



# The HUNTER Dynamic Human Reliability Analysis Tool: Development of a Module for Performance Shaping Factors

June 2022

*Changing the World's Energy Future*

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**Prepared for the  
U.S. Department of Energy  
Under DOE Idaho Operations Office  
Contract DE-AC07-05ID14517**

# The HUNTER Dynamic Human Reliability Analysis Tool: Development of a Module for Performance Shaping Factors

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# 1. Introduction

## ► Performance Shaping Factor (PSF)

- Any factor that influences human performance such as experience, stress, and complexity
- It highlights error contributors and adjusts nominal human error probabilities.

**Table 1**

The summary of PSFs and assessment for HRA methods (Kim et al., 2016).

HRA methods	Suggested PSFs	Underlying theory
A technique for human error rate prediction (THERP) (U.S. NRC, 1983)	Physiological stressors, psychological stressors Task and equipment characteristics Organization factors Situational characteristics Job and task characteristics	A general descriptive model of human performance in an NPP
Human error assessment and reduction technique (HEART) (Williams, 1986)	A channel capacity overload, a need for absolute judgments that are beyond the capabilities or experience of an operator, operator inexperience, a shortage of available time, lack of clear, direct, and timely confirmation corresponding to an intended actions, etc.	Error producing conditions (EPC) identified by the author's experience
Cognitive reliability and error analysis method (CREAM) (Hollnagel, 1998)	Adequacy of HSI and operational support, working conditions, adequacy of organization, adequacy of training and experience, available time, crew collaboration quality, number of simultaneous goals, time of day, and availability of procedures/plans	Common performance conditions (CPCs) identified through the salient or dominant features of performances, as links in the space of man-technology-organization (MTO)
Human reliability management system (HRMS) (Kirwan, 1997)	Time, task complexity, task organization, procedures, training/expertise/experience/competence, and quality of information/interface	A large number of techniques and applications surveyed.
Standardized plant analysis risk HRA (SPAR-H) (U.S. NRC, 2005)	Available time, complexity, procedures, fitness for duty, stress/stressors, experience/training, ergonomics/HSI, and work processes	Human behavior model and PSF comparisons between HRA methods performed.
A technique for human error analysis (ATHEANA) (U.S. NRC, 2000a)	Applicability and suitability of training/experience, available staffing/resources, suitability of relevant procedures and administrative controls, ergonomic quality of the HSI, operator action tendencies and informal rules, environment, etc.	The context developing process to identify the PSFs and plant conditions that are most relevant to the human action addressed.

# 1. Introduction

## ► PSFs in Dynamic HRA

- The characteristics of dynamic HRA (e.g., time-dependent effects) may require novel approaches for adapting PSFs dynamically.
- In a dynamic context, triggered events (e.g., the burden of starting new tasks) could cause the effects of some PSFs (e.g., stress) to directly vary over time.
- Some PSFs could be indirectly influenced or determined by time-dependent information (e.g., parameters over time).

Dynamic PSF Function	Effect on PSF	Notation
lag	A PSF will be slow to change at the outset of a new effect	$PSF(t_{i+1}) = \lim_{t \rightarrow t_{i+1}}^- PSF(t)$
linger	A PSF will be slow to change at the termination of an existing effect	$PSF(t_{i+1}) = \lim_{t \rightarrow t_{i+1}}^+ PSF(t)$
memory	General form of lag and linger, denoting that the effect of the current PSF is a function of preceding values for that PSF	$PSF(t_{i+1}) = f(t_i)$
decay	A PSF will settle to its original state over time	$PSF(t) = PSF(0) \quad \text{for } t \gg t_N$

Boring, R., Mandelli, D., Rasmussen, M., Herberger, S., Ulrich, T., Groth, K., & Smith, C. (2016). *Integration of Human Reliability Analysis Models into the Simulation-Based Framework for the Risk-Informed Safety Margin Characterization Toolkit*, INL/EXT-16-39015. Idaho Falls: Idaho National Laboratory.

