEP for each subtask

Mapped the GOMS-HRA operators to procedure steps

- Used procedural guidance from Professional Procedure Writer's Association (PPA)
- Each procedure step yields a set of GOMS-HRA operators

GOMS-HRA Time and HEP Estimates

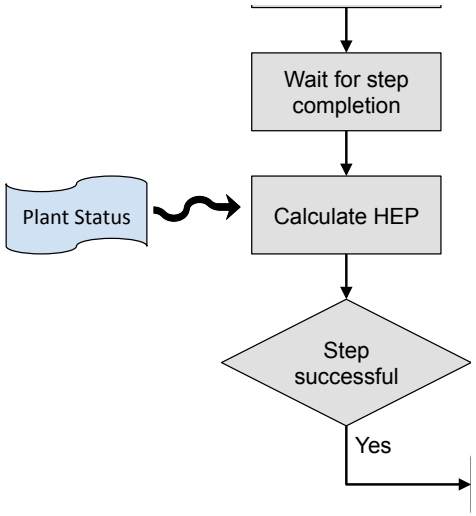
- Empirical data from operator-in-the-loop studies using a full scope simulator (Human Systems Simulation Laboratory)
  - Analog interactions were sampled for time estimates

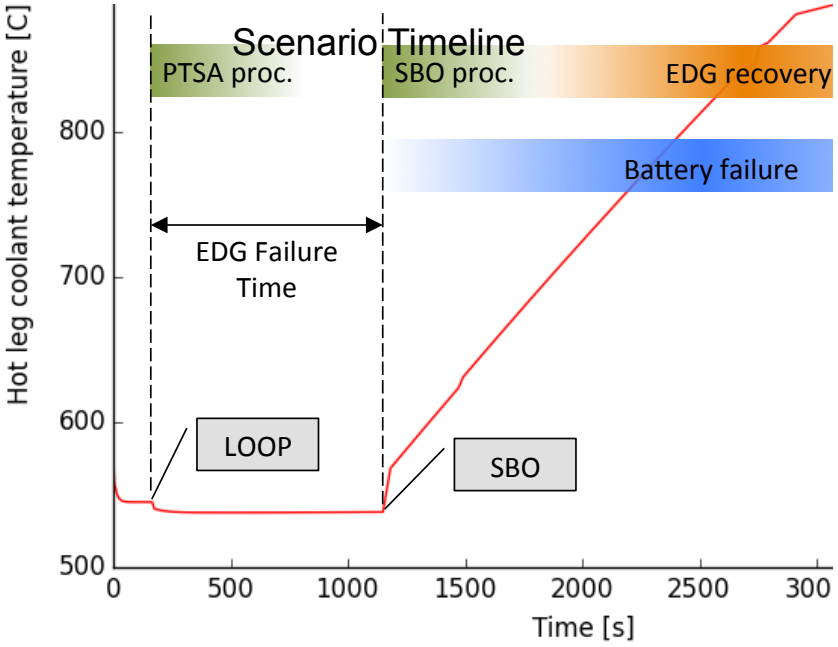
- Time Estimates
  - Distribution of procedure execution time coded to TLPs
- HEP Estimates
  - Taken from THERP

Empirical use of GOMS-HRA

- HUNTER-RAVEN
  - Computation based human reliability analysis
  - Station blackout scenario

SBO	5	-	Minimize reactor coolant system leakage	Minimize	-
SBO	5	a	Ensure letdown is isolated	Ensure	C_C
SBO	5	b	Ensure reactor coolant pump controlled bleedoff is isolated	Ensure	C_C
SBO	5	c	Ensure reactor coolant system sampling is isolated	Ensure	C_C





HRA Methodologies and Digital HMIs

- Existing HRA methodologies were developed within the context of analog main control rooms
  - THERP
  - ASEP
  - SPAR-H
  - HEART
- The HEP estimates generated using these methods for digital interfaces significantly differ from empirical HEP quantifications (E. M. Hickling and J.E. Bowie, 2013)

Analog versus Digital – What Differs?

