Digital Development and Analysis of SOPs

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Background

What is Standard Operating Procedures?

- Standard Operating Procedures (SOPs) are a set of rules & guidelines for operating a complex system
- SOPs is a framework for executing task & processes:
  - What must be accomplished?
    - Each operator action that must be executed in a sequence
  - When (under what conditions)?
  - Who is responsible for each step?
  - How each step is performed?
  - How to confirm that the step was performed?
- Procedures for operators play crucial role in its effectiveness

The Problem with SOPs

1. Missing imperative steps in the SOPs due to automatic level of consciousness
2. WHAT must be done is specified, but not WHEN
3. Information required to perform the next step is not available
4. Race conditions – information not available in a timely manner
5. Procedure cannot be completed in time (i.e., before a hazardous event)
6. Procedure difficult to learn due to user-interface cues
7. Poor procedural training
8. No procedure for the scenario
9. Procedures across System-of-Systems are not compatible

Objective Overview

- A methodology and digital tool are needed to ensure the inclusion of the operator in the development and revision of Standard Operating Procedures (SOPs)
- Following three main goals to apply MBSE activities to improve SOP development:
  - Digitize SOPs in a database
  - Perform modeling, simulation, and analysis of SOPs
  - Verify and validate each SOP can be performed as intended

Need

There is a growing need to improve aviation safety following recent airliner accidents. The following areas are candidates for improved SOPs:

NASA Applications:

General Areas include:

- Mission Control
- Launch Procedures
- Extravehicular Activities (EVA) procedures
- Space & Aircraft Maintenance Procedures
- Medical Procedures

Other Applications:

Some of the organizations that have expressed interest in digital assistants include:

- Swiss International Air Lines
- Southwest Airlines
- United Airlines
- Boeing Commercial Aircraft Group (BCAG)
- Honeywell Technology Center
- Rockwell Collins
- U.S. Navy- Strategic Warfare Systems

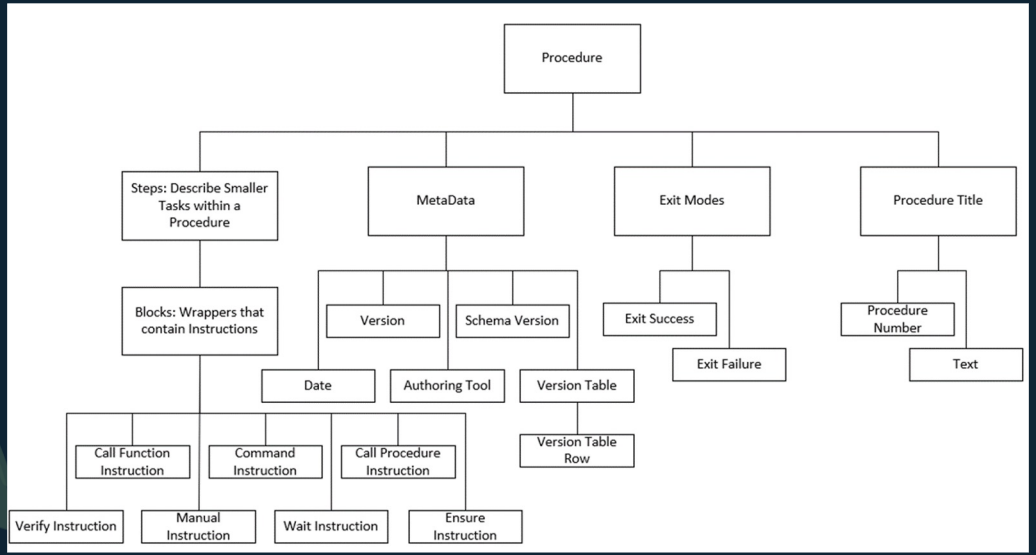
Context

SOP Step Model

- SOP steps are governed by the SOP Step Model
  - Designed to reflect steps involved in operator cognition to Observe, Orient, Decide, and Act
- **Observe**: Operator senses triggering information
  - Changes in environment
  - Changes in plant
- **Orient:** Information is coupled with pre-existing knowledge and mental models
- **Decide:** Formulate an appropriate response or decision
- **Act:** Perform an action or response that was decided
- SOP Step Model will depend on process based on innovative approach of procedural representative language (PRL)