# 1. Introduction

## ► Purpose

- Developing the PSF Module (a.k.a., the individual module) applicable to the HUNTER 2.0
  - Modeling PSFs in Dynamic Context through Literature Survey
  - Based on SPAR-H PSFs

## ► Contents

- Conceptual Design of the PSF Module in HUNTER 2.0
  - Modification of the existing SPAR-H PSFs
- Treatment of PSFs in Dynamic Contexts
  - Stress/stressors PSF
  - Fitness for duty PSF
  - Available time PSF

## 2. Conceptual Design

### ► Treatment of SPAR-H PSFs in HUNTER 2.0

- Categorization of the SPAR-H PSF qualification and quantification functions

		Qualification Function	
		Manually Assigned	Automatically Assigned
Quantification Function	Static	The level of the PSF and its multiplier are manually assigned in the model, equivalent to static HRA.	The PSF level is automatically assigned, and static (i.e., predefined) multipliers are applied for each level.
	Dynamic	The PSF level is manually assigned but the multiplier is automatically calculated (e.g., adjusted for lag/linger effects).	The PSF level is automatically assigned, and the PSF multiplier is auto-calculated.



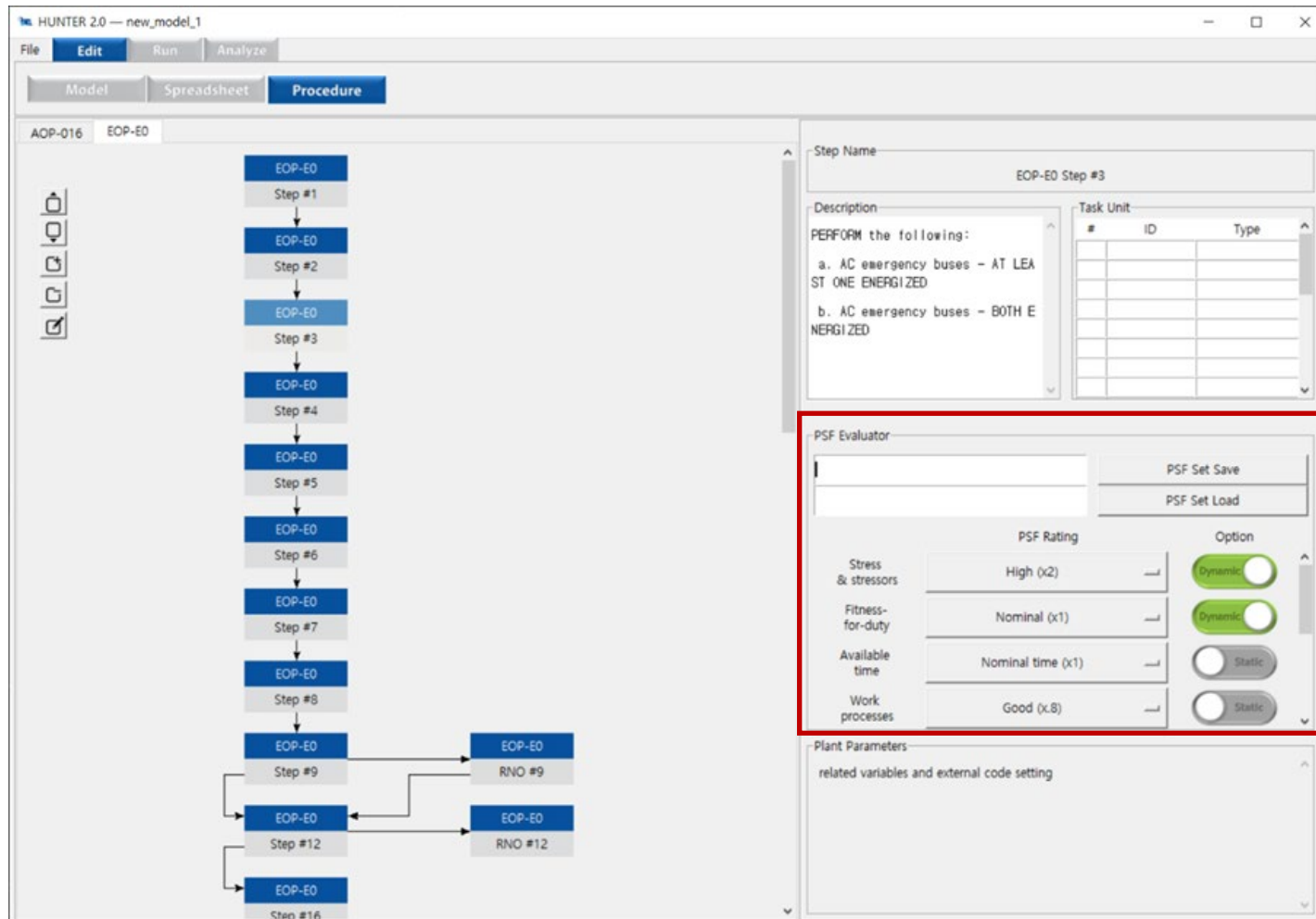
## 2. Conceptual Design

### ► Treatment of SPAR-H PSFs in HUNTER 2.0 (Cont'd)

SPAR-H PSFs	PSF Qualification Function	PSF Quantification Function