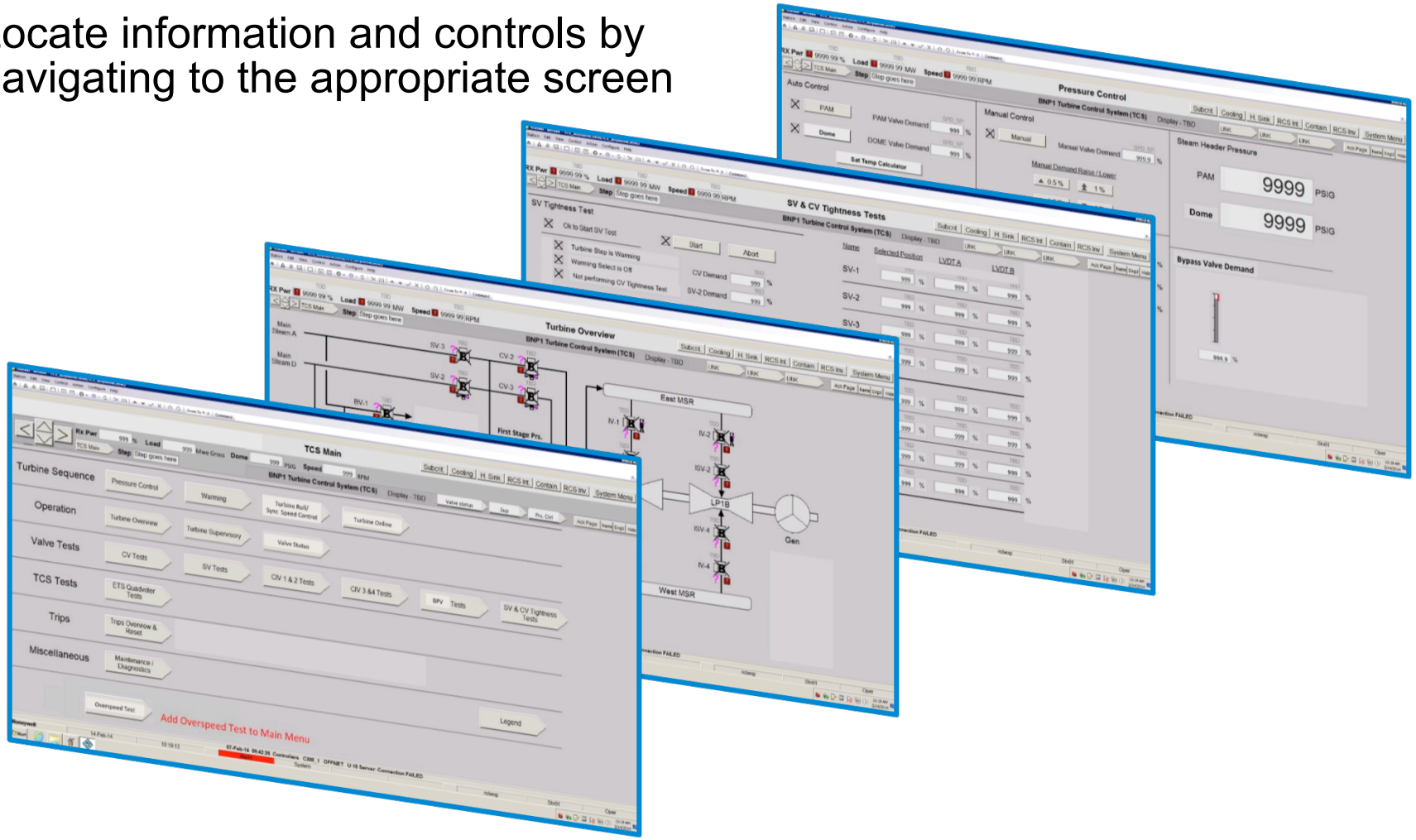
- Analog
  - : of, relating to, or being a mechanism or device in which information is represented by continuously variable physical quantities
- Digital
  - : of, relating to, or using calculation by numerical methods or by discrete units

Analog in the Main Control Room

- All information is present and readily visible
- Locate information and controls by physically moving your body

Digital in the Main Control Room

- Most information is hidden
- Locate information and controls by navigating to the appropriate screen



Can GOMS-HRA be applied to digital interfaces?