Procedure Representation Language

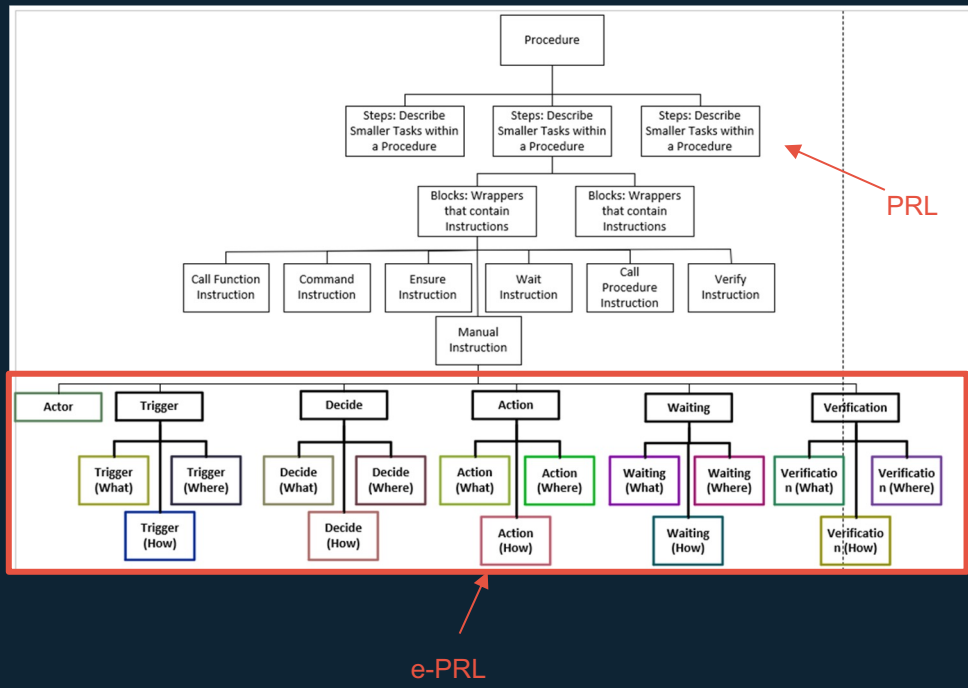
- Formal representation of procedures
- XML Schema Structure
- Instructions
  - Lowest level of abstraction
- Manual Instruction
  - Used for commands that must be completed by the human operator
- No underlying structure to the manual instruction



Kortenkamp, David et al. 2007

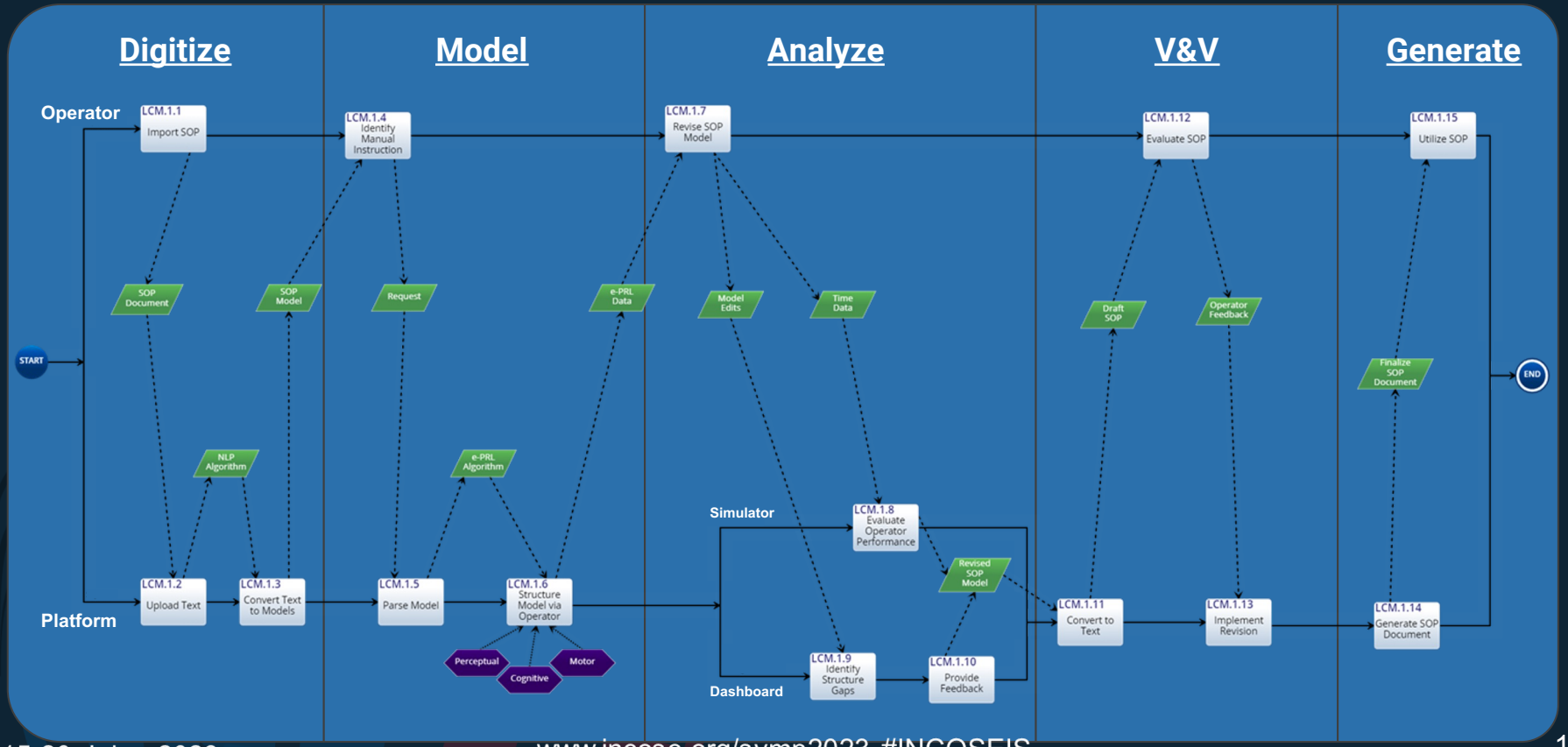
Extended PRL (e-PRL)

