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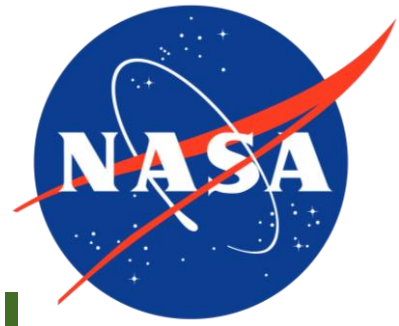

Analyzing Standard Operating Procedures (SOPs) Using Model-Based Systems Engineering Diagrams

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Agenda

1. Introduction
2. Overview of Modelling Standard Operating Procedures (SOPs)
3. MBSE SOP
    1. Model an SOP Action Diagram from a Text SOP
    2. Evaluate an SOP Action Diagram
    3. Simulate SOP Action Diagram
4. Case Study: Takeoff SOP
5. Conclusions & Future Work

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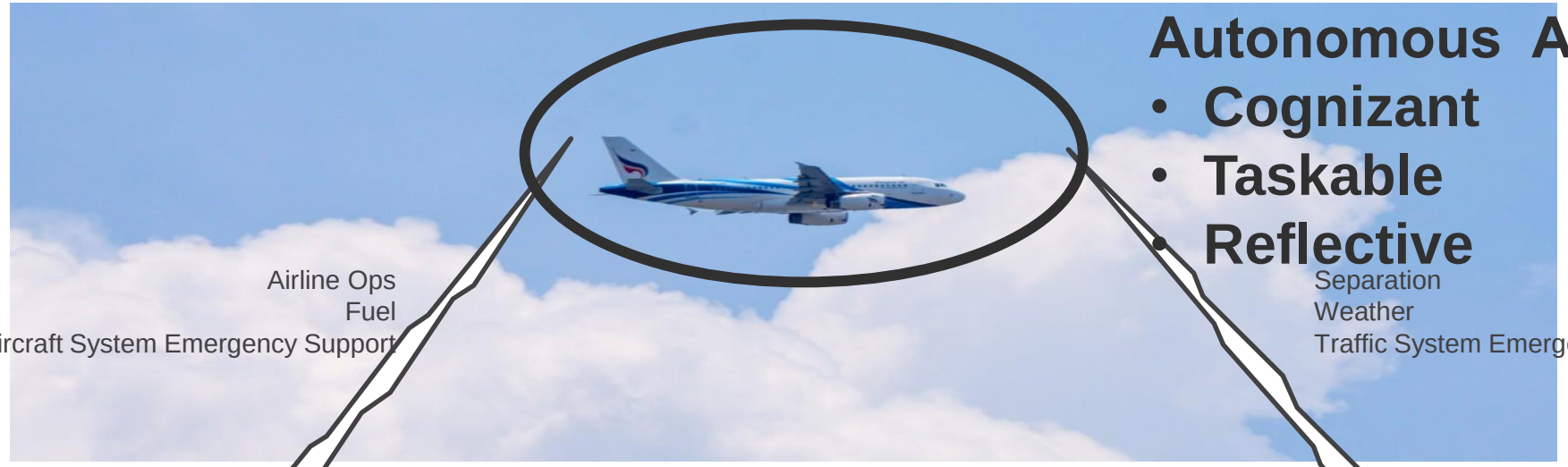
Introduction - Airliner is an Autonomous "System"



Autonomous Airliner "System"

- **Cognizant**
- **Taskable**
- **Reflective**

Airline Ops
Fuel
Aircraft System Emergency Support

Separation
Weather
Traffic System Emergency Support

Remote Operators

Airline Dispatch

Traffic Flow Management

Air Traffic Control

Introduction - “Autonomous Airliner System” Decision-making (Flightdeck)

• Filed flightplan (i.e. desired 4-D trajectory)
• Procedures for expected, planned mission

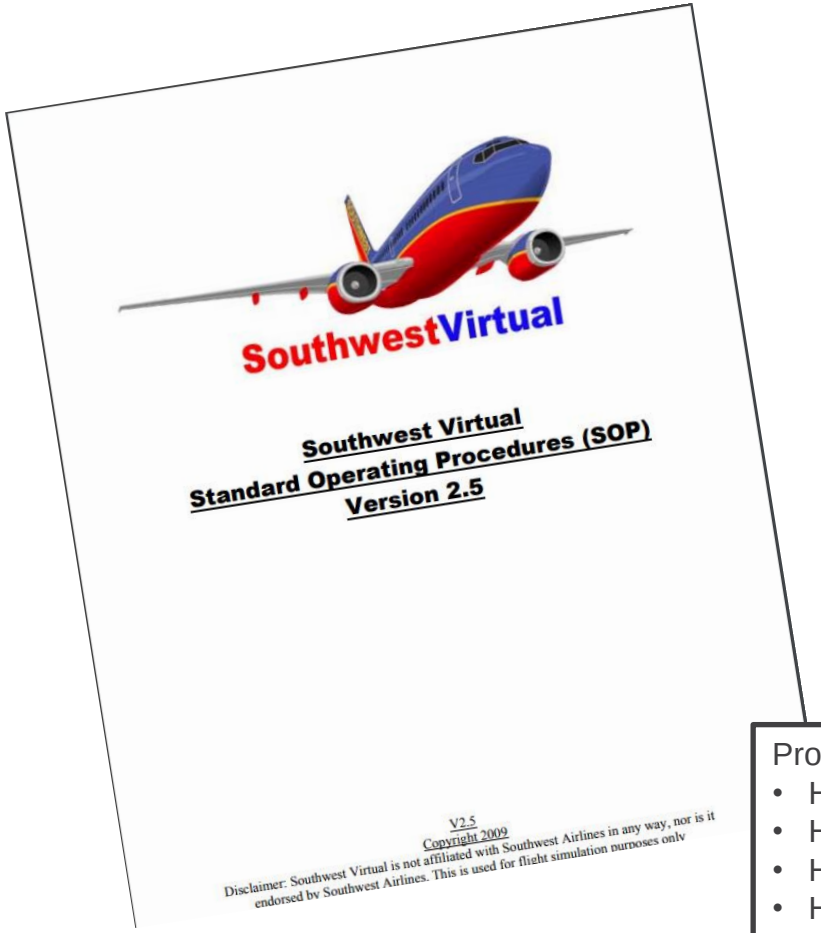
1. Completed 4-D Trajectory for filed flightplan

Control Surface & Propulsion Commands

•Environment (traffic, weather, …)

Wind, storms, ceiling & visibility, traffic (ATC), airspace restrictions (ATC), …

Introduction - Standard Operating Procedures



1) What must be accomplished/Tasks
   - Each Operator Action that must be executed in a sequence
2) When (under what conditions)
3) Who is responsible for each step
4) How each step is performed/Functions
5) How to confirm

Procedures define:
- Human-Machine Interaction
- Human Automation Interaction
- Human-Human Interaction
- Human-External Actors Interaction

Types of Operartor Actions:
- Info gathering
- Info processing
- Conditional branching
- Decision-making
- Waiting/Timing
- Action
- Verification
- Validation

Problems with Using SOPs

1. Procedure cannot be completed in time (i.e. before hazardous event)
   - *Swiss Air 111*
   - SOP Requirements creep
2. Missing Steps
   - *Ethiopian Airlines 302 (Disconnect Auto Throttle Missing)*
3. WHAT must be done specified, but not WHEN
   - *TK1951*
   - Timing
4. Information required to perform next Step is not available
5. Race conditions – information not available in timely manner
6. No procedure for scenario
   - *AF447?*
7. Procedures across System-of-Systems not compatible
   - *SQ 237 – Runway Excursion*
8. Procedure difficult to learn due to user-interface cues
   - *OZ 214*
9. Procedures poorly trained

Swiss Air 111

- Crew of Swissair's Boeing MD-11 flight SR111 made a "Pan" emergency call … reporting smoke in the cockpit
- *Sixteen minutes later* the aircraft crashed into the sea, killing all 215 passengers and 14 crew on board
- Very complex tasks

Template: Flight-crew Response to In-flight Smoke, Fumes, Fire

STEP	ACTION	RESPONSE
1	Diversion may be required.	
2	Oxygen masks (if required)	On, 100%
3	Smoke goggles (if required)	On
4	Crew and cabin communications	Establish
5	Manufacturer's initial steps	Accomplish
	Anytime smoke or fumes become the greatest threat, accomplish separate *Smoke or Fumes Removal Checklist.*	
6	Source is immediately obvious and can be extinguished quickly:	
	If YES → go to Step 7.	
	If NO → go to Step 9.	
7	Extinguish the source. If possible, remove power from affected equipment by switch or circuit breaker on the flight deck or in the cabin.	
8	Source is visually confirmed to be extinguished:	
9		
10		
11		
12	[These are further actions to control/extinguish source.] If dissipating, go to Step 16.	
13	"Y" system actions [These are further actions to control/extinguish source.] If dissipating, go to Step 16.	Accomplish
14	"Z" system actions [These are further actions to control/extinguish source.] If dissipating, go to Step 16.	Accomplish
15	SFF continues after all system-related steps are accomplished: Consider landing immediately. Go to Step 16.	
16	Review Operational Considerations.	
17	Accomplish *Smoke or Fumes Removal Checklist*, if required.	
18	Checklist complete.	