- GOMS-HRA method was developed using data from an analog platform similar to existing HRA methods
  - Analog scenarios from operator-in-the-loop studies
  - Analog Station Blackout case study

- Will timing distributions calculated from a digital study differ from the those calculated from the original analog study?

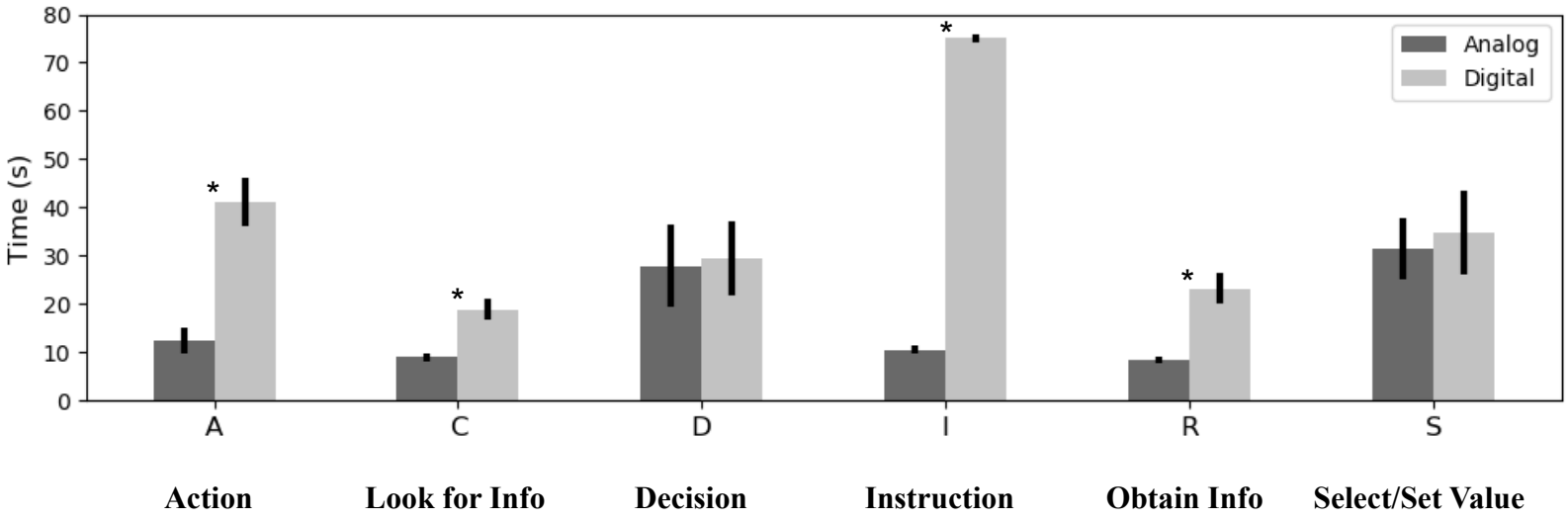
Data

- **Operator-in-the-loop studies**
  - PWR simulators
    - HSSL (analog)
    - Glass-top plant simulator (digital)
  - Collected as part of turbine control system upgrade project
  - Scenarios: latching the turbine, ramping the turbine, testing the overspeed protection systems, and valve testing
  - Pre-populated digital timestamp logging tool
    - Capture timing data used to estimate completion times

Results

Performed a 2 (HMI format: analog vs. digital) by 6 (task level primitive type) ANOVA on the timing data

Source	SS	df	MS	F	p
HMI Format	18089.13	1	18089.13	53.88	< 0.001
Primitive Type	19884.20	5	3976.84	11.85	< 0.001
Format * Primitive Type	10500.35	5	2100.07	6.26	< 0.001



Conclusion

- Overall results are preliminary and therefore inconclusive, but they provide some evidence for a meaningful difference between the time required to perform analog and digital TLPs
  - Digital interface demonstrated overall longer times
  - Navigation related TLPs show significant differences
  - Cognitive format independent TLP (**D** = Decide) similar
- GOMS-HRA TLPs only implicitly capture navigation time
  - A new primitive shall be added to the GOMS suite: ***N*** = *Navigate*
- Future Directions
  - Acquire timing data post system digital TCS deployment
  - Collect additional data to better quantify HEPS and TLP timing
    - Microworld studies comparing analog and digital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