- Extended PRL (e-PRL) is based on the canonical structure of SOPs using a Human-Machine Interface (HMI)
  - HMI focuses on cognitive, perceptual, and motor interactions between the human and the machine
- Each SOP component has the following:
  - **Trigger (Perceptual):** Events that prompt the operator to take action
  - **Decision (Cognitive):** Making a decision based on the information available to the operator
  - **Action (Motor):** Operator takes in the response to the trigger and decision
  - **Waiting/Time (Perceptual):** Waiting for a specific amount of time before taking action
  - **Verification (Perceptual):** Verifying the action taken is correct & completed successfully
- Each of the five components has elements that define the data and the source of the data



MBSE for SOP Development and Analysis

To-Be Concept of Operations



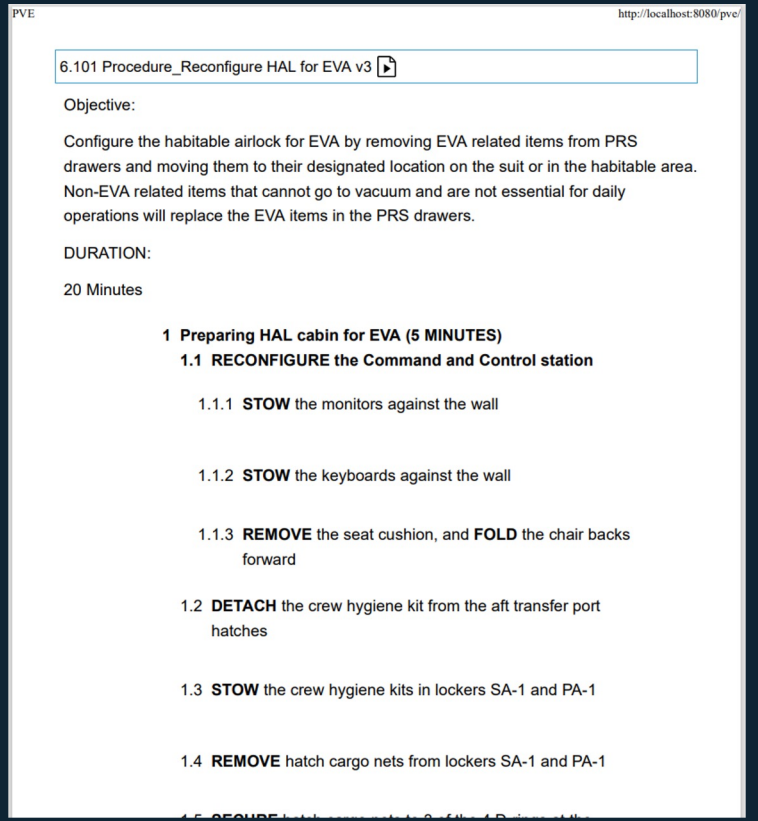
Digitizing SOPs

Digitization Approach

- SOPs need to be digitized in a database by importing and parsing using NLP rules to consider:
  a. Actors
  b. Actions of Actors/Operators
  c. Cues from:
     - Output Displays
     - Environment
  d. Input Devices
- NLP can incorporate the Extended Procedural Representative Language (e-PRL) to identify elements in each step and improve converting textual documents into a database

Formatting SOP

- An importer and parser will be required to import SOP documents to a database
- Each document will be processed using NLP & e-PRL algorithm
  - **NLP Algorithm**: Parses into document components such as title, number, objective, steps, etc.
  - **e-PRL Algorithm**: Parses manual operator instructions into e-PRL components


PVE http://localhost:8080/pve/

6.101 Procedure_Reconfigure HAL for EVA v3

Objective:

Configure the habitable airlock for EVA by removing EVA related items from PRS drawers and moving them to their designated location on the suit or in the habitable area. Non-EVA related items that cannot go to vacuum and are not essential for daily operations will replace the EVA items in the PRS drawers.

DURATION:

20 Minutes

1 Preparing HAL cabin for EVA (5 MINUTES)

1.1 RECONFIGURE the Command and Control station

1.1.1 **STOW** the monitors against the wall

1.1.2 **STOW** the keyboards against the wall

1.1.3 **REMOVE** the seat cushion, and **FOLD** the chair backs forward

1.2 **DETACH** the crew hygiene kit from the aft transfer port hatches

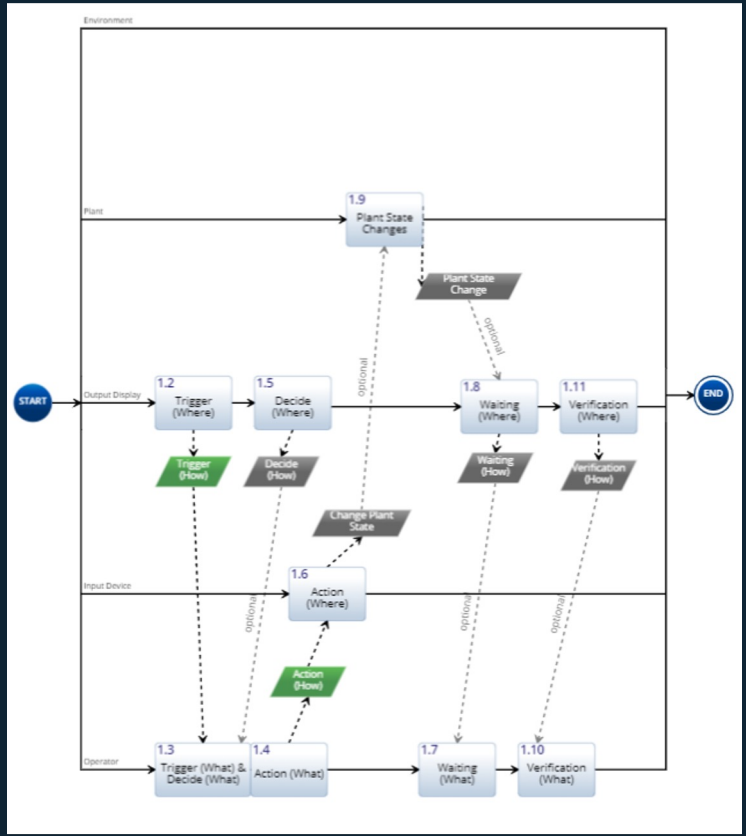
1.3 **STOW** the crew hygiene kits in lockers SA-1 and PA-1

1.4 **REMOVE** hatch cargo nets from lockers SA-1 and PA-1

Modeling SOPs

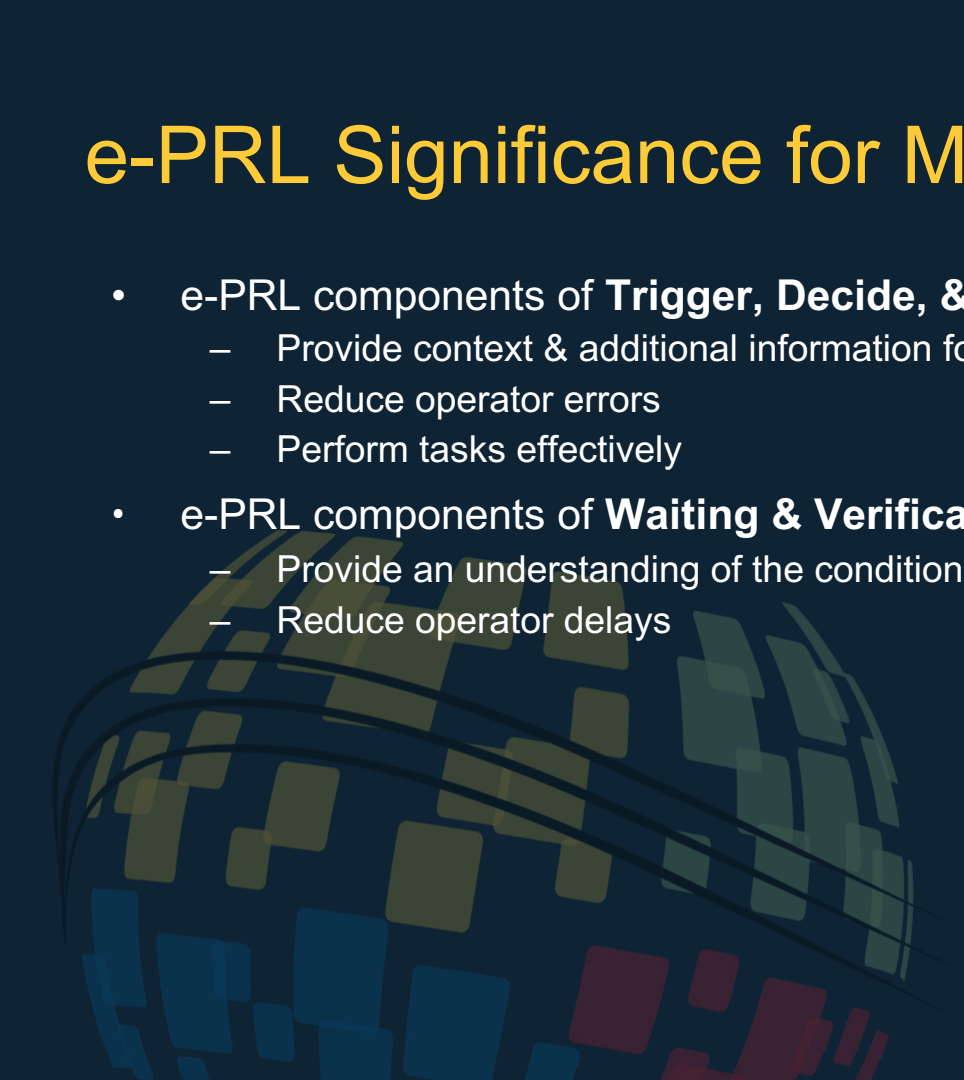
e-PRL Standard with Models

- Models will identify e-PRL components and HMI elements
- e-PRL's canonical structure will assist the NLP algorithm in accurately identifying operator's cognitive behavior
  - Annotations will aid in recognizing patterns & classifying e-PRL components
- e-PRL will provide a standardized format for creating the models using HMI elements
  - What
  - How
  - Where



e-PRL Significance for Modeling

- e-PRL components of **Trigger, Decide, & Action** assist on:
  - Provide context & additional information for the operator
  - Reduce operator errors
  - Perform tasks effectively
- e-PRL components of **Waiting & Verification** will assist on:
  - Provide an understanding of the conditions to proceed to the next procedure
  - Reduce operator delays



