A Short Introduction to HUNTER: Human Unimodel for Nuclear Technology to Enhance Reliability

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The HUNTER Session

- **We've divided HUNTER into five topics**
  - Introduction – Ron Boring
  - Task Module (= Procedures) – Tom Ulrich
  - Environment Module (= RELAP5-3D Interface) – Yun Heo
  - Individual Module (= Performance Shaping Factors) – Jooyoung Park
  - Graphical User Interface – Jeeyea Ahn
- **Represents work primarily from the period Summer 2021 – Spring 2022**

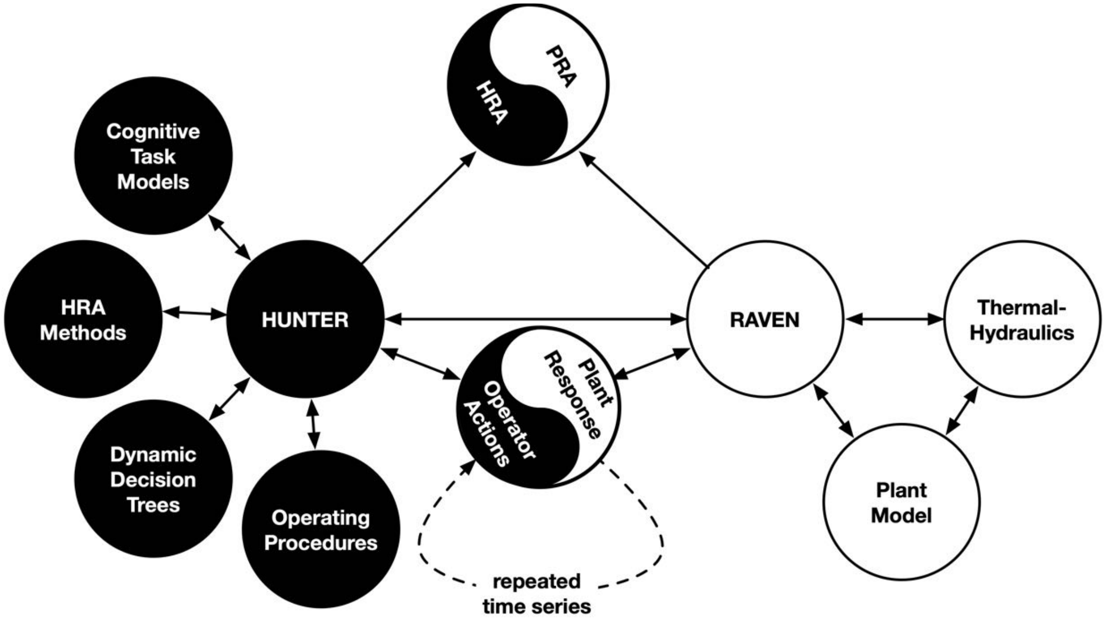
HUNTER Origins

What's in a Name?

- **HUNTER: Human Unimodel for Nuclear Technology to Enhance Reliability**
  - A *unimodel* is a cognitive framework that favors simplified decision models
  - The HUNTER name is a tongue-in-cheek reference to many of the INL animal-named modeling and simulation codes
    - HUNTER is the human element coupled to the hardware model, e.g., MOOSE-HUNTER or RAVEN-HUNTER
    - We disavow any reference to harming the animal-named codes we work with of course! ☺

HUNTER in Context

- **HUNTER Introduced at PSAM in Korea**
  - Goal: Create a dynamic version of SPAR-H
  - Develop simple, easy-to-use dynamic HRA as proof of concept
    - Stepping stone to more complete dynamic HRA methods like ADS-IDAC
  - Framework required many parts beyond SPAR-H



Another HRA Method?

- **Context for HUNTER**
  - ***Origins were in creating a dynamic version of one of the simplest HRA methods, SPAR-H***
  - ***Dynamic HRA and PRA have not been widely adapted***
    - The approaches are necessarily complex
    - They have been slow to become releasable software tools
      - A lot of research needed just to get them going
      - The tools have successfully answered many research questions but have not translated into widespread use
  - ***If we can create the right tools, dynamic HRA has strong advantages over static HRA***
    - Modeling what-if scenarios that are not possible in static HRA
    - Modeling more realistic contexts and event progressions
    - Providing coupled data between plant models and human models
    - Providing new metrics beyond HEPs
      - E.g., HUNTER calculates time on task in addition to HEPs