- SFF source identification.
- Actions to perform regardless of source.
- Crew communication.
- Timing for diversion and landing initiation.
- Smoke or fumes removal.
- Additional actions to perform if smoke persists.
- Loss of capability and operational consequences

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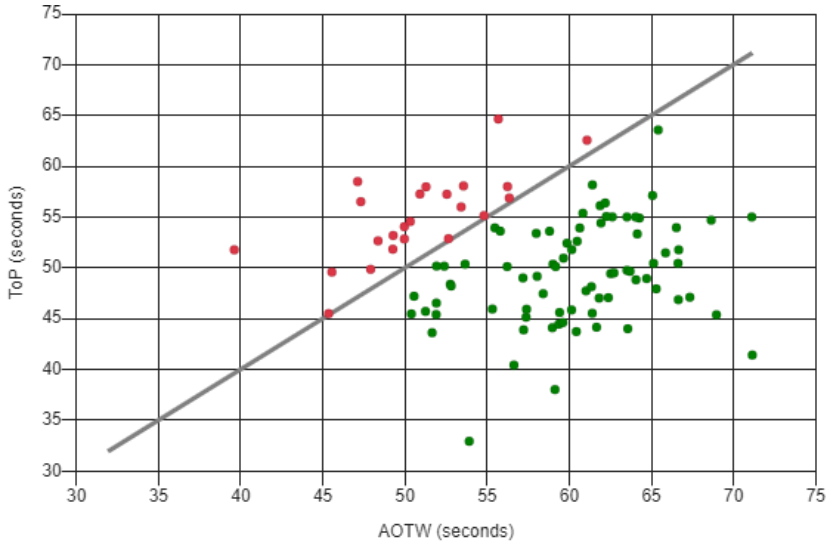
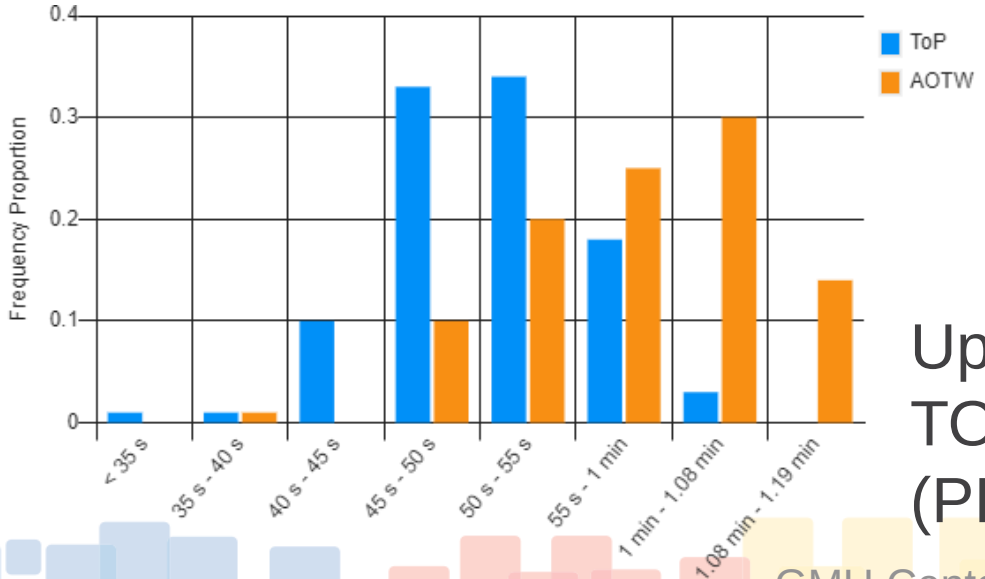
Overview of Modelling SOPs

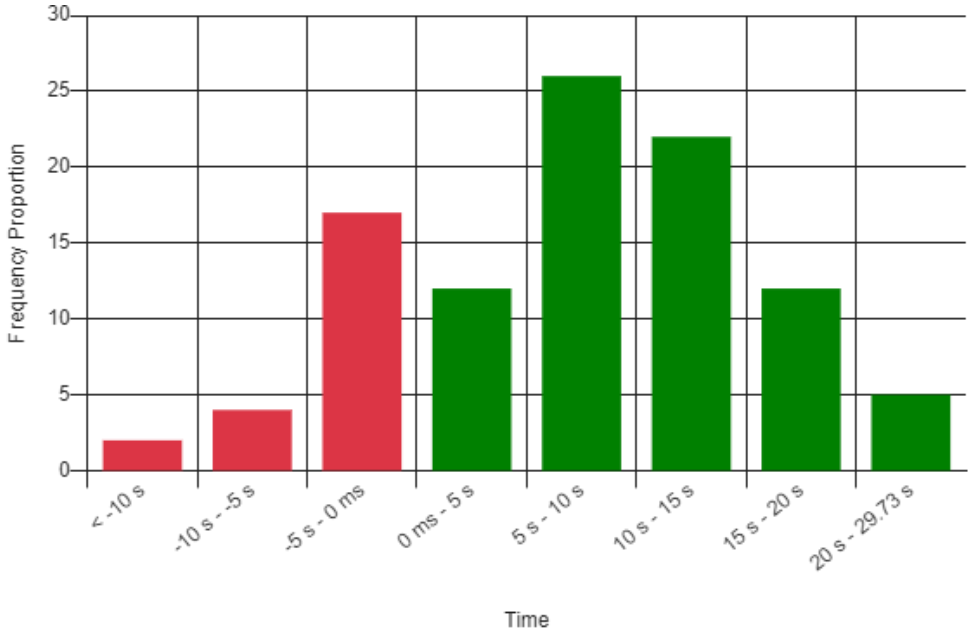
- SOP Evaluation Metrics:
  - Time on Procedure (ToP): The time to complete all actions of the SOP.
    - Different each run due to varying level of expertise of operators
  - Allowable Operational Time Window (AOTW): The time in which the procedure must be completed.
    - Different due to environmental factors
  - Procedure Buffer Time (PBT): AOTW – ToP
    - Distribution
  - Probability of Failure to Complete (PFtC): Probability PBT < 0.
    - Left tail of the PBT Distribution.
    - Higher PFtC = Unreliable SOP

Overview of Modelling SOPs

-Time on Procedure (ToP): The time to complete all actions of the SOP.
-Allowable Operational Time Window (AOTW): The time in which the procedure must be completed.
-Procedure Buffer Time (PBT): AOTW – ToP
-Probability of Failure to Complete (PFtC): Probability PBT < 0.







Upper Left: ToP vs AOTW. Lower Left: AOTW and TOP (Intersection not wanted). Middle Right: PBT (PFtC = P(PBT <0))

Overview of Modelling SOPs

-Time on Procedure (ToP): The time to complete all actions of the SOP.
-Allowable Operational Time Window (AOTW): The time in which the procedure must be completed.
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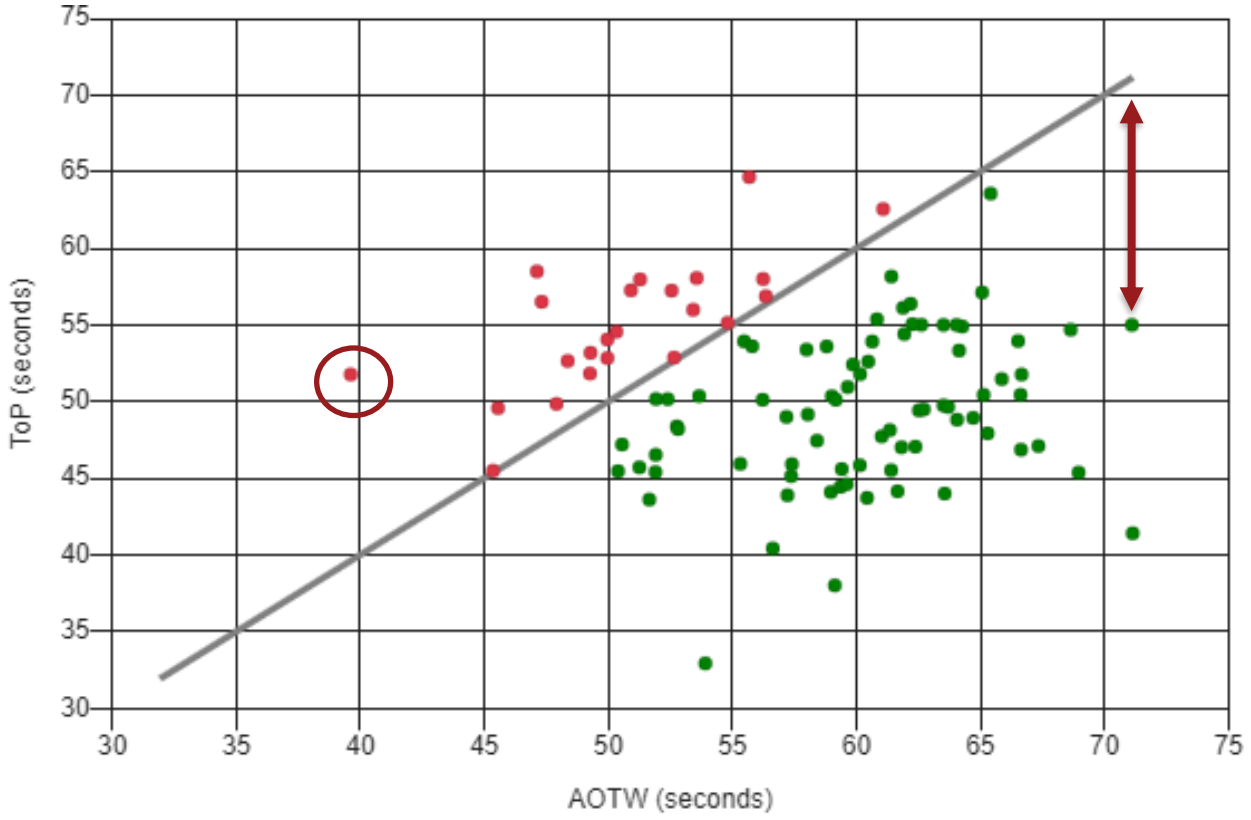