Stress/stressors	“Manually Assigned” only	“Static” or “Dynamic”
Fitness for duty	“Manually Assigned” “Automatically Assigned” (if “Dynamic” is selected in the PSF quantification function)	“Static” or “Dynamic”
Available time	“Manually Assigned” “Automatically Assigned” (if “Dynamic” is selected in the PSF quantification function)	“Static” or “Dynamic”
Work processes	“Manually Assigned” only	“Static” only
Experience/ training	“Manually Assigned” only	“Static” only
Complexity	“Manually Assigned” only	“Static” only
Ergonomics/human system interface	“Manually Assigned” only	“Static” only
Procedures	“Manually Assigned” only	“Static” only

## 2. Conceptual Design

- Treatment of SPAR-H PSFs in HUNTER 2.0 (Cont'd)
  - PSF Option Selection

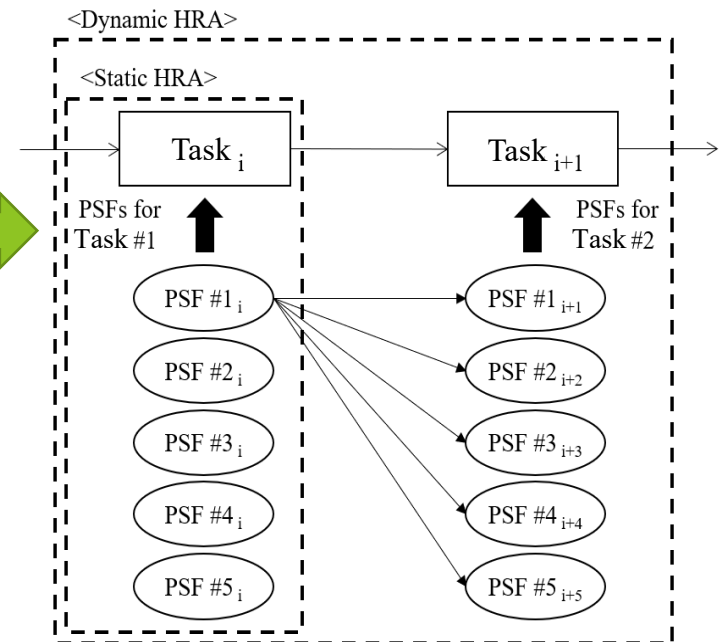


## 2. Conceptual Design

### ► Treatment of SPAR-H PSFs in HUNTER 2.0 (Cont'd)

- PSF Quantification in Dynamic Contexts
  - Extending the PSF concept from static to dynamic
    - Intra-PSF influence of a PSF on the same PSF for subsequent tasks
    - Inter-PSF influence of a PSF on different PSFs for subsequent tasks
    - Inter-PSF influence of a PSF on different PSFs during the same task

SPAR-H PSFs	PSF Qualification Function	PSF Quantification Function
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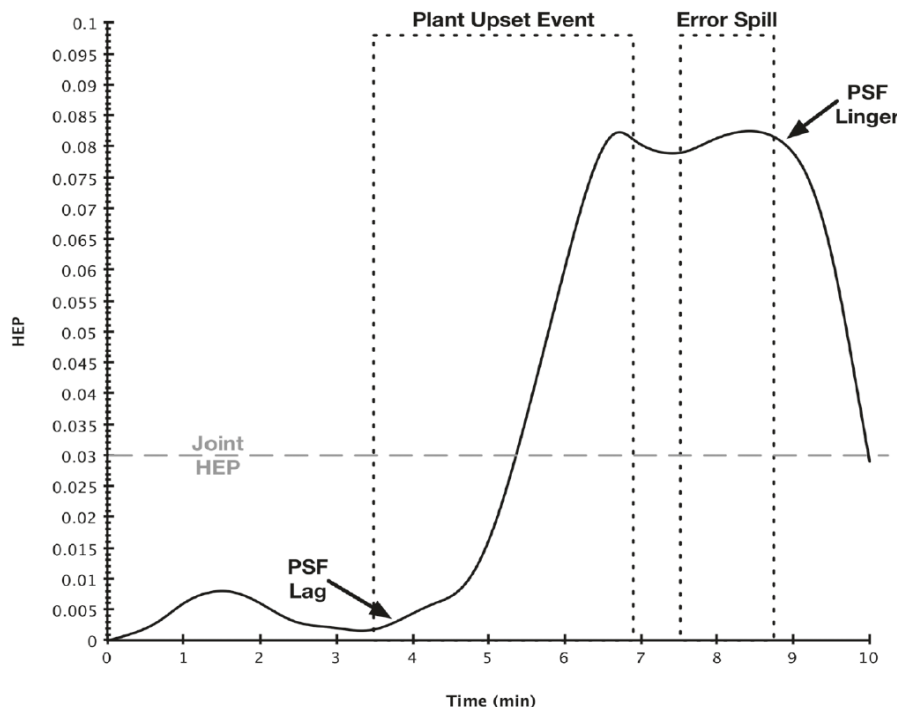
### 3. Stress/stressors PSF