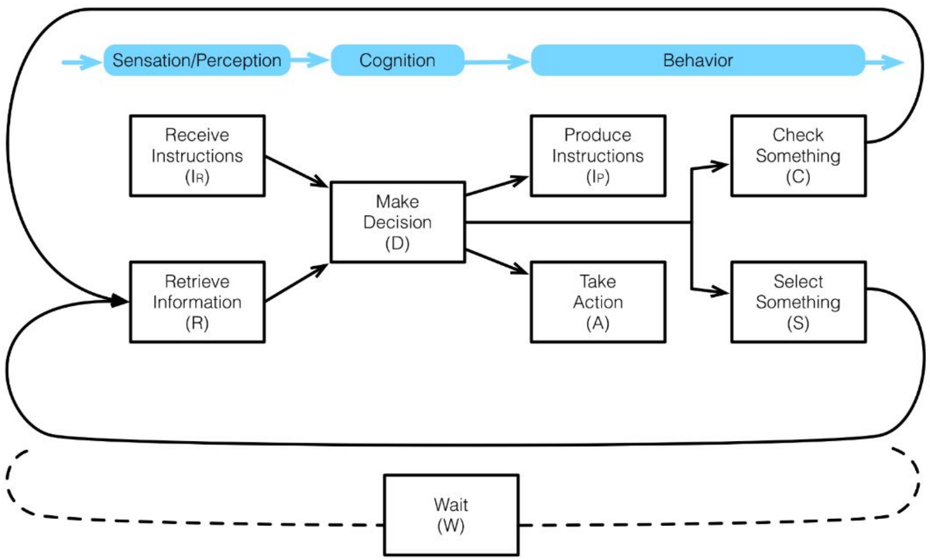
Original HUNTER Elements

- **Original HUNTER Addressed Three Main Concepts**

Concept	Purpose
GOMS-HRA	Taxonomy of task-level primitives that can be paired to operating procedures to provide base error rates and timing for each human action
PSF Autocalculation	Calculate modifiers on HEPs based on objective plant conditions that realistically change over an event
Dynamic Dependency	Method to aggregate HEPs across multiple tasks for backwards compatibility to static HRA

Original HUNTER Elements

- **GOMS-HRA**
  - GOMS (Goals-Operators-Methods-Selection rules) was method developed to support task analysis
  - GOMS-HRA is INL method to develop a taxonomy of basic elements of human performance



Term	Abbreviation	Definition
Task Level Primitive	TLP	A basic human operation occurring at the subtask level. Multiple operations are typically required to achieve specific actions and goals.
Procedure Level Primitive	PLP	A human activity occurring at the procedure step level. Often, multiple task level primitives will be required to achieve a procedure level primitive activity.
Task Level Error	TLE	A nominal human error associated with a task level primitive. Each task level primitives is associated with multiple possible task level errors.

Original HUNTER Elements

- **GOMS-HRA**
  - GOMS Task Level Primitives provide basic error rates, calibrated to THERP or SPAR-H

Operator	Description	Nominal HEP	THERP Source	Notes
A_C	Performing required physical actions on the control boards	0.001	20-12 (3)	Assume well-delineated controls
A_F	Performing required physical actions in the field	0.008	20-13 (4)	Assume series of controls
C_C	Looking for required information on the control boards	0.001	20-9 (3)	Assume well-delineated indicators
C_F	Looking for required information in the field	0.01	20-14 (4)	Assume unclear indication
R_C	Obtaining required information on the control boards	0.001	20-9 (3)	Assume well-delineated indicators
R_F	Obtaining required information in the field	0.01	20-14 (4)	Assume unclear indication
I_P	Producing verbal or written instructions	0.003	20-5 (1)	Assume omit a step
I_R	Receiving verbal or written instructions	0.001	20-8 (1)	Assume recall one item
S_C	Selecting or setting a value on the control boards	0.001	20-12 (9)	Assume rotary style control
S_F	Selecting or setting a value in the field	0.008	20-13 (4)	Assume series of controls
D_P	Making a decision based on procedures	0.001	20-3 (4)	Assume 30-minute rule
D_W	Making a decision without available procedures	0.01	20-1 (4)	Assume 30-minute rule

Original HUNTER Elements

- **GOMS-HRA**
  - GOMS also provides nominal timing data in addition to human error probabilities
  - Derived from studies conducted in INL's Human Systems Simulation Laboratory

Task-Level Primitive	Distribution	Mean (log scale)	Standard Deviation (log scale)	5th Percentile	95th Percentile
A_C	Lognormal	2.23	1.18	1.32	65.30
C_C	Lognormal	2.14	0.76	2.44	29.90
D_P	Exponential	0.02	N/A	2.62	152.80
I_P	Lognormal	2.46	0.76	3.35	40.70
I_R	Lognormal	1.92	0.93	1.47	31.80
R_C	Lognormal	2.11	0.60	3.08	21.90
S_C	Lognormal	2.93	1.11	3.01	115.60
W	Lognormal	2.66	1.26	1.79	113.60