AOTW VS ToP Runs:
Red: Runs where ToP exceeded AOTW
Green: Runs where ToP was less than AOTW

Overview of Modelling SOPs

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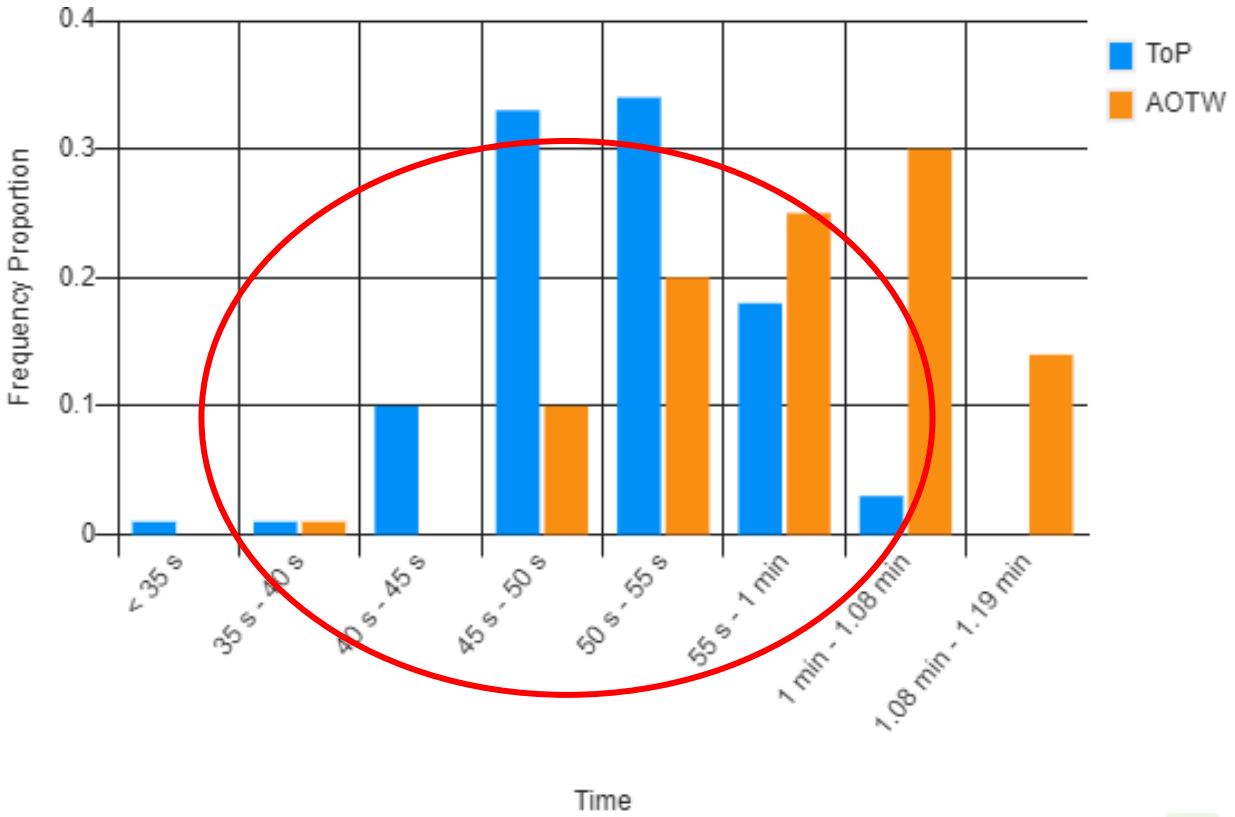
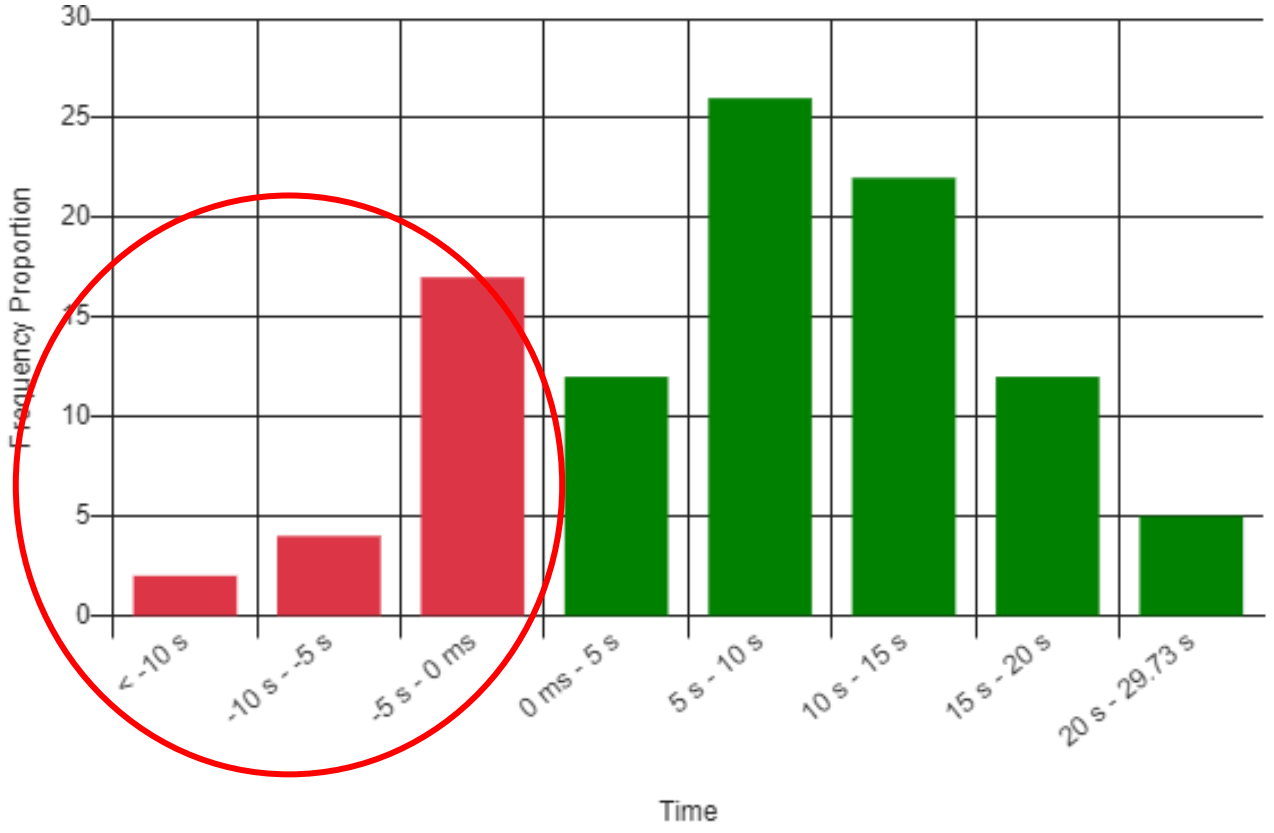


Distributions of AOTW and ToP: Intersection: Runs where ToP > AOTW

Overview of Modelling SOPs

-Time on Procedure (ToP): The time to complete all actions of the SOP.
-Allowable Operational Time Window (AOTW): The time in which the procedure must be completed.
-Procedure Buffer Time (PBT): AOTW – ToP
-Probability of Failure to Complete (PFtC): Probability PBT < 0.