Customize and Review Models

- Can be viewed and changed to ensure it's correctness
- Process Model will be presented in a hierarchical structure similar to the imported textual SOP
- Allow operators and users to include any missing context and/or data

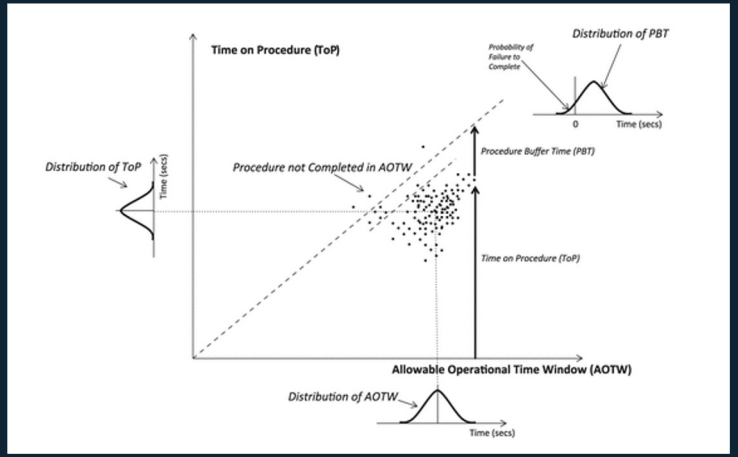
Analyzing SOPs

Operator Performance for SOPs

- Currently, SOP development and revision excludes the operator's performance
- SOPs that include operator's the performance could lead to:
  - **Consistency:** Operators perform the task in a consistent manner
  - **Accuracy:** Operator allocates the appropriate amount of time
  - **Training:** Provides a benchmark to evaluate performance & help identify areas for help
- Incorporating operator performance will be a key when revising SOPs

Operator Performance Approach

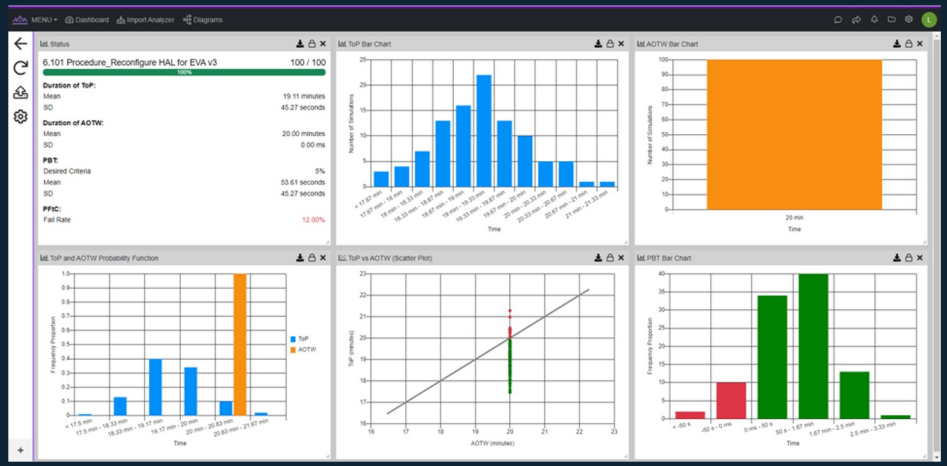
- Time metrics will be used to aid in providing data of the operator's performance in SOPs
- Time metric will include:
  - **Allowable Operational Time Window (AOTW)**
    - Time that the SOP must be completed within the time window to avoid any hazards
  - **Time of Procedure (ToP)**
    - Time it takes to complete the procedure
  - **Procedure Buffer Time (PBT)**
    - Difference between AOTW & ToP
    - Value < 0, then the Procedure is not feasible
- Operator will be needed to input time distribution data
- Time metrics will provide a high-level view to find the operator's performance gaps



Monte Carlo Simulation

- Time metrics can be added to procedure entities by the user
- Monte Carlo can run multiple iterations to assess the feasibility of tasks with the operator
- Monte Carlo utilizes time metrics (AOTW, ToP, PBT) to evaluate an operator's performance in the SOP
- Monte Carlo simulation allows operators:
  - Insight into factors that contribute to good/bad performance
  - To develop strategies to improve the SOP

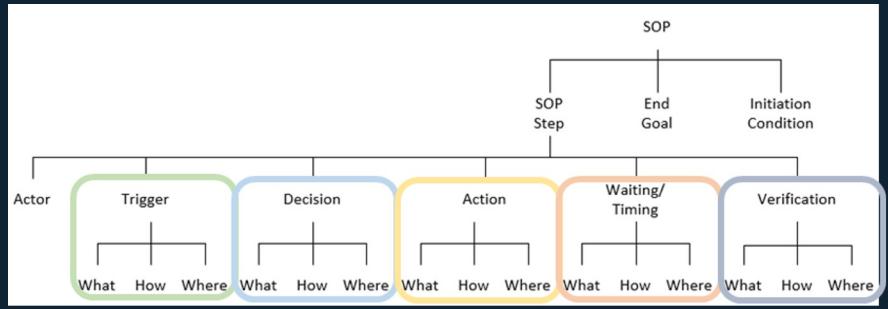
Monte Carlo View for Operator Performance