SPAR-H PSFs	PSF Qualification Function	PSF Quantification Function
Stress/stressors	“Manually Assigned” only	“Static” or “Dynamic”
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### 3. Stress/stressors PSF

#### ► The PSF Lag and Linger Effects

- Boring (2015) conceptually suggested **PSF lag and linger effects** as an option to treat dependence between operator actions.
  - **PSF lag**: Indicating that the effect of the PSF on performance does not immediately psychologically or physically appear
  - **PSF linger**: Meaning that the influence of PSFs on previous operator actions is not finished after the actions, resulting in residual effects on the next operator actions

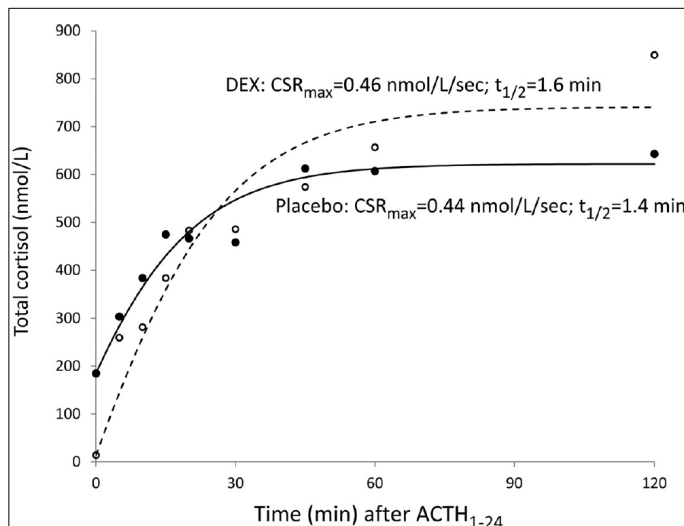


<Illustration of dynamic dependence considerations (Boring, 2015)>

### 3. Stress/stressors PSF

#### ► Modeling the PSF Lag Effect

- For modeling the PSF lag effect, it is important to know 1) the increasing trend, i.e., how they reach a maximum PSF level, and 2) the time that it takes to reach the maximum value.
  - Dorin et al. (2012) tried to estimate maximum cortisol secretion rates.
    - Cortisol is a hormone that increases dramatically during adaptation to physiological stress.
    - The results of their study include 1) a trend that the cortisol concentrations reach maximum level, i.e., natural log function, and 2) the time that it takes to reach the maximum value (i.e., 60min).



<Dorin et al., 2012>



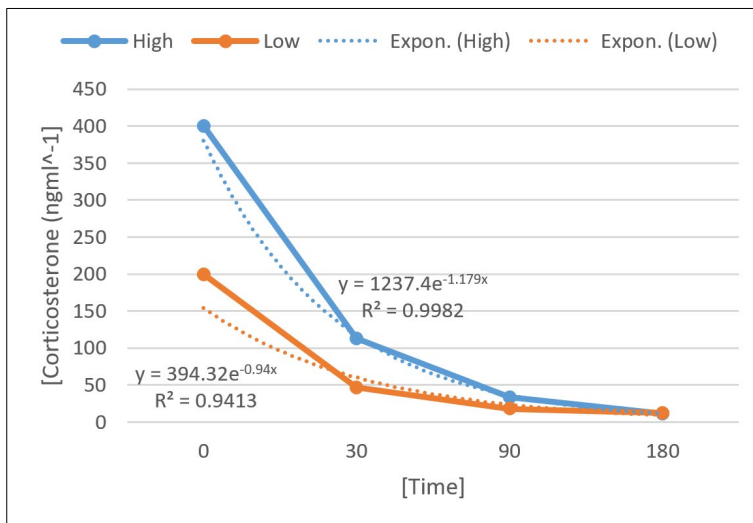
1) Trend:  $y = A \cdot \ln(x - a) + b$

2) Time to a maximum value: 60min

### 3. Stress/stressors PSF

#### ► Modeling the PSF Linger Effect

- To identify the linger effect of stress PSF, 1) the decreasing trend, i.e., how they reach a normal PSF level, and 2) the time that it takes to reach the normal state need to be identified.
  - Vitousek et al. (2018) experimentally investigated the decrease of corticosterone hormones, which represents the decrease of stress, depending on the change over time.
    - In the results of their study, it is identified that the concentration of the corticosterone hormone, i.e., stress, 1) exponentially decreases depending on change of time and 2) reaches a normal state after 180min.