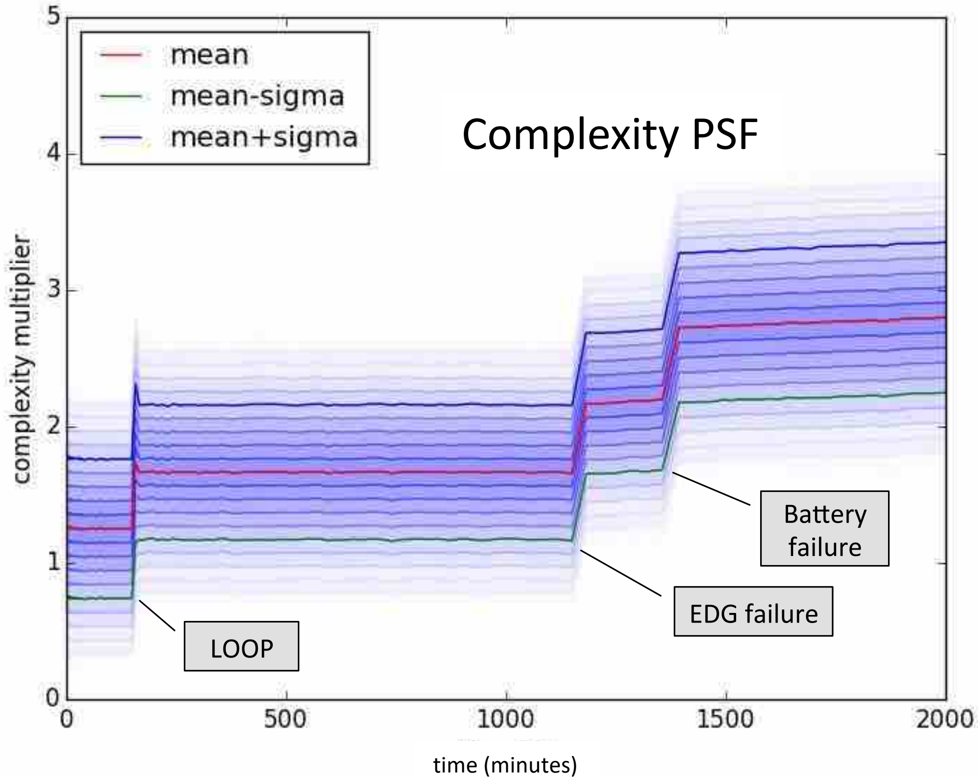
Original HUNTER Elements

- **GOMS-HRA**
  - GOMS Task Level Errors map common types of errors that occur

TLP	Task Level Errors
A	TLE-A1: Failure to execute desired action TLE-A2: Execute desired action incorrectly
C	TLE-C1: Wrong information checked TLE-C2: Information missed TLE-C3: Information misinterpreted TLE-C4: Failure to check information
R	TLE-R1: Information not attended to TLE-R2: Information not perceived TLE-R3: Information misinterpreted
I_P	TLE-IP1: Failure to produce desired communication TLE-IP2: Failure to produce correct communication
I_R	TLE-IR1: Communication not attended to TLE-IR2: Communication not perceived TLE-IR3: Communication misinterpreted
S	TLE-S1: Failure to select TLE-S2: Selection make incorrectly
D	TLE-D1: Incorrect goals or priorities TLE-D2: Incorrect use of information TLE-D3: Incorrect mental model
W	TLE-W1: Incorrect inaction TLE-W2: Waiting too long TLE-W3: Waiting too short

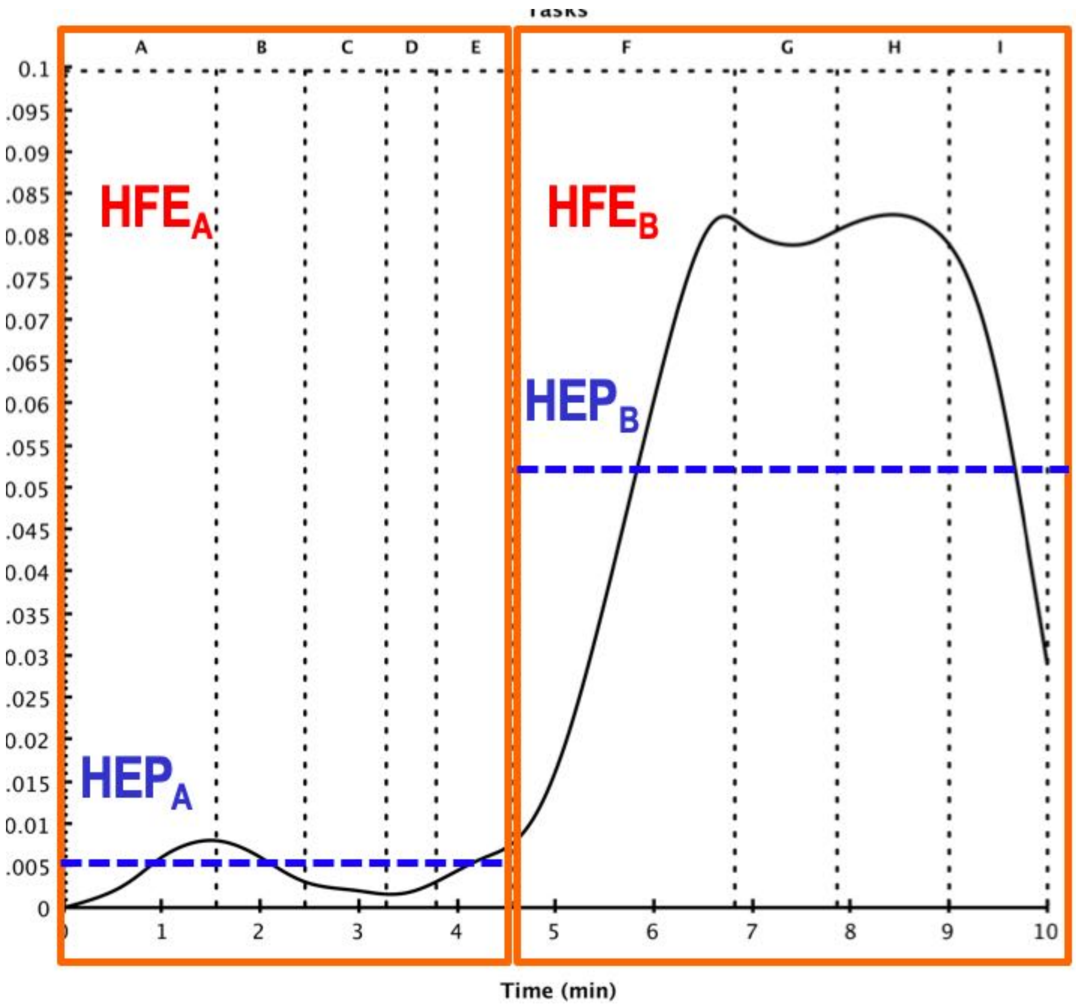
Original HUNTER Elements

- **Autocalculation of SPAR-H Performance Shaping Factors (PSFs)**
  - Use plant parameters to calculate influence of PSF on the nominal error rate
  - PSF is calculated without analyst intervention



Original HUNTER Framework

- **HUNTER Mapping of Dynamic Dependency**
  - Dynamic HRA consists of continuous not discrete action sequences
  - Traditional static ways of calculating discrete human error probabilities (HEPs) for human failure events (HFEs) may not carry over to dynamic models