Structure of SOP Steps

- Each e-PRL component correlates with HMI to provide an step structure type:
    1. Action-ONLY Steps
        - **Includes:** Trigger & Action ePRL components
    2. Decision-Action Steps
        - **Includes:** Trigger, Decision, & Action ePRL components
    3. Action w/ Waiting and Verification Steps
        - **Includes:** Trigger, Action, Waiting, & Verification ePRL components
    4. Decision-Action w/ Waiting & Verification Steps
        - **Includes:** Trigger, Decide, Action, Waiting, & Verification ePRL elements
- e-PRL step structure cognitively aligned with how operators perceive, decide, and take actions in real-world scenarios
- e-PRL step structure shall provide:
    a. **Clarity**: Allows operator to find information efficiently
    b. **Consistency**: Reduce confusion and update easily

Extended PRL Examples



SOP Step Types:

1. Action Only steps
   - Trigger-Action:

[*When FUEL PMP STAB L and R messages are displayed*], [push both Stabilizer tank L and R switches off].

2. Decision Steps
   - Trigger-Decision-Action:

[*After initiating takeoff roll*], [***If the crosswind is at or below 20 knots:***] [Apply half forward stick].

3. Action with Waiting & Verification Steps
   - Trigger-Action-Waiting-Verification:

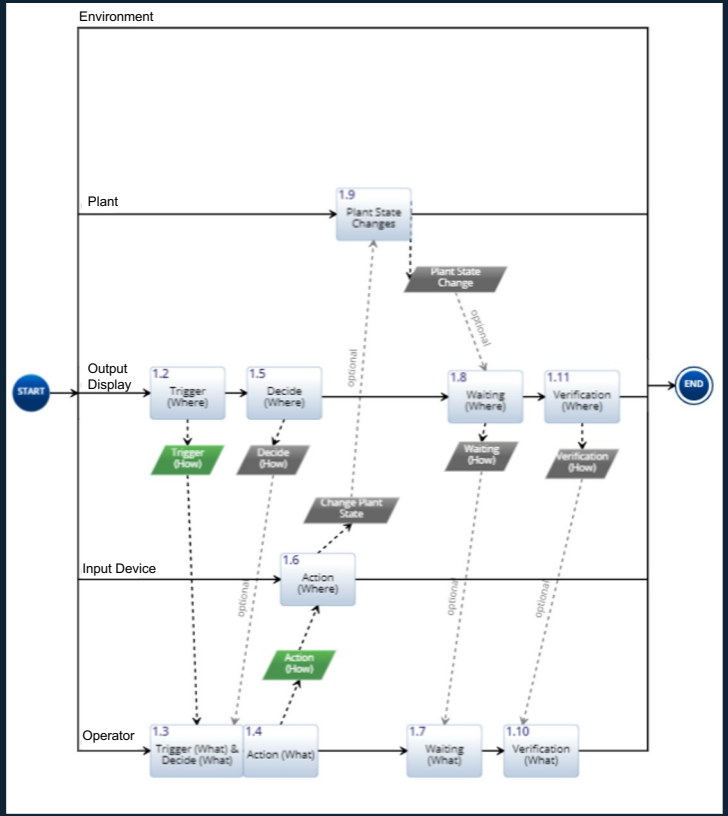
[*(After completion of previous step)*], [STANDBY POWER selector ……. BAT]. [**Verify EICAS advisory messages BAT DISCH MAIN and BAT DISCH APU display**]. [Messages may take up to 3 minutes to display].

4. Decision with Waiting & Verification Steps
   - Trigger-Decision-Action-Waiting-Verification:

[(After completion of previous step)][If external power desired],[push EXTERNAL POWER 1 switch]. [(Instantaneous)] [**Then verify ON light illuminated**].

SOP Structure Analysis

- e-PRL step structure can be utilized by heuristics to identify and analyze gaps
- Operators can provided feedback based on heuristics
- Each heuristic will determine if the model follows the proper structure between HMI elements & e-PRL components
- This analysis shall allow operators to:
  - Identify proper relationship
  - Locate and fix gaps
  - View data analytics of SOP structure