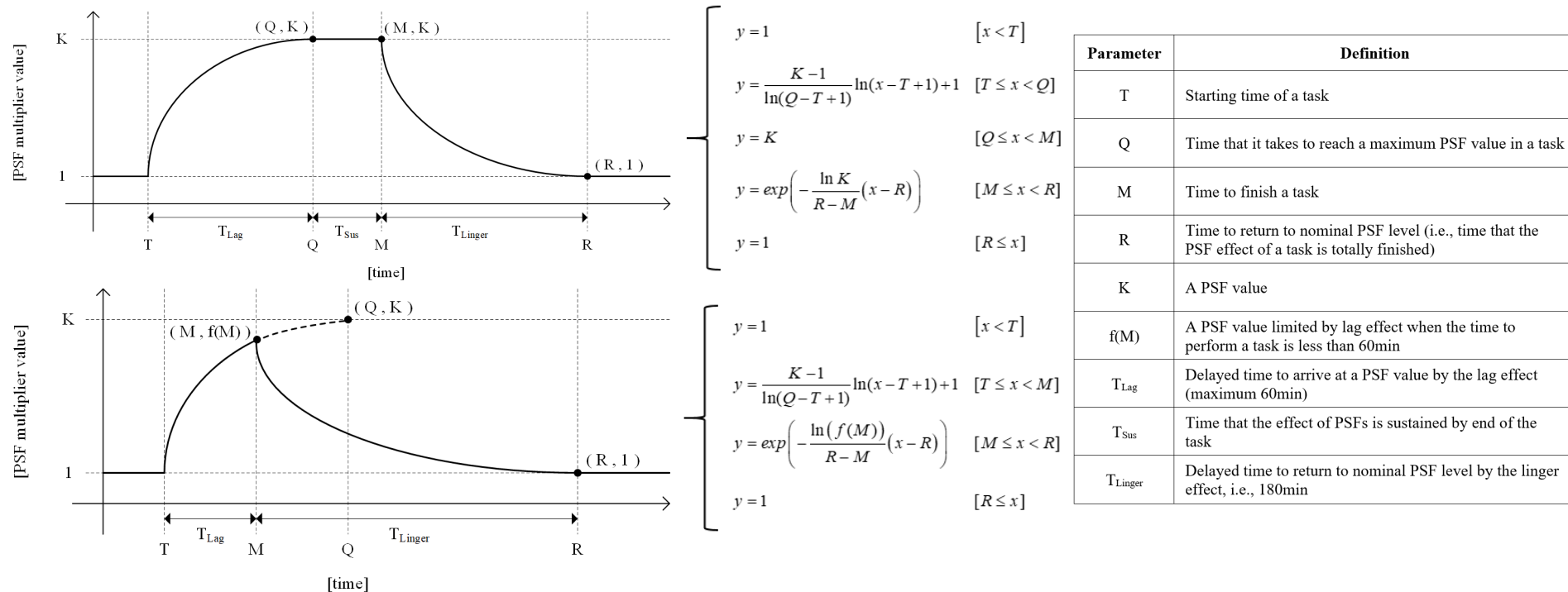
1) Trend:  $y = A \cdot \exp(-ax) + b$

2) Time to a normal state: 180min

<Vitousek et al., 2018>

# 3. Stress/stressors PSF

## ► The PSF Lag and Linger Models



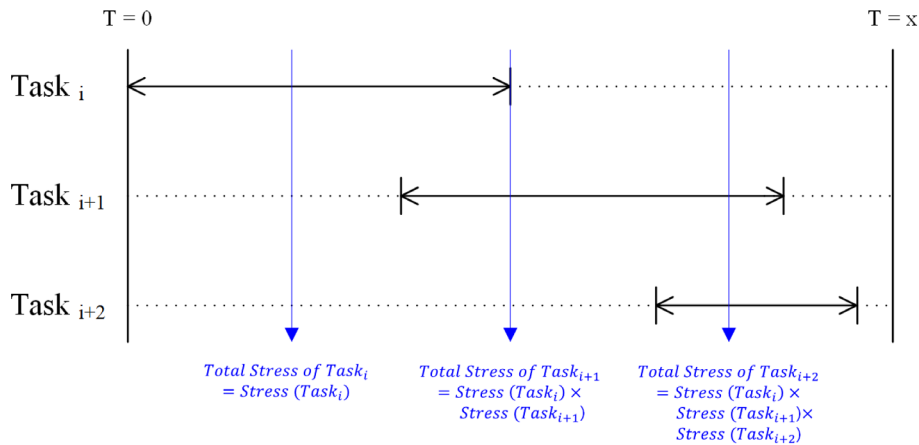
- The biggest difference between the two models concerns **PSF lag time, i.e., 60min.**
  - For the first model, the time to perform a task is more than 60min, and therefore there is the time that the effect of the PSF is sustained at the end of the task.
  - On the other hand, for the second model, the time to perform a task is less than 60min. It is finished before the PSF value reaches to maximum level due to the PSF lag.



### 3. Stress/stressors PSF

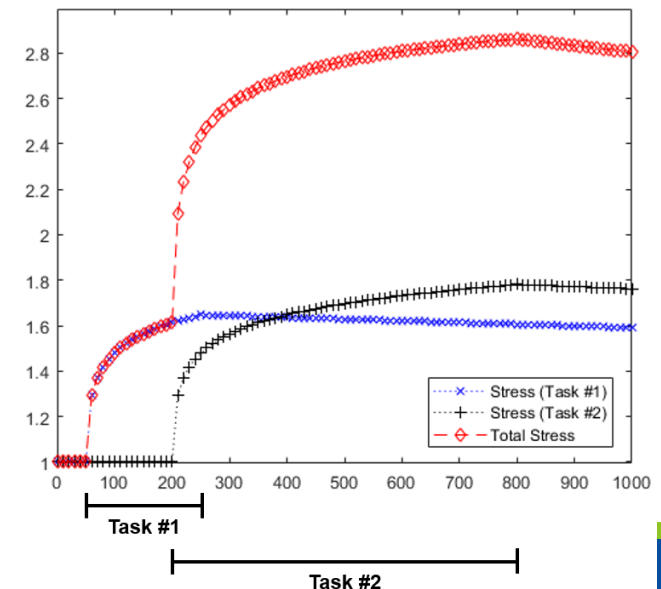
#### ► Stress Effect Integration

- Estimation of a multiplier value per each task



$$\text{Total Stress of Task } i [t = j] = \prod_{n=1}^i \text{Stress (Task } n) [t = j]$$

Task No.	Parameter						
	Time required [sec]	T [sec] (Starting time of a task)	M [sec] (Time to finish a task)	Q [sec] (Time to reach the maximum PSF value)	R [sec] (Time to return to nominal PSF level)	K [sec] (A PSF value for a task)	f(M) [sec] (A PSF value limited by lag effect)
#1	200	50	250	3,650	11,050	2	1.648
#2	600	200	800	3,800	11,600	2	1.781



## 4. Fitness for Duty PSF

SPAR-H PSFs	PSF Qualification Function	PSF Quantification Function
Stress/stressors	“Manually Assigned” only	“Static” or “Dynamic”
Fitness for duty	“Manually Assigned” “Automatically Assigned” (if “Dynamic” is selected in the PSF quantification function)	“Static” or “Dynamic”
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Procedures	“Manually Assigned” only	“Static” only

## 4. Fitness for Duty PSF

### ► Modeling Fatigue

- A factor representing the fitness for duty
- Close to a general thing rather than personal things

#### ***2.4.4.7 Fitness for Duty***

Fitness for duty refers to whether or not the individual performing the task is physically and mentally fit to perform the task at the time. Things that may affect fitness include fatigue, sickness, drug use (legal or illegal), overconfidence, personal problems, and distractions. Fitness for duty includes factors associated with individuals, but not related to training, experience, or stress.