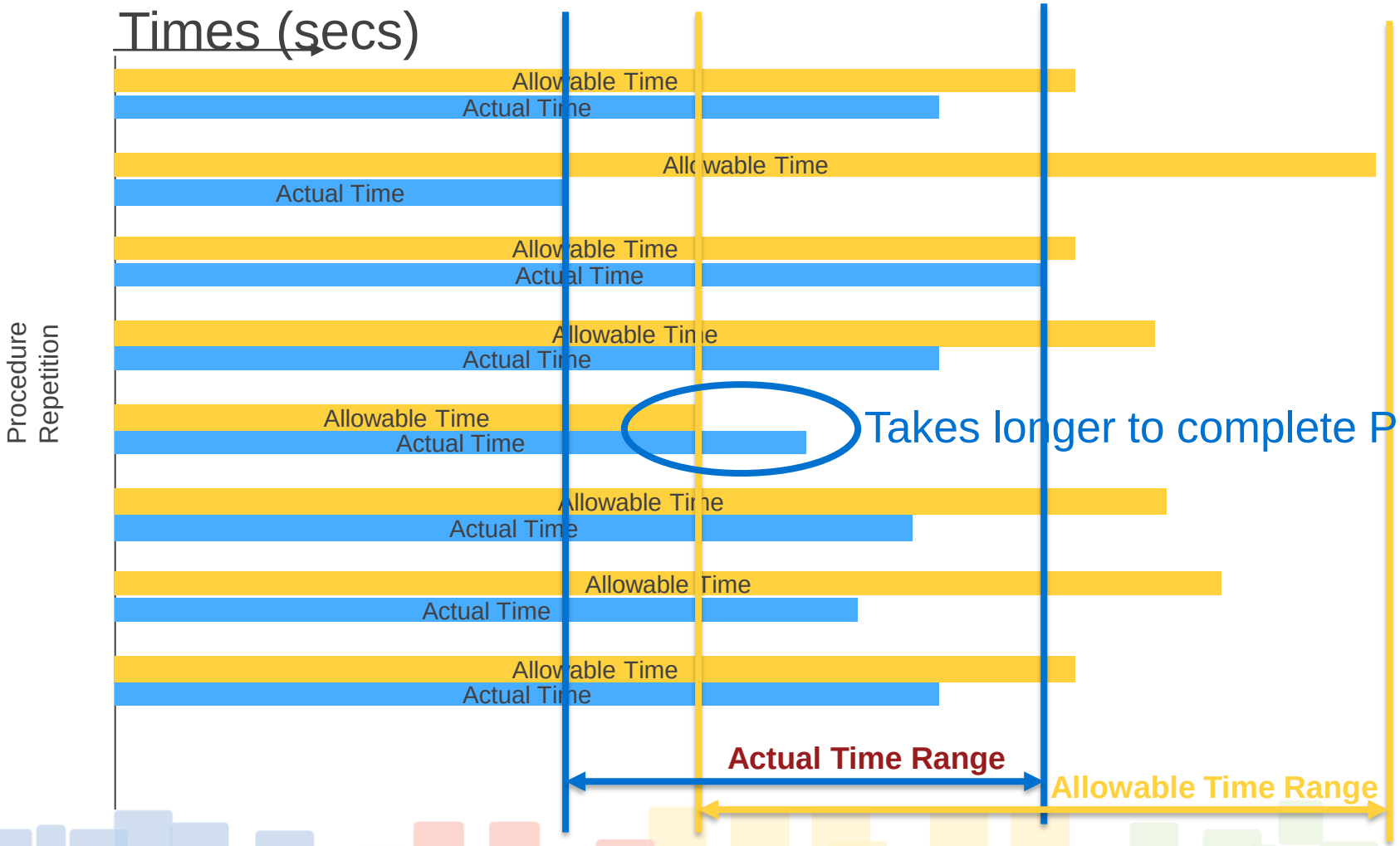


Distribution of PBT
PBT = AOTW – ToP
PFtC: Left tail of PBT Dist.

Overview of Modelling SOPs

- Tasks performed frequently have high reliability
- Tasks performed infrequently/rarely must rely on “cues” for reliability
- All Operator Actions are triggered by *cues*
  - Visual cues, Aural cues, Tactile cues
    - No cue
    - Cue, but Outside of Field-of-View (FOV)
    - Cue, in FOV, but lost in clutter
    - Cue, in FOV, no clutter, ambiguous label semantics
    - Cue, in FOV, no clutter, no ambiguity in label semantics
  - Long-term Memory (LTM)
    - Memorization item
    - Don’t use it, lose it