Original HUNTER Framework

- **HUNTER Mapping of Dynamic Dependency**
  - What are the effects of one task on another?
  - PSFs do not just turn on and off; they lag and linger

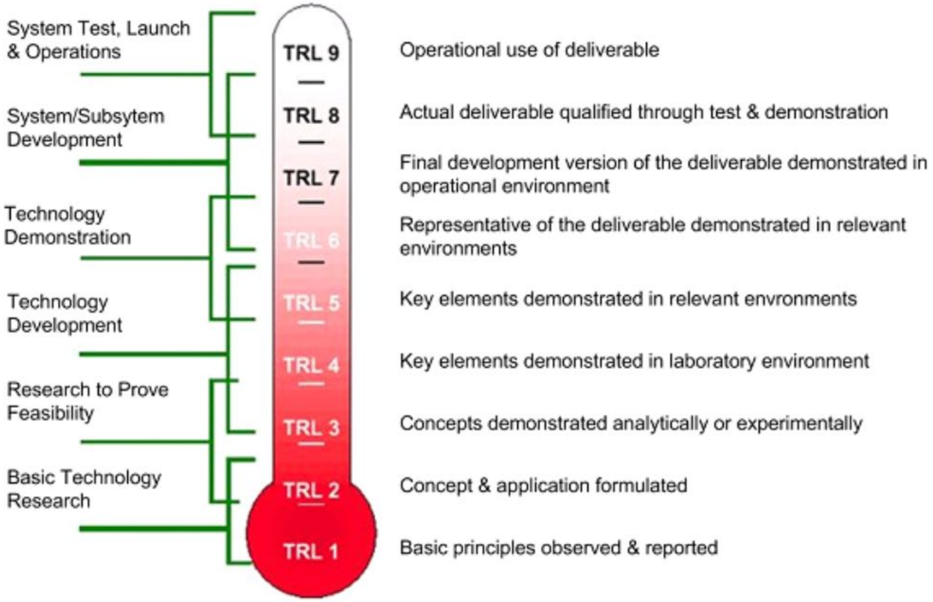
Dynamic PSF Function	Effect on PSF	Notation
lag	A PSF will be slow to change at the outset of a new effect	$PSF(t_{i+1}) = \lim_{t \to t_{i+1}}{}^{-} PSF(t)$
linger	A PSF will be slow to change at the termination of an existing effect	$PSF(t_{i+1}) = \lim_{t \to t_{i+1}}{}^{+} PSF(t)$
memory	General 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	$PSF(t) = PSF(0) \quad for\ t \gg t_N$

New HUNTER Developments

Toward HUNTER 2.0

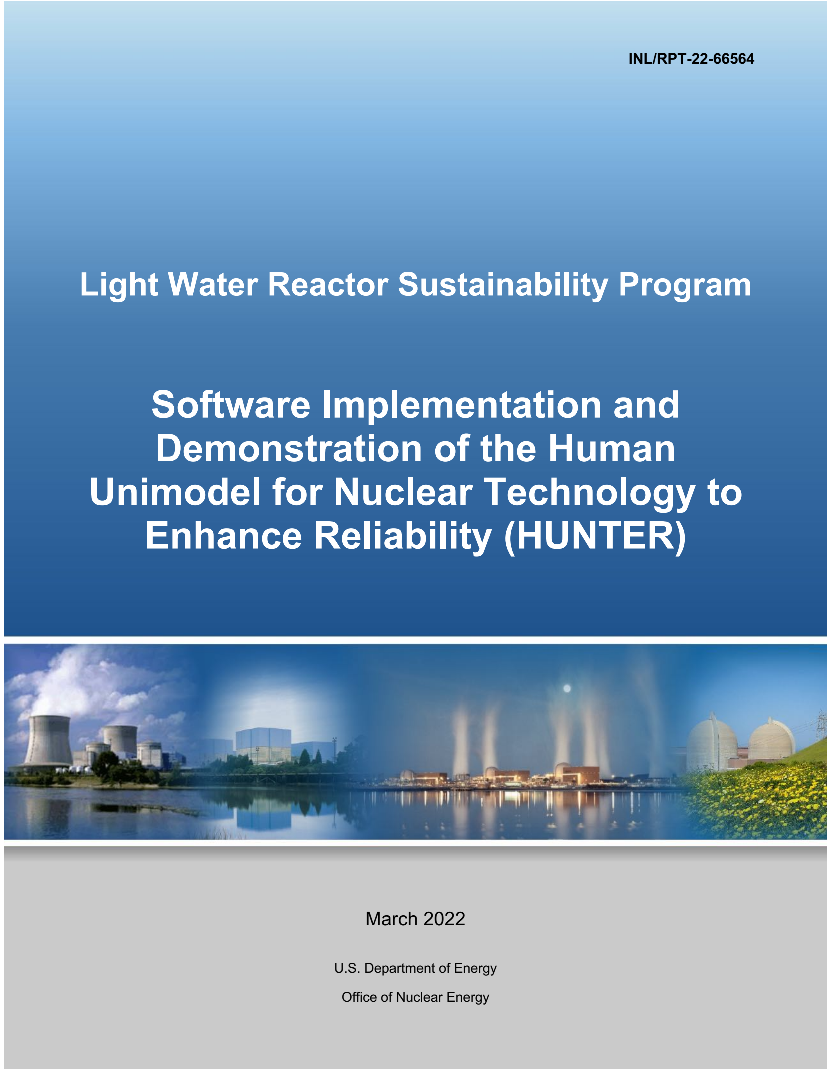
- **The Original HUNTER was a Disparate Collection of Research Tools**