Verifying and Validating SOPs

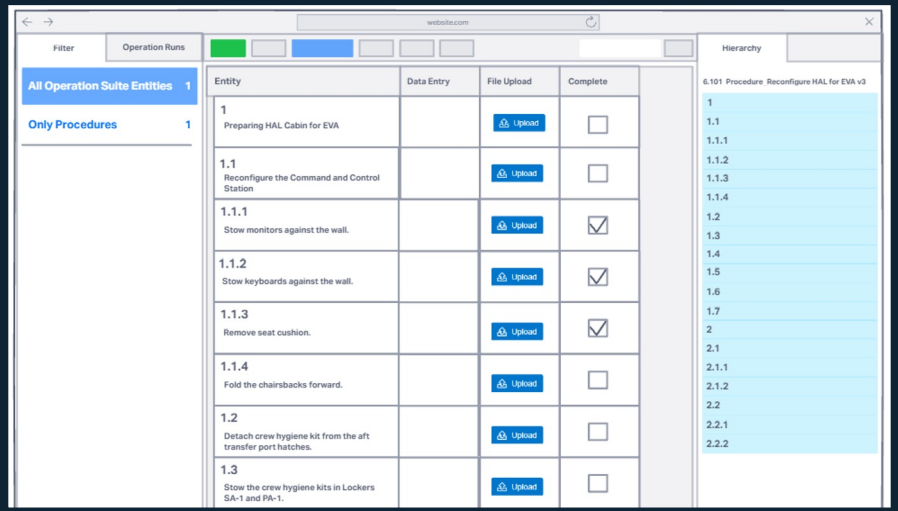
V&V SOPs

- Why?
  - SOP revisions need to be verified and validated
  - Ensure the content is accurate and relevant
  - The revision made are consistent & DO NOT disrupt the flow or cause confusion
- Approach
  - Current version of the model will be converted back text into an operational dashboard
  - The dashboard will be a text-based checklist for the operator to re-run
  - Operators can provide inputs related to performance, notes, and completion for each step

Operation Center

- The proposed view will allow the operator to perform and track the performance of SOPs
  - Track multiple runs in a single view
- View and track in real-time
- Monitor performance to identify areas for improvement
- Ensure SOP is followed correctly & consistently
- Provide a central repository for revisions and associated data

Operation Center Dashboard:



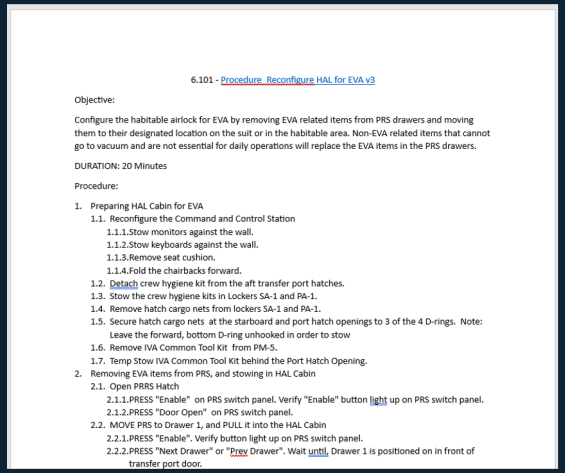
Generating SOPs

Output Approach

- Sentences will be generated for each e-PRL SOP step type based on it's e-PRL elements
  1. Action-ONLY Steps
  2. Decision-Action Steps
  3. Action w/ Waiting and Verification Steps
  4. Decision-Action w/ Waiting & Verification Steps
- Each SOP step type has a sentence template that formats e-PRL element syntax & language
- Output structure is going to assist operators with:
  - Concise and coherent procedure steps
  - Provide analytics for future revisions

Final SOP Document

- Once the SOP is approved and tested the operator will receive two documentations
  i. Finalized SOP Document
     - Contains the revised procedures
  ii. SOP Data Analytic Document
     - Contains the data on operator performance & procedure structure
- This process shall:
  i. Provide data and feedback on revisions
  ii. Make aware of changes within the procedure
  iii. Set a process for ongoing review and improvement



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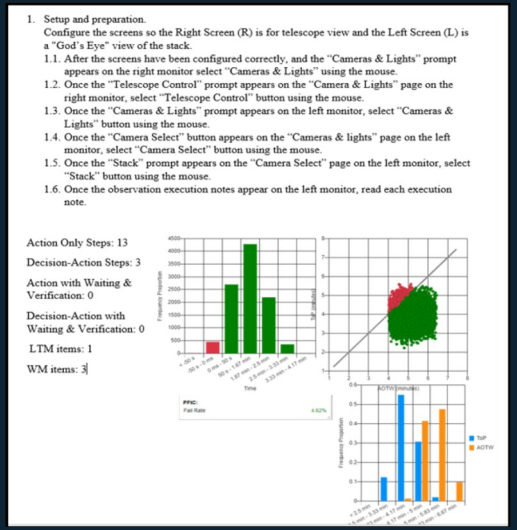
DURATION: 20 Minutes

Procedure:

1. Preparing HAL Cabin for EVA
   1.1. Reconfigure the Command and Control Station
      1.1.1.Stow monitors against the wall.
      1.1.2.Stow keyboards against the wall.
      1.1.3.Remove seat cushion.
      1.1.4.Fold the chairbacks forward.
   1.2. Detach crew hygiene kit from the aft transfer port hatches.
   1.3. Stow the crew hygiene kits in Lockers SA-1 and PA-1.
   1.4. Remove hatch cargo nets from lockers SA-1 and PA-1.
   1.5. Secure hatch cargo nets at the starboard and port hatch openings to 3 of the 4 D-rings. Note: Leave the forward, bottom D-ring unhooked in order to stow
   1.6. Remove IVA Common Tool Kit from PM-5.
   1.7. Temp Stow IVA Common Tool Kit behind the Port Hatch Opening.
2. Removing EVA items from PRS, and stowing in HAL Cabin
   2.1. Open PRRS Hatch
      2.1.1.PRESS "Enable" on PRS switch panel. Verify "Enable" button light up on PRS switch panel.
      2.1.2.PRESS "Door Open" on PRS switch panel.
   2.2. MOVE PRS to Drawer 1, and PULL it into the HAL Cabin
      2.2.1.PRESS "Enable". Verify button light up on PRS switch panel.
      2.2.2.PRESS "Next Drawer" or "Prev Drawer". Wait until, Drawer 1 is positioned on in front of transfer port door.