Time to Complete Procedure Vs Time Available

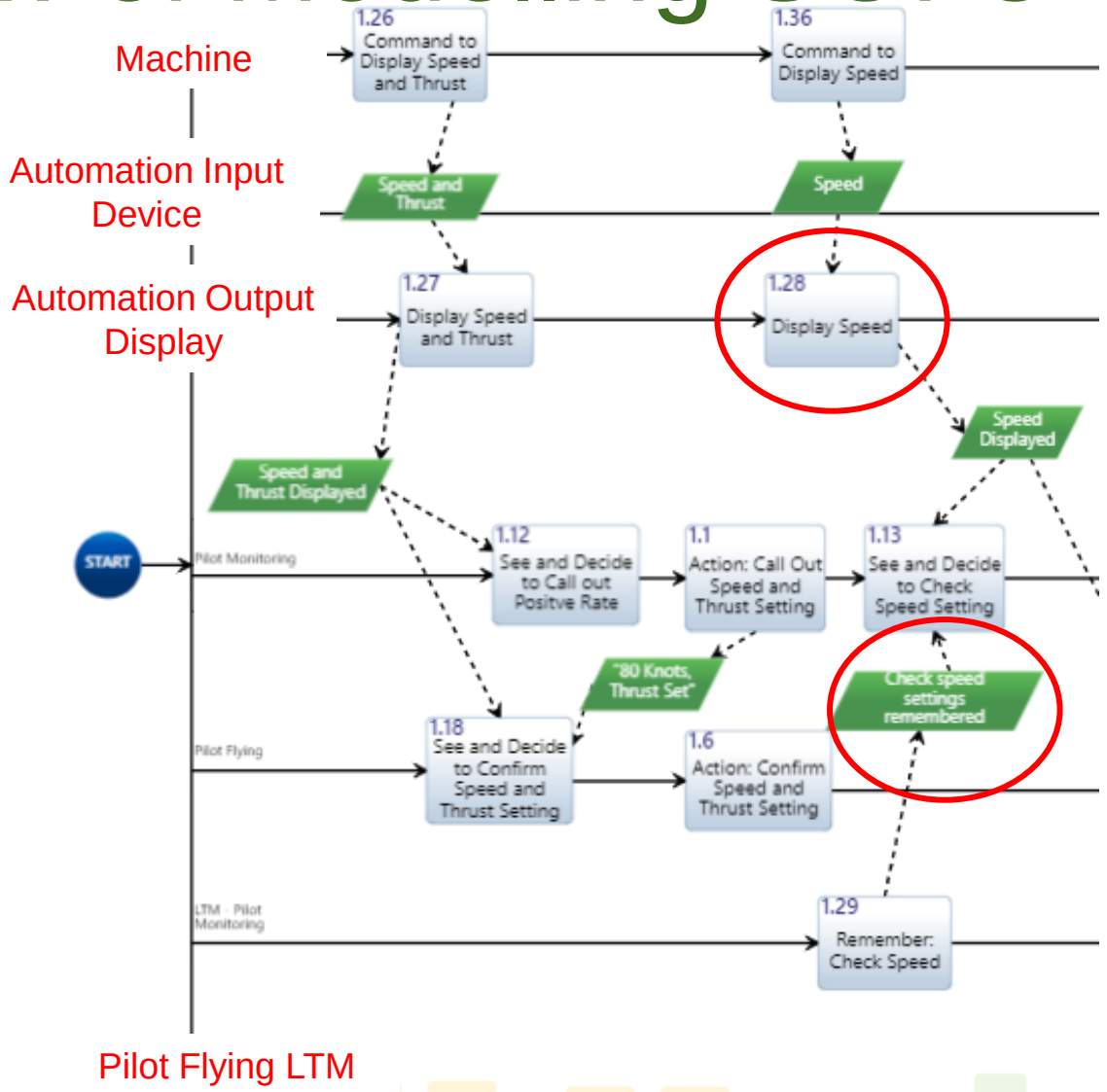


How do Procedure Designers/Testers know this wont happen

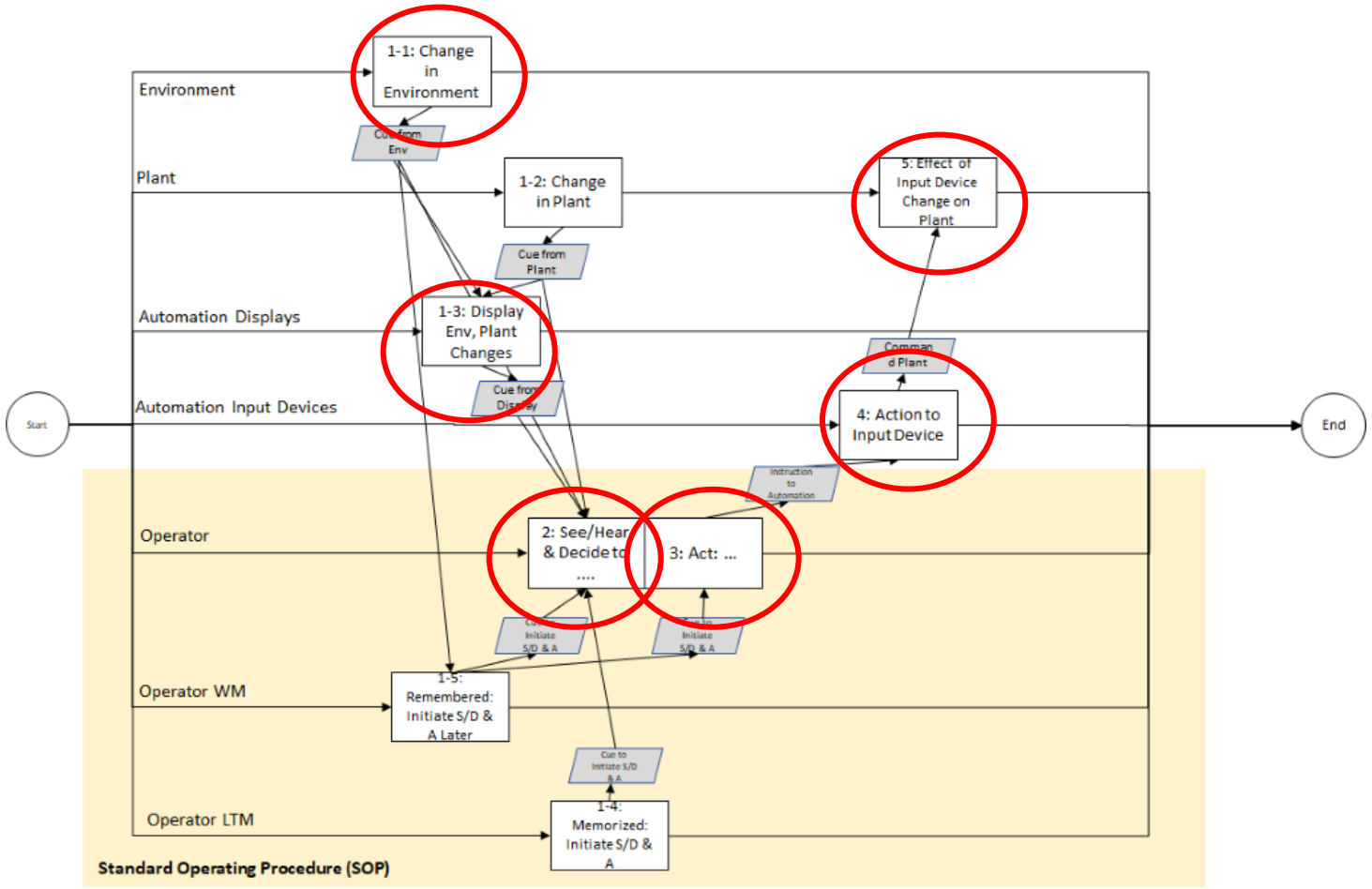
Overview of Modelling SOPs

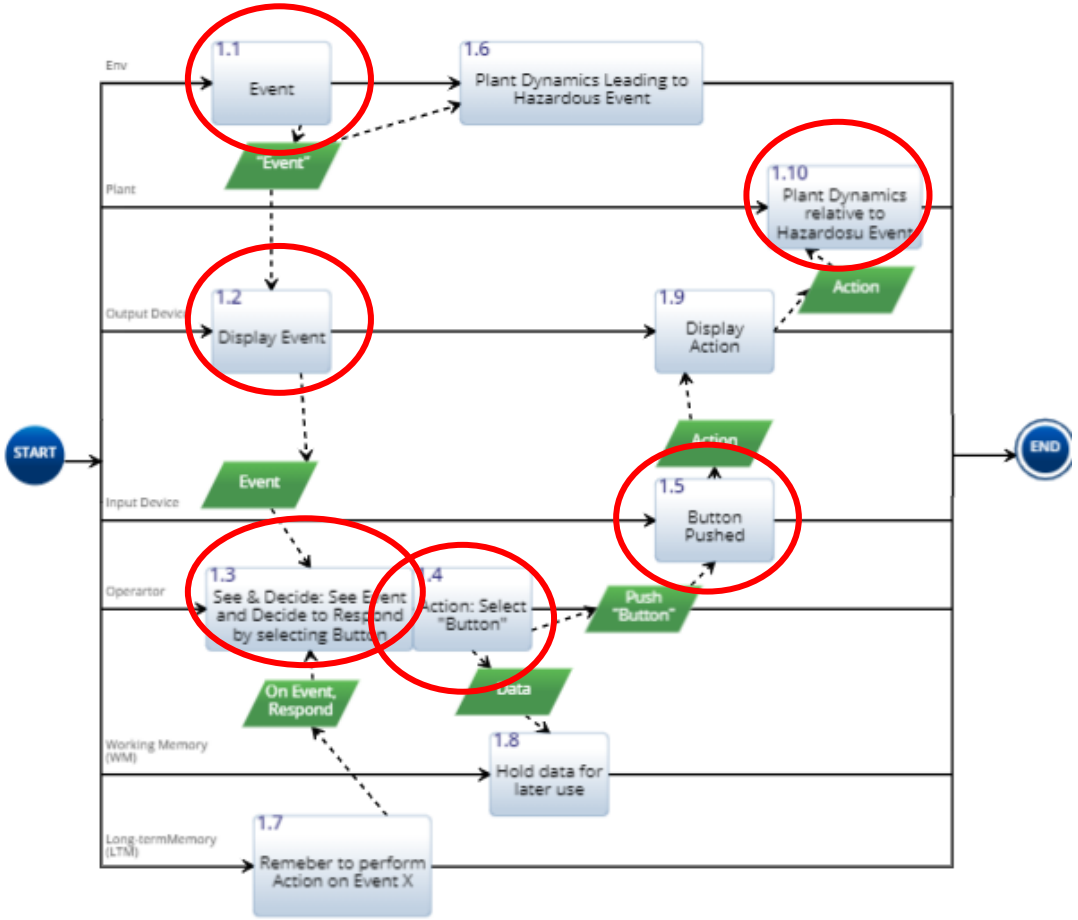
- SOP Action Diagrams contain:
  - Actions
  - Branches
  - Input/Output (I/Os)
- Actions: actions are shown as squares on AD.
- Branches: Actors that perform SOP actions are depicted as branches. Each action is performed by the branch (actor) where the action sits.
- I/Os: Information flow between actions. Depicted as parallelograms.
  - I/Os must be present between two actions not performed by the same actor.

Overview of Modelling SOPs



- Operator and automation create a “Command and Control” system
  - Based on state of the plant and the environment
- Inputs are derived from:
  - Automation sensors
  - Human senses
- HAPE Interaction is governed by SOPs





Example: Generic SOP Action Diagram

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Step-by-Step Method to Create an SOP Action Diagram from a Text SOP

1- Identify and create branches for the Action Diagram (AD).

2- For each operator, insert operator actions

3- For each operator action, add a “See and Decide” or “Hear and Decide” or “remember and Decide” action.

4- Add the initiation action of the SOP.

5- Insert Automation Output Display and Automation Input Device actions and add I/Os as appropriate.

6- Identify the cues of the SOP, and identify the type of each cue; visual, aural, memory.

7- Identify the source action/actor of each cue identified in step 6.

8- Using table generated in Step 7, add the cues to the diagram and make sure to connect a cue to each See/Hear & Decide Action

9- Using table generated in Step 7, connect each cue to its source action.

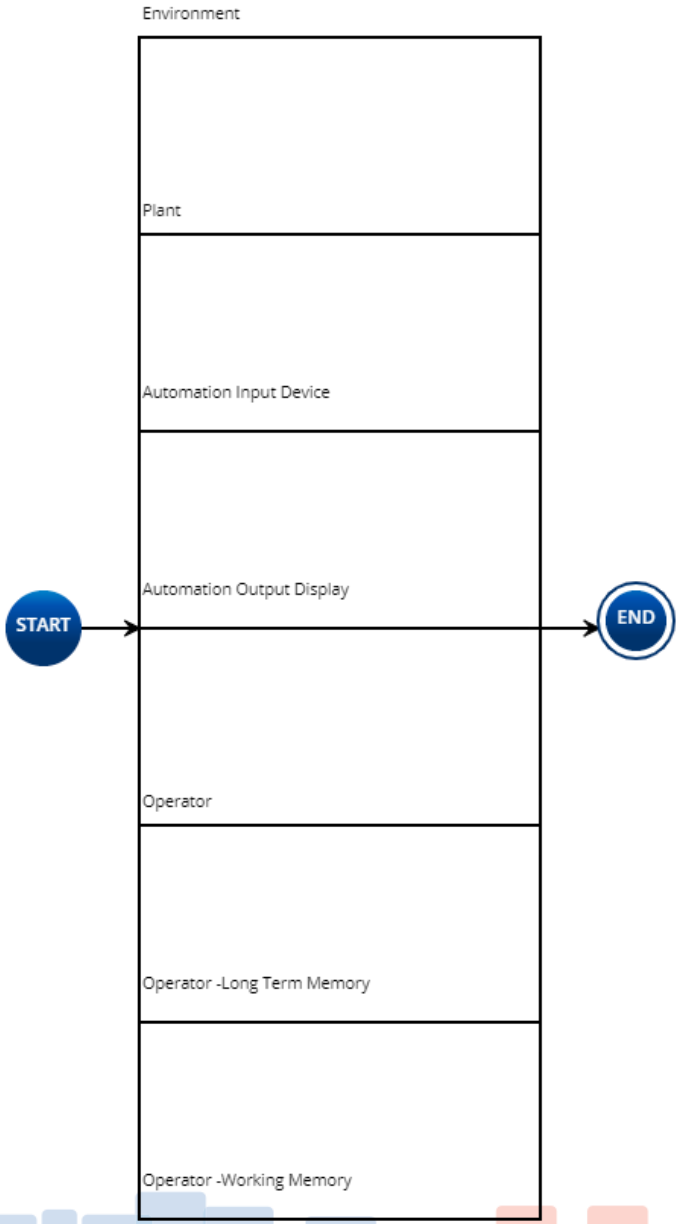
10- Follow the “Cue Wording Rules.

11- For each operator action, add an Automation Input Device action and I/O as appropriate.

12- For each Automation Input Device action, add an output to a Machine Action and add I/Os as appropriate.

13- For each Machine Action, add an output to an Automation Output Display Action and I/O as appropriate.