- **A Review of the Technology Readiness Level of HUNTER Suggested These Parts Were Mature, but the Overall Tool Was Not Complete**
  - HUNTER needs to be developed as a standalone software program
  - HUNTER needs to have a library of analyses
  - Addressing these issues will help make HUNTER a useful tool for human reliability analysts



Toward HUNTER 2.0

- **New HUNTER Developments**
  - Captured in report released by DOE LWRS in March 2022
  - Includes refined overall framework
  - Standalone software
    - Emphasis on simplified graphical user interface that promotes ease of use
  - New use case to demonstrate capabilities
  - Clear delineation between HUNTER dynamic HRA and dynamic PRA software like EMRALD


INL/RPT-22-66564

Light Water Reactor Sustainability Program

Software Implementation and Demonstration of the Human Unimodel for Nuclear Technology to Enhance Reliability (HUNTER)

March 2022

U.S. Department of Energy

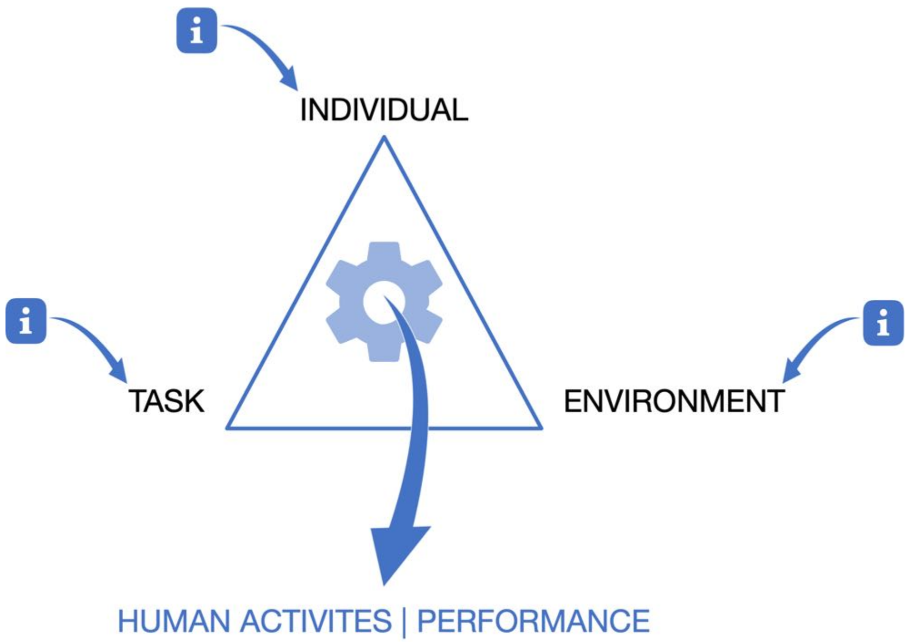
Office of Nuclear Energy

Toward HUNTER 2.0

- **Software Architecture Emphasizes Adaptability**
  - ***Flexible***
    - HUNTER should be able to model a variety of applications
    - From main control room to balance of plant
    - Much of the advantage of dynamic HRA may be realized in areas not yet captured by static HRA
  - ***Modular***
    - HUNTER code should not be fixed to one HRA method
    - Initial efforts have centered on SPAR-H and new GOMS-HRA
    - Should be able to align with other HRA methods like IDHEAS or IDAC
  - ***Scalable***
    - Features can be added in the future as they are developed
    - Features can be turned on or off depending on the granularity of analysis