## 4. Fitness for Duty PSF

### ► Literature on a Fatigue Model

- A fatigue model suggested by the Health and Safety Executive (HSE) (i.e., Britain's national regulator for workplace health and safety)
  - The six fatigue factors, i.e., 1) duty length, 2) rest length, 3) average duty per day, 4) cumulative component, 5) duty timing component, and 6) job type / breaks component
  - Estimation of a relative fatigue trend
    - Dividing each fatigue value into the average between 0 to 12hr
    - Including an unknown phenomenon: Individuals' circadian rhythms—meaning physical, mental, and behavioral changes that follow a 24-hour cycle

Fatigue Index Calculator																							
Company Location Shift ID Date												Assessor											
Mode												<input checked="" type="checkbox"/> Display schedule <input checked="" type="checkbox"/> Display charts											
Fatigue												© Crown Copyright 2005 Version 2.2											
Fatigue												About											
Day												Fatigue Index											
On Duty												Off Duty											
Job type / Breaks												Countdown Time											
Duty Length												Rest Length											
Average duty per day												Cumulative component											
Duty timing component												Job type / Breaks component											
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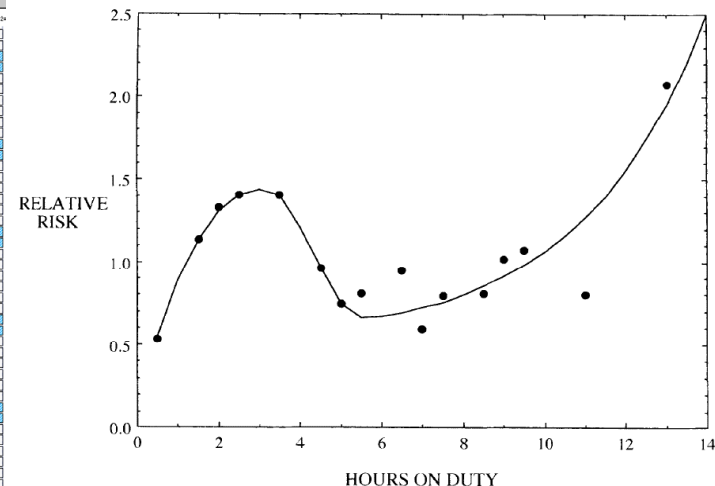
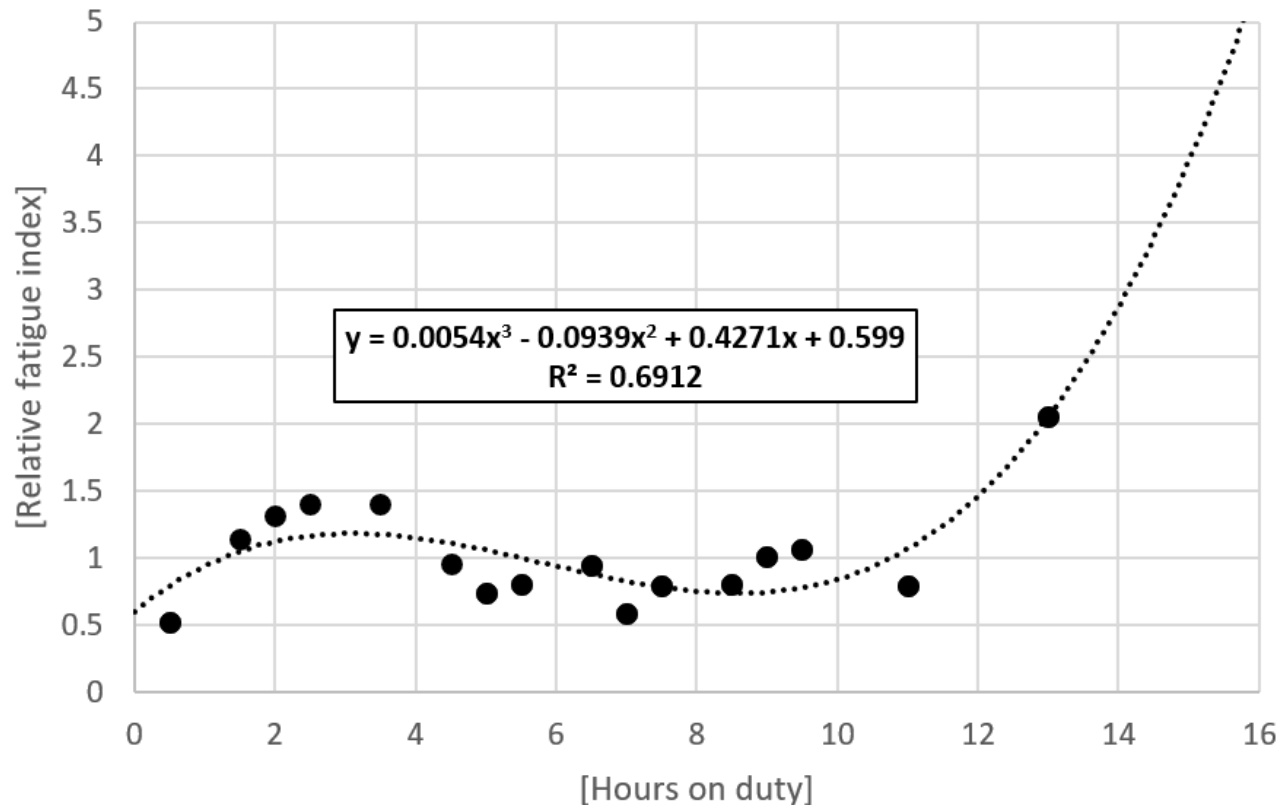