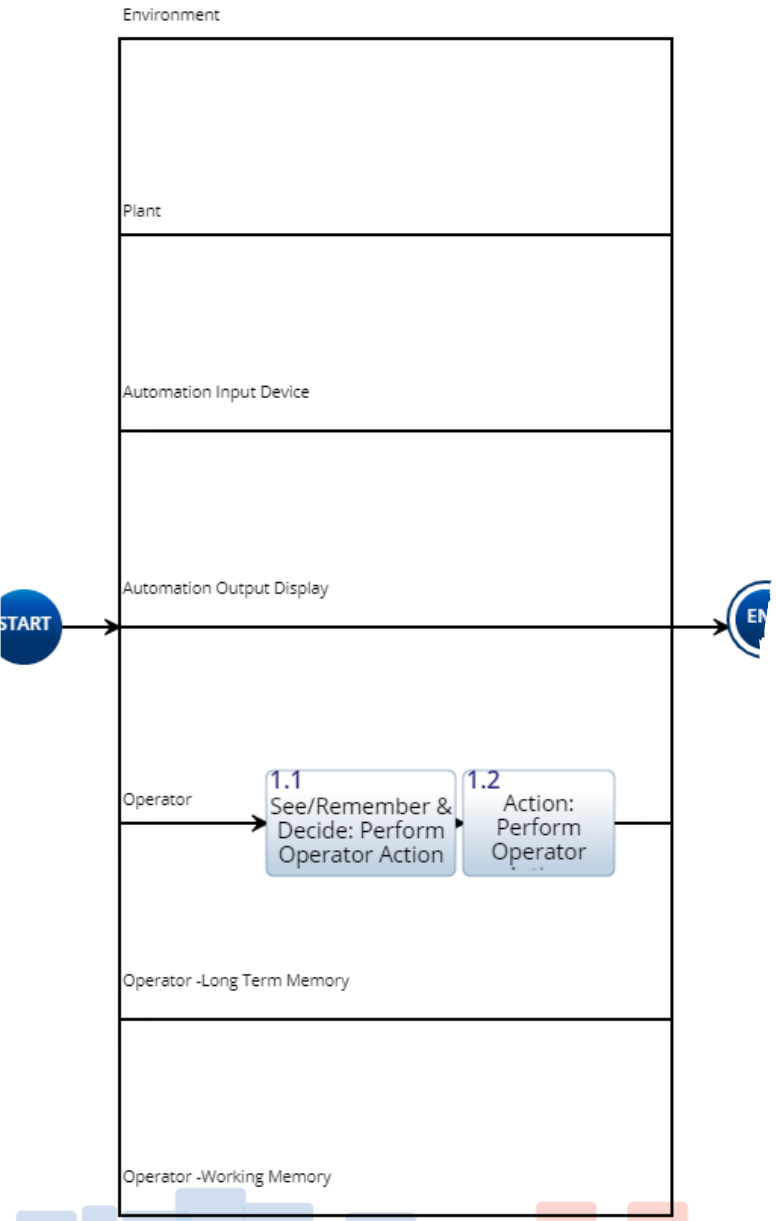
14- Compare SOP to action diagram, go back to step 5 as appropriate.



Step 1

1- Identify and create branches for the Action Diagram (AD).

- 7 actors
  - Environment
  - Plant
  - Automation Input Device
  - Automation Output Display
  - Operator(s)
  - Operator(s) – Long Term Memory (LTM)
  - Operator(s) – Working Memory (WM)



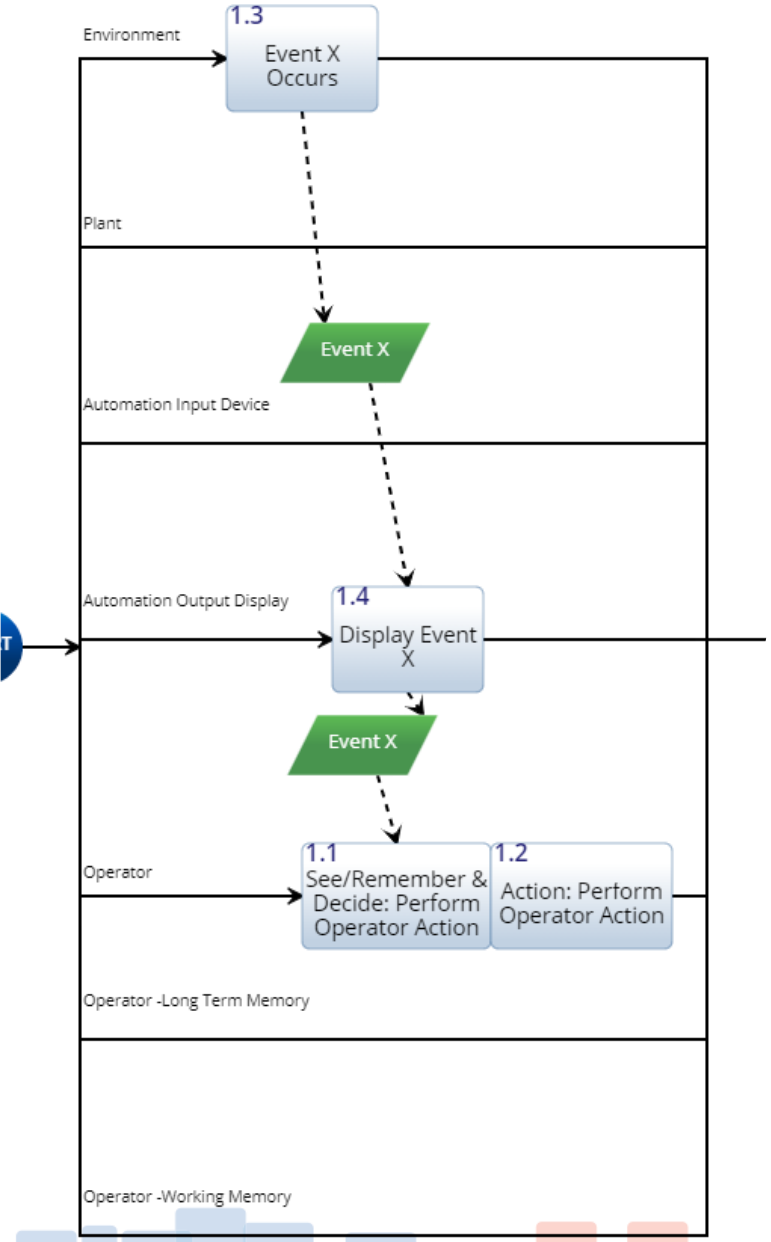
Step 2 and Step 3

2- For each operator, insert operator actions

- Actions from SOP.
- Use syntax “Action:” followed by the SOP action.

3- For each operator action, add a “See /Remember and Decide” or “Hear/Remember and Decide” .

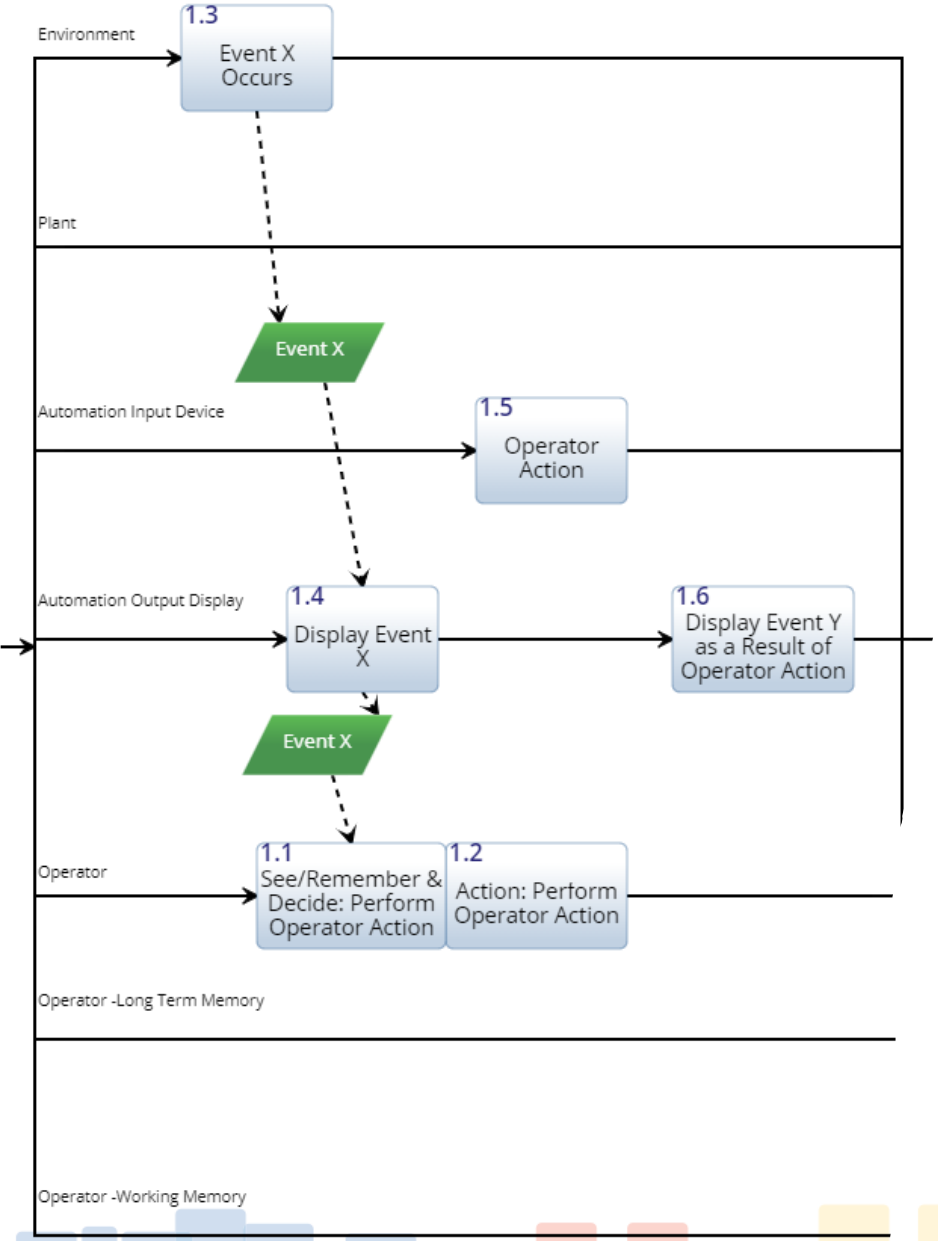
- Decision-making actions where actor is triggered by a cue:
  - Visual
  - Aural
  - Memory



Step 4

4- Add the initiation action and cue of the SOP.

- Action may come from:
  - Automation Output Display
  - Environment
  - Operator LTM
  - Operator WM
- Cue may be:
  - Visual
  - Aural
  - Memory



Step 5

5- Insert Automation Output Display and Automation Input Device actions and add I/Os as appropriate.

- Identify Automation Output Display and Input Device actions on SOP. Add to diagram.

Step 6

6- Identify the cues of the SOP, and identify the type of each cue; visual, aural, memory.

- Identify and “Straightforward” cues
  - Call “Positive Rate”.
  - Aircraft reaches 80 knots.
- Might not identify all cues at this point.

CUE
“Call outs”
80 knots

Step 7

7- Identify the source action/actor of each cue identified in step 6.

- Each cue identified in step 6 is a result of an action. Identify the actions and actors associated with the cue.

Cue	Source Action	Source Action
“call out”	Action: Call “Call out”	Pilot flying

Step 8 and Step 9

- 8- Using table generated in Step 7, add the cues to the diagram and make sure to connect a cue to each See/Hear & Decide Action

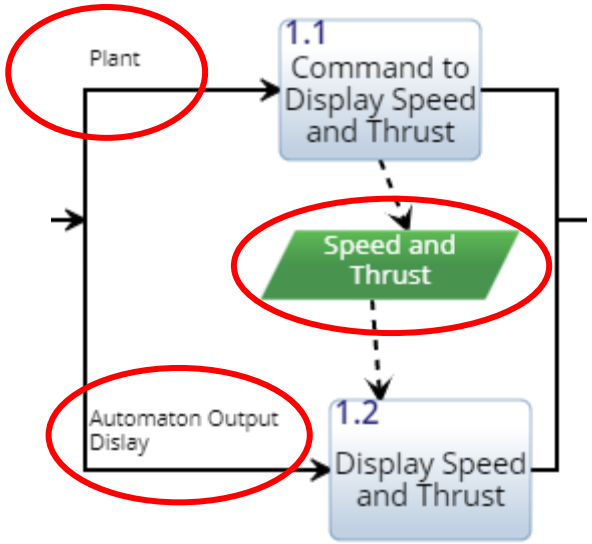
- 9- Using table generated in Step 7, connect each cue to its source action.

Step 10

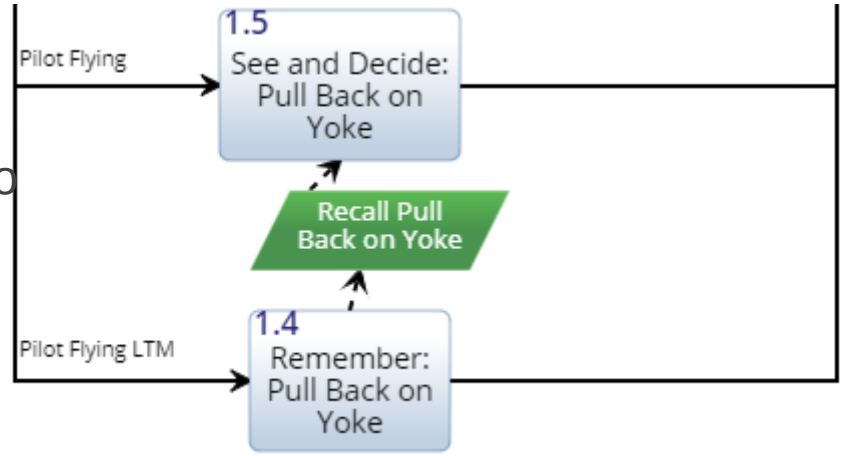
10- Re-write the cues to follow the “Cue Wording Rules”.

- Outputs from the Plant to the Automation Output Display: nouns.
- Outputs from the Automation Output Display to the Operator(s): nouns.
- Outputs from the Automation Input Device to the Plant: verb noun, e.g. extend flaps
- Outputs from the Operator(s) to the Automation Input Display: verb noun, e.g. raise landing gear lever
- Outputs from an Operator to another Operator: A word or phrase coming from an operator. E.g. “V-One”
- Outputs from the LTM – WM to an Operator: Verb sentence E.g. Recall check for V-One speed.

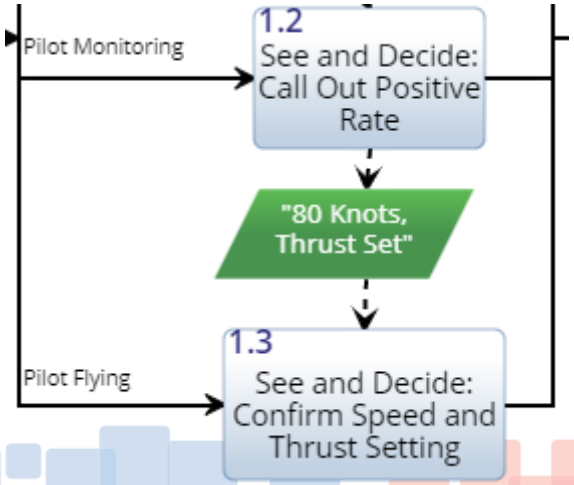
Step 10 Example



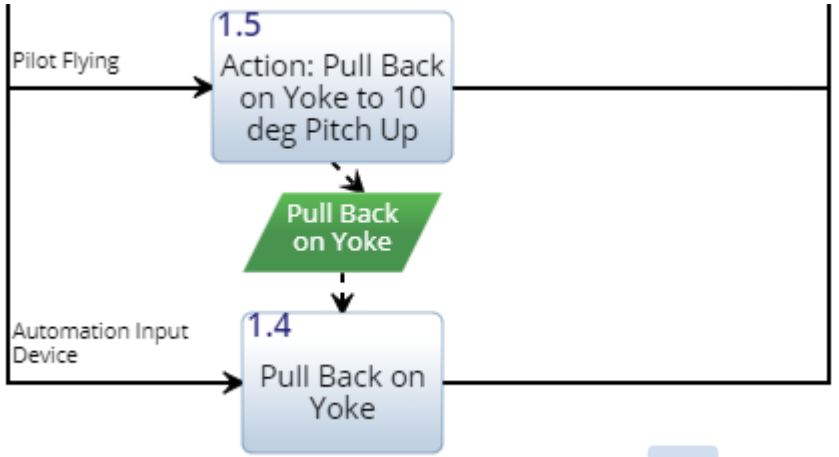
Output from Plant to Automation Output Display: Noun



Output from Operator LTM to Operator: Verb sentence

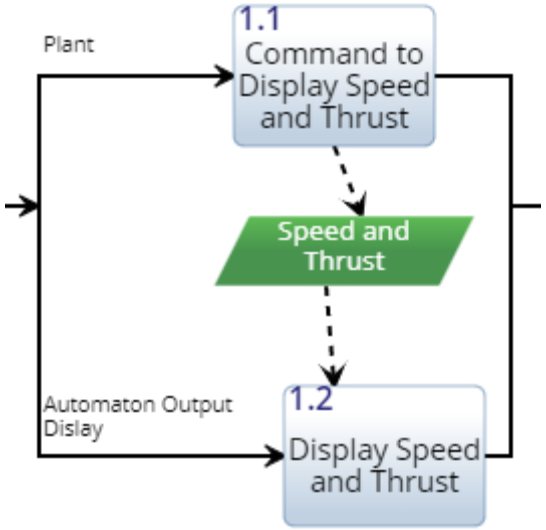


Output from Operator to Operator: Word or Phrase in quotes

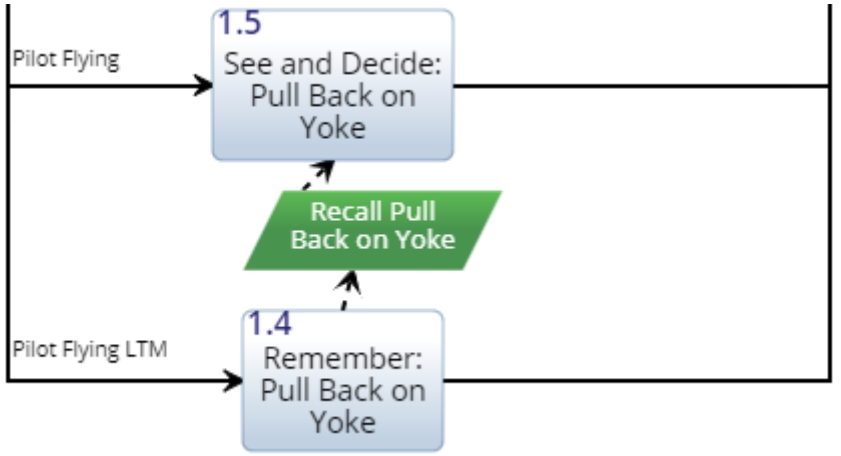


Output from Operator to Automation Input Device: Verb Noun

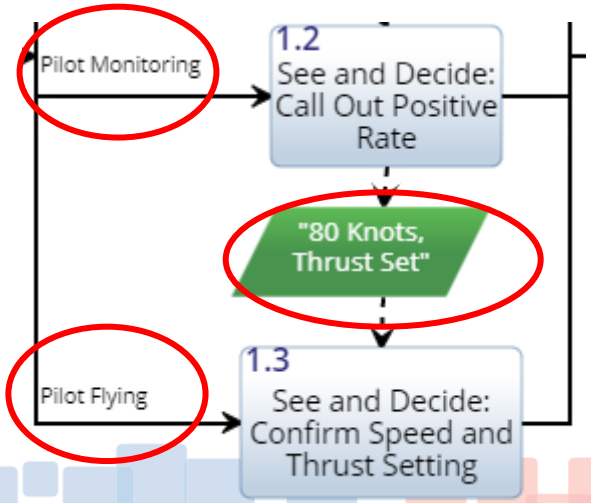
Step 7 Example



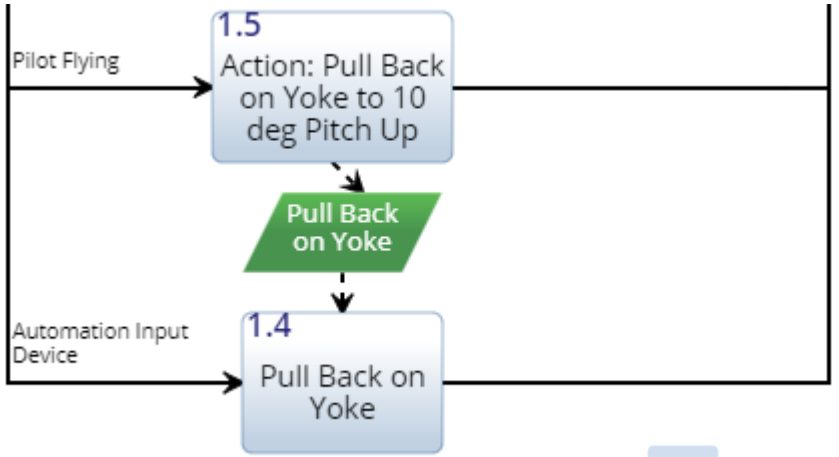
Output from Plant to Automation Output Display: Noun



Output from Operator LTM to Operator: Verb sentence



Output from Operator to Operator: Word or Phrase in quotes



Output from Operator to Automation Input Device: Verb Noun

Step 11, Step 12 and Step 13

11- For each operator action, add an Automation Input Device action and I/O as appropriate.

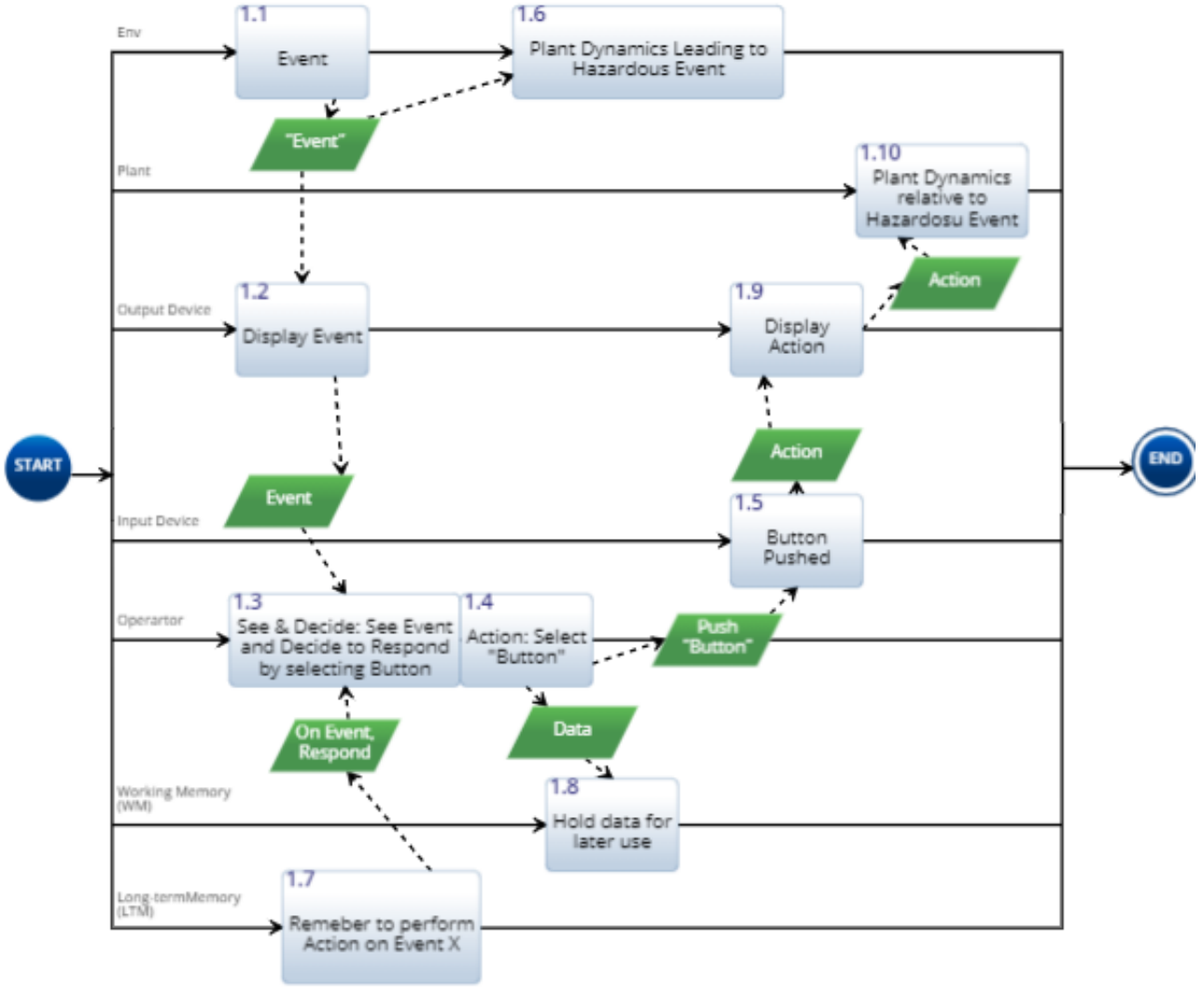
- For operator “physical” action (i.e. push a button)

12- For each Automation Input Device action, add an output to a Machine Action and add I/Os as appropriate.

- Add a machine action as a result of ANY AND ALL Automation Input Device actions.

13- For each Machine Action, add an output to an Automation Output Display Action and I/O as appropriate.

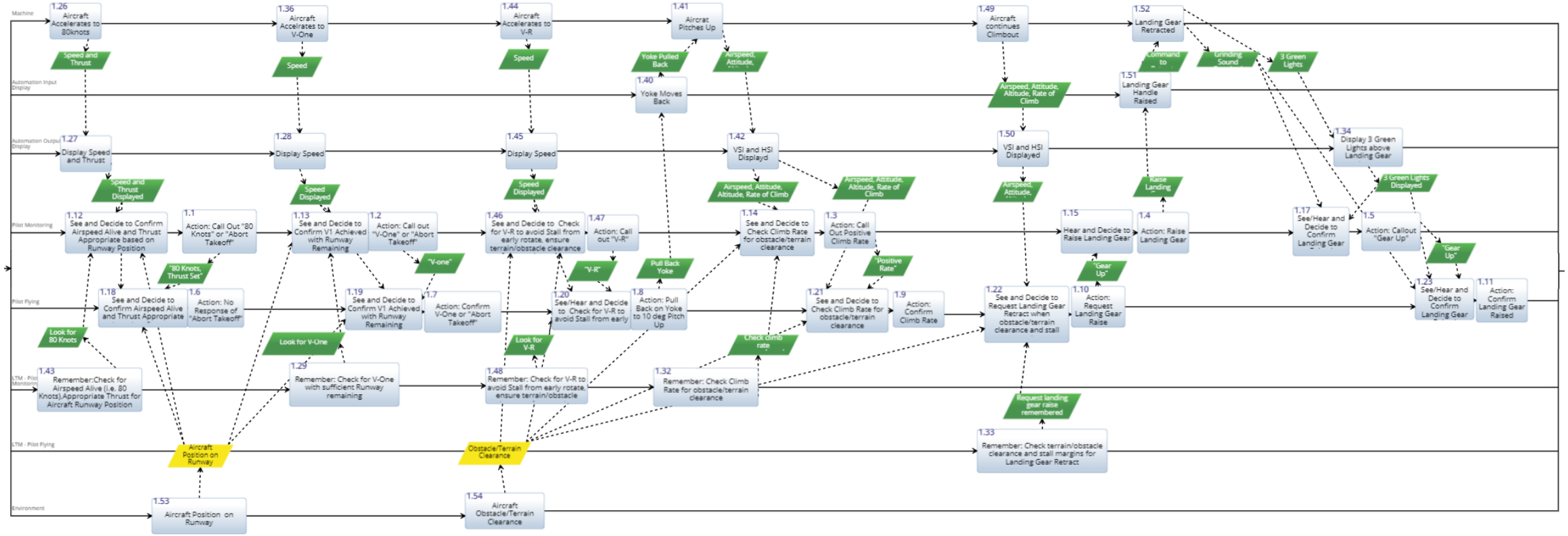
- Add an Automation Output Display action as a result of ANY AND ALL Machine actions.



Step 14 – Final Step of First Iteration

14- Compare SOP to action diagram, go back to step 5 as appropriate.

- Add actions
  - WM
  - LTM
  - Input Device
  - Output Display
- Add/Modify Cues



Complete SOP Action Diagram for Airliner Takeoff SOP

Step-by-Step Method to Analyze an SOP Action Diagram

15- Assess Operator Actions Performance.

16- Assign Time Distributions to all Actions (from Database) and adjust for performance assessment.

17- Assign allowable operational time window (AOTW) Distribution Thresholds (5th percentile)

18- Run Action Diagram (MC Simulation) to generate distributions for AOTW, ToP, and PBT, and to calculate PFtC.