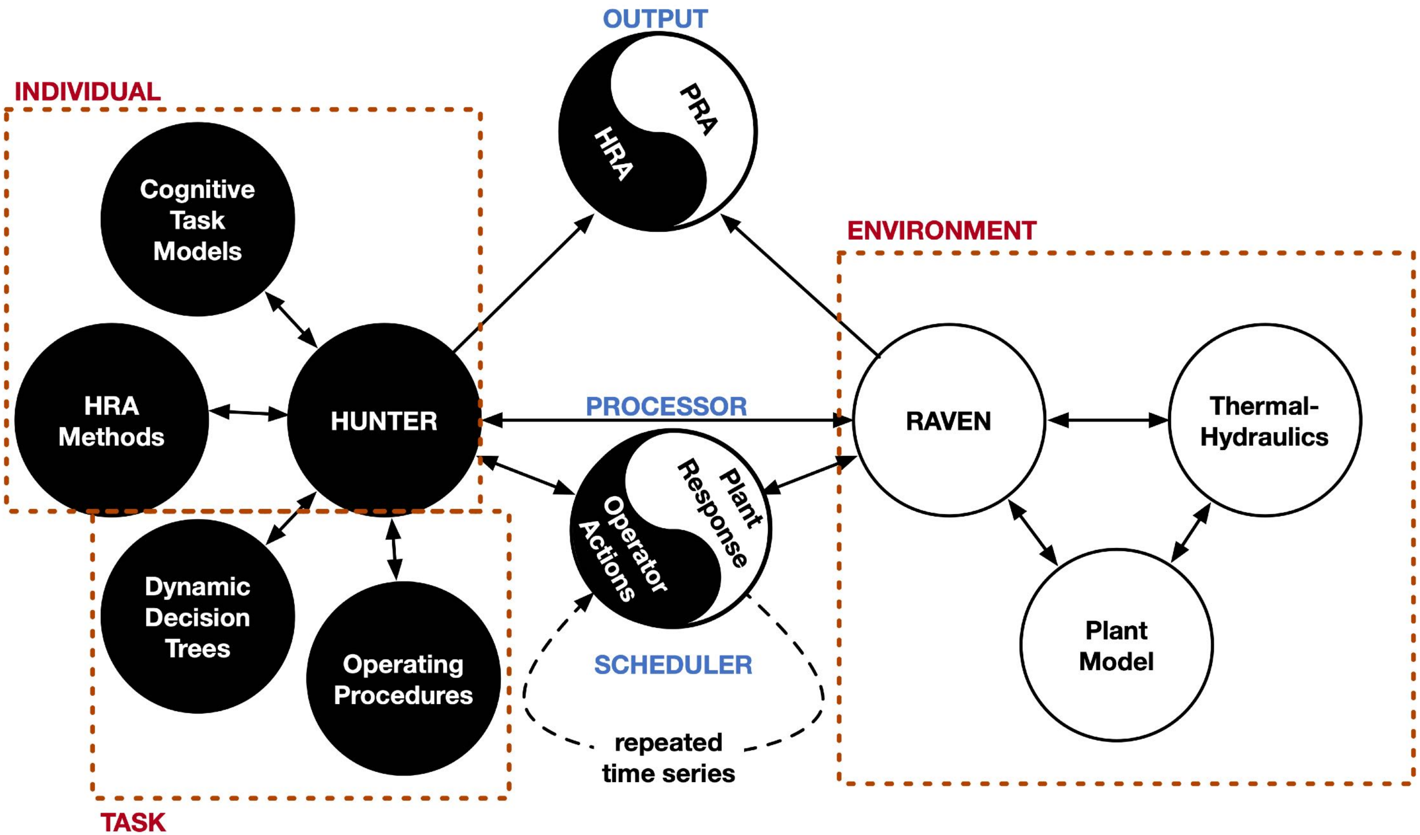
Toward HUNTER 2.0

- **New Conceptual Model**
  - Three basic modules
    - **Individual**: What affects person performing the task (PSFs)
    - **Task**: What task is being performed (procedures)
    - **Environment**: What system is being used (plant model)



Toward HUNTER 2.0

- **HUNTER 2.0 Maps to the Original HUNTER**
  - Note that blue are support classes



LWRS LIGHT WATER REACTOR SUSTAINABILITY

Toward HUNTER 2.0

- **Task Module**
  - Built on plant operating procedures (task = procedure step)
    - Steps mapped to GOMS-HRA task level primitives
    - Steps have input and output to environment such as controls and indicators
  - Logic to handle if-then and response not obtained

stepNumber	isRno	stepText	branchStep	branchProcedure	procedureExit	simulationExit	withinTarget
1		Verify Reactor Trip					TRUE
2		Check Turbine Trip - ALL THROTTLE VALVES SHUT					TRUE
3		PERFORM the following:					TRUE
3							TRUE
4		Safety Injection - ACTUATED (BOTH TRAINS)					TRUE
5		Evaluate EAL Matrix.					TRUE
6		Verify CSIPs - ALL RUNNING					TRUE
7		Verify RHR Pumps - ALL RUNNING					TRUE
8		Safety Injection flow - GREATER THAN 200 GPM					TRUE
9		RCS Pressure - LESS THAN 230 PSIG					
9	TRUE	GO TO Step 12.	12				TRUE
12		Main Steam Line Isolation - ACTUATED					
12	TRUE	Perform the following:					TRUE
12	TRUE		16				FALSE
12	TRUE						TRUE
16		Check CNMT Pressure - HAS REMAINED LESS THAN 10 PSIG					TRUE
17		Verify AFW flow - AT LEAST 210 KPPH ESTABLISHED					TRUE
18		Sequencer Load Block 9 (Manual Loading Permissive) - ACTUATED (BOTH TRAINS)					TRUE
19		Energize AC buses 1A1 AND 1B1.					TRUE
20		Verify Alignment Of Components From Actuation Of ESFAS Signals Using Attachment 3, "Safeguards Actuation Verification", While Continuing With This Procedure.					TRUE
21		Stabilize AND Maintain Temperature Between 555F AND 559F Using Table 1.					TRUE
22		PRZ PORVs - SHUT					TRUE
23		PRZ Spray Valves - SHUT					TRUE
24		PRZ PORV Block Valves - AT LEAST ONE OPEN					TRUE
25		Any SG pressure - DROPPING IN AN UNCONTROLLED MANNER OR COMPLETELY DEPRESSURIZED					
25	TRUE	GO TO Step 27.	27				TRUE
27		Any SG - ABNORMAL RADIATION OR UNCONTROLLED LEVEL RISE					TRUE
28		Check Feed Flow To Ruptured SG(s) - ISOLATED					TRUE
29		GO TO E-3, "STEAM GENERATOR TUBE RUPTURE", Step 1.		EOP-3	TRUE	TRUE	TRUE