Fig. 8. The smooth curve fitted to the various data points shown in Fig. 7.

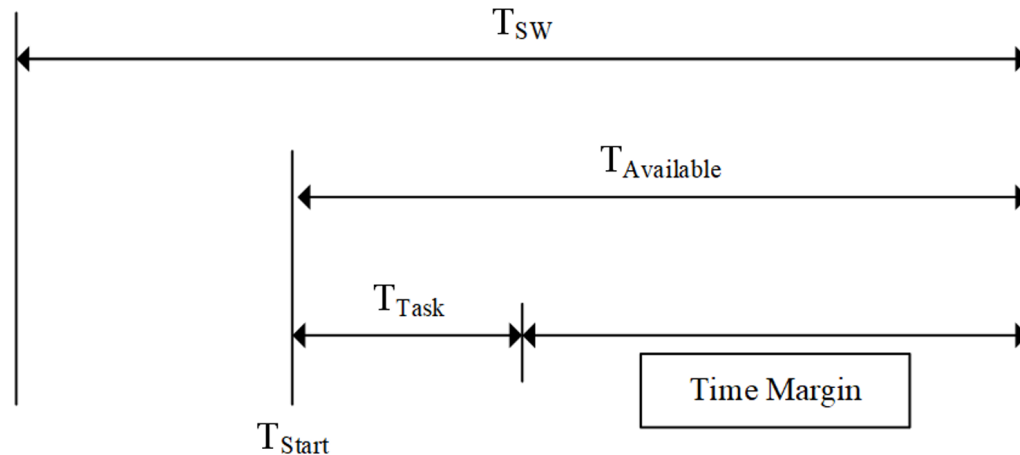
## 4. Fitness for Duty PSF

### ► A Simplified Dynamic Model for Fitness for Duty



## 5. Time Available PSF

### ► Simplification of Timeline and Logic to Determine a Multiplier Value



GOMS-HRA Primitive Type	Evaluation Logic	Multiplier Value
Diagnosis-based primitive	$(T_{Available} > 30 \text{ mins}) \ \& \ (T_{Available} / T_{Task} > 2)$	0.01
	$(T_{Available} > 30 \text{ mins}) \ \& \ (T_{Available} / T_{Task} \leq 2)$	0.1
	$(T_{Available} \leq 30 \text{ mins})$	1
	$(T_{Available} < T_{Task})$	Task Failed
Action-based primitive	$(T_{Available} / T_{Task} \geq 50)$	0.01
	$(50 > T_{Available} / T_{Task} \geq 5)$	0.1
	$(5 > T_{Available} / T_{Task} \geq 1)$	1
	$(T_{Available} < T_{Task})$	Task Failed

## 6. Conclusion

### ► Summary

- Developing the PSF Module (a.k.a., the individual module) applicable to the HUNTER 2.0
  - Conceptual Design of the PSF Module in HUNTER 2.0
    - Modification of the existing SPAR-H PSFs
  - Treatment of PSFs in Dynamic Contexts

### ► Future Work

- Modeling other PSFs through additional literature survey
  - Complexity PSF modeling based on the TACOM method
- Calibration and validation of dynamic PSF models

SPAR-H PSFs	PSF Qualification Function	PSF Quantification Function
Stress/stressors	“Manually Assigned” only	“Static” or “Dynamic”
Fitness for duty	“Manually Assigned” “Automatically Assigned” (if “Dynamic” is selected in the PSF quantification function)	“Static” or “Dynamic”
Available time	“Manually Assigned” “Automatically Assigned” (if “Dynamic” is selected in the PSF quantification function)	“Static” or “Dynamic”
Work processes	“Manually Assigned” only	“Static” only
Experience/ training	“Manually Assigned” only	“Static” only
Complexity	“Manually Assigned” only	“Static” only
Ergonomics/human system interface	“Manually Assigned” only	“Static” only
Procedures	“Manually Assigned” only	“Static” only