1. Setup and preparation.
   Configure the screens so the Right Screen (R) is for telescope view and the Left Screen (L) is a "God's Eye" view of the stack.
   1.1. After the screens have been configured correctly, and the "Cameras & Lights" prompt appears on the right monitor select "Cameras & Lights" using the mouse.
   1.2. Once the "Telescope Control" prompt appears on the "Camera & Lights" page on the right monitor, select "Telescope Control" button using the mouse.
   1.3. Once the "Cameras & Lights" prompt appears on the left monitor, select "Cameras & Lights" button using the mouse.
   1.4. Once the "Camera Select" button appears on the "Cameras & lights" page on the left monitor, select "Camera Select" button using the mouse.
   1.5. Once the "Stack" prompt appears on the "Camera Select" page on the left monitor, select "Stack" button using the mouse.
   1.6. Once the observation execution notes appear on the left monitor, read each execution note.

Action Only Steps: 13

Decision-Action Steps: 3

Action with Waiting & Verification: 0

Decision-Action with Waiting & Verification: 0

LTM items: 1

WM items: 3

Sopatra

Sopatra

- The digital assistant revision software that is implemented & tested
- Sopatra is a digital assistant that will convert text to a diagram and execute simulation
- Procedure information is visually accessible and easier to understand
- Test out modifications to the process to understand their impacts

Conclusion

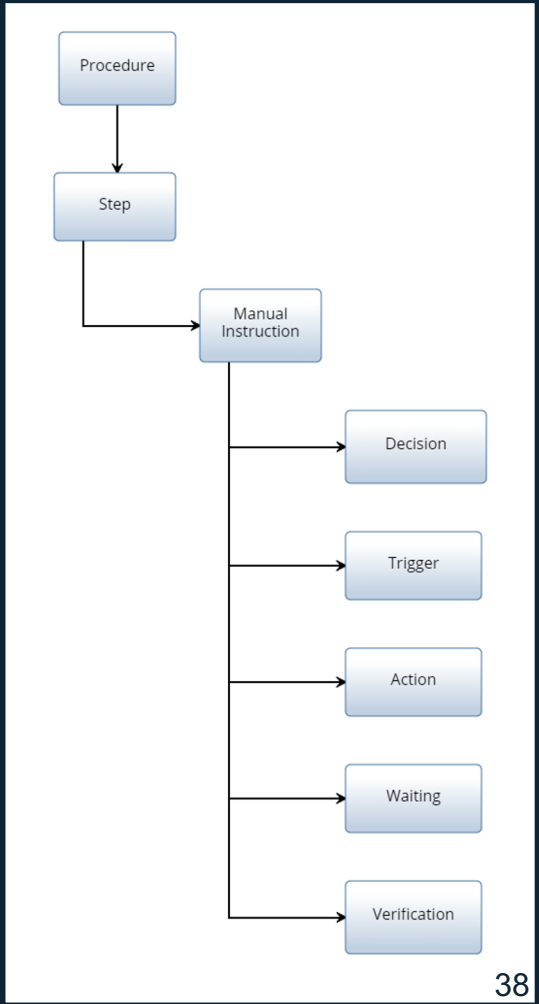
- SOPs are important but traditional revision processes lack operator involvement
- The new SOP revision process involves the operator & ensure cognitive alignment using NLP & model-based approach
- SOP step format will assist in considering the operators cognitive behavior
- Sopatra's platform will utilize the digital assistant revision process
  - Modeling SOP step structures
  - Analyzing the operator's performance
  - Iterative feedback loop between operators and procedures
- Bridge the gap between SOPs and real-world operational environments

Questions?

Appendix

e-PRL Modeling

- e-PRL component & tags will be used for procedure entities to be referenced for analysis
- Root entity = Procedure
- Top and mid-level steps = Step
- Bottom-level steps = Manual Instruction
  - Contains entities that are given e-PRL labels
    - **Procedure entities are**: Trigger (What), Trigger (Where), Decision (What), Decision (Where), Action (What), Action (Where), Waiting (What), Waiting (Where), Verification (What), Verification (Where)
    - **Input/Output entities are**: Trigger (How), Decision (How), Action (How), Waiting (How), Verification (How)



e-PRL & HMI Definitions for Operator(s)

e-PRL Component	Definition
Trigger (What)	Condition for initiating the SOP step
Trigger (How)	Data required for initiating the SOP step
Trigger (Where)	Source Data for initiating the SOP step
Decide (What)	Decision to be made
Decide (How)	Data required to make a decision
Decide (Where)	Source of data required to make a decision
Action (What)	Action for the SOP step
Action (How)	Physical motion required for the action
Action (Where)	Input device used to complete the action

e-PRL & HMI Definitions for Operator(s)

e-PRL Component	Definition
Waiting (What)	Meeting waiting requirements (if present)
Waiting (How)	Data needed for fulfilling waiting requirements
Waiting (Where)	Source data needed to fulfilling waiting requirement
Verification (What)	Verification action after a waiting requirement has been met
Verification (How)	Data required for verification