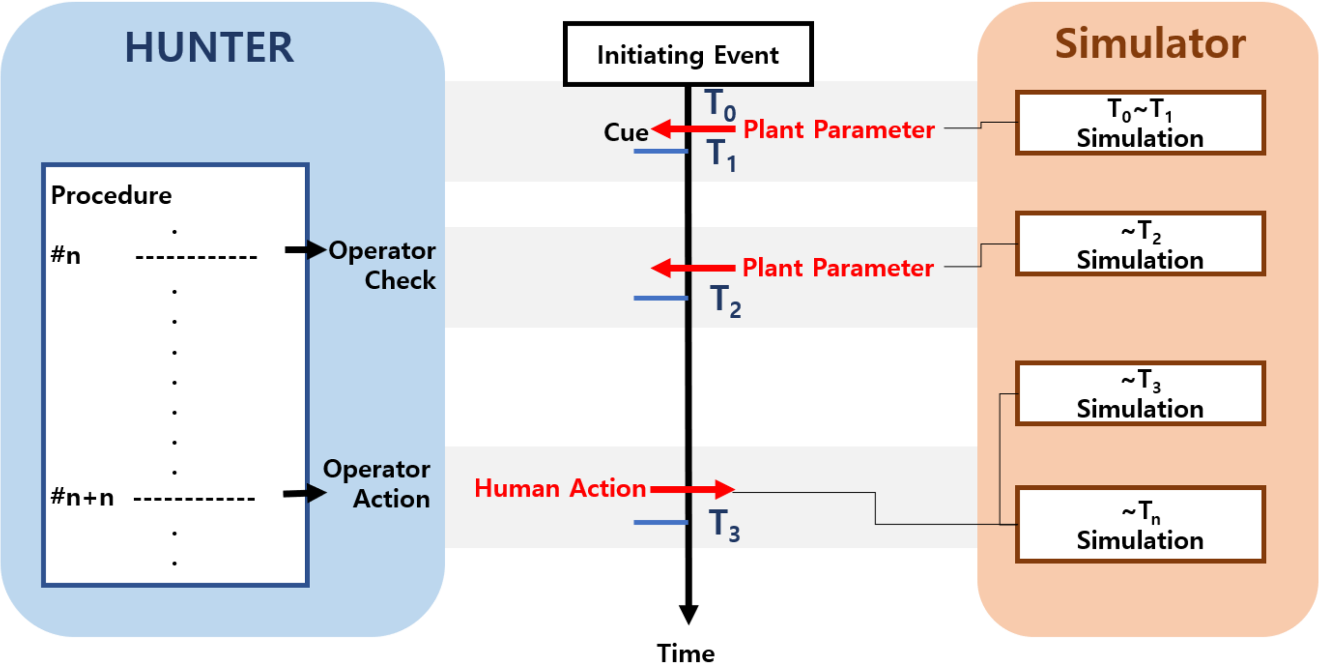
Toward HUNTER 2.0

- **Individual Module**
  - Currently handles PSFs based on SPAR-H
  - Dynamic implementations for Stress, Fitness for Duty (Fatigue), and Available Time
    - Not all PSFs lend themselves to dynamic assignment, but may have trigger points (e.g., upset event at plant)
    - Even manually triggered PSFs may have lag and linger effects

		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 level of the PSF is automatically assigned, and static (i.e., predefined) multipliers are applied for each level.
	Dynamic	The level of the PSF is manually assigned, but the multiplier is automatically calculated (e.g., adjusted for lag and linger effects).	The level of the PSF is automatically assigned and the PSF multiplier is autocalculated.

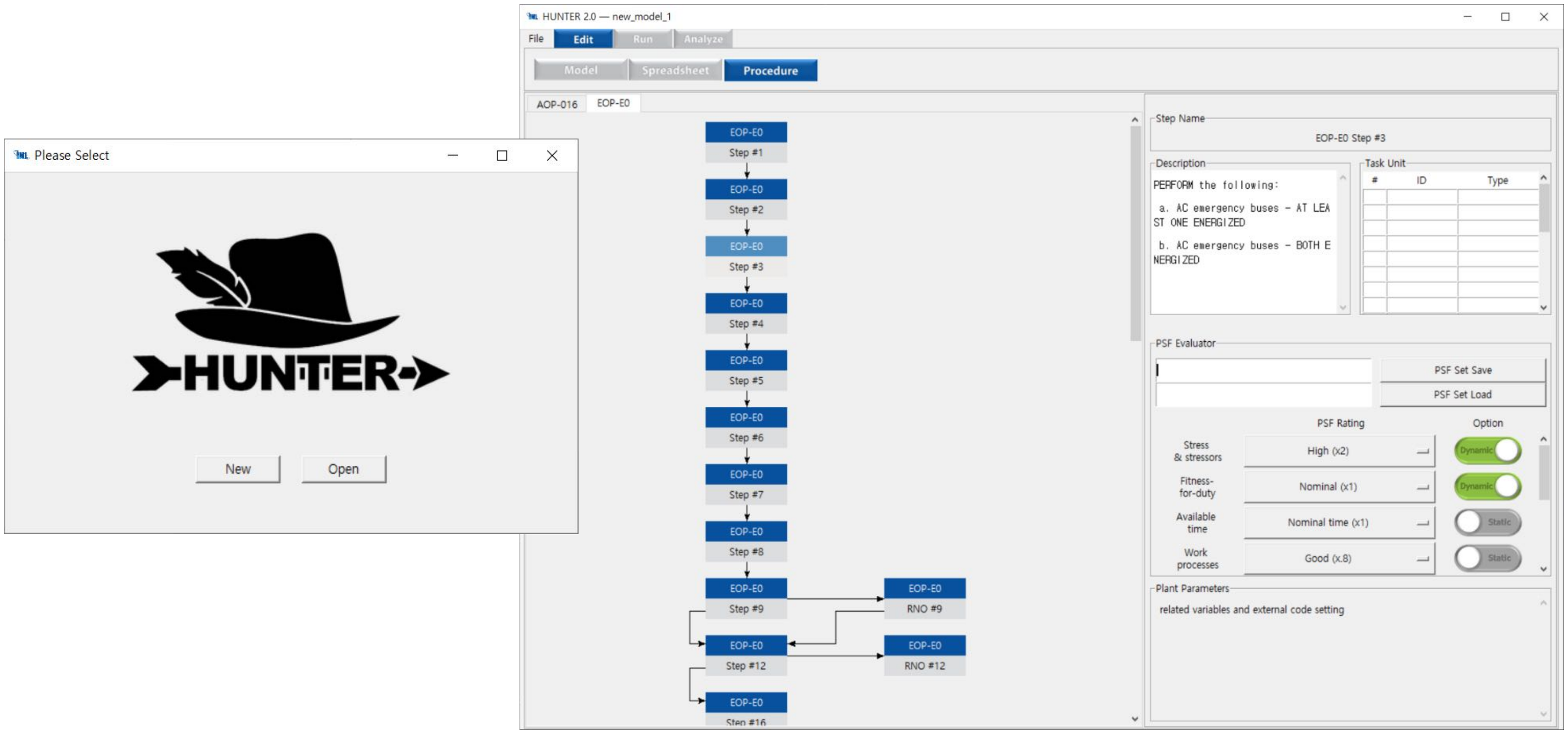
Toward HUNTER 2.0

- **Environment Module**
  - HUNTER represents a virtual operator who must interact with a virtual world
  - Current focus has been on coupling HUNTER with RELAP5-3D thermalhydraulics
  - Tight coupling means operator action triggers change in model and operator responds to changes in plant parameters



Toward HUNTER 2.0

- **Graphical User Interface**
  - Python-based code that integrates various parts of HUNTER



Sample HUNTER Outputs

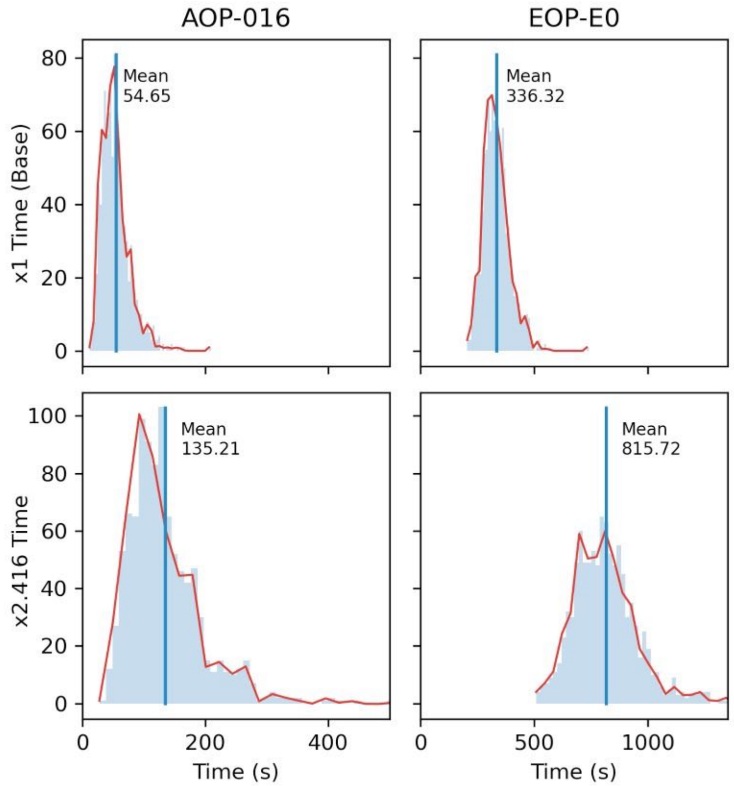
Example SGTR

- **Modeled Steam Generator Tube Rupture**
  - Example scenario well documented in HRA (e.g., *International HRA Empirical Study,* NUREG/IA-0216)
  - Scenario frequently run in INL's simulator with available log parameters for validation
  - Example presented here is from NUREG/IA-0216
    - Focus on modeling simple (HFE-1A) and complex (HFE-1B) identification and isolation of ruptured steam generator

HFE	Descriptions	Base case	Complex case
HFE-1	Failure to identify and isolate the ruptured SG	HFE-1A	HFE-1B
HFE-2	Failure to cool down the RCS expeditiously	HFE-2A	HFE-2A
HFE-3	Failure to depressurize the RCS expeditiously	HFE-3A	HFE-3B
HFE-4	Failure to stop the safety injection (SI)	HFE-4A	N/A
HFE-5	Failure to give a closing order to the PORV block valve	N/A	HFE-5B1 HFE-5B2

Example SGTR

- **Modeled Steam Generator Tube Rupture**
  - Time for simple and complex scenarios



	Mean Time (s)		
	Basic	Complex	
NUREG/IA-0216	370	894	
HUNTER	391	951	×2.416 Time

Next Steps

Future Developments in HUNTER

- **Task Module**
  - Auto parsing of PDF procedures to populate more scenarios
  - Building decision-making module using cognitive modeling
  - Building continuous actions
- **Individual Module**
  - More PSFs modeled
  - Expanding PSFs with effects for both time and error
- **Environment Module**
  - Coupling HUNTER with additional external codes
    - Rancor Microworld Simulator
    - GSE Systems Generic Pressurized Water Reactor (GPWR)
- **Other**
  - Population of greater number of scenarios
    - HRA for novel applications like design and procedure verification and first-of-a-kind steam extraction
    - Reusable scenarios to benefit industry
  - Consideration of other HRA methods beyond underlying SPAR-H
    - IDHEAS? Phoenix? Petro-HRA?

How You Can Help

- **What modeling scenarios are not currently being covered that we can use for demonstrations?**
  - We are not trying to replace static HRA—just enhance it where it makes sense
- **What analysis outputs other than HEPs are needed?**
- **What software does HUNTER need to integrate with to be useful?**
  - Simulators?
  - PRA software?

Questions?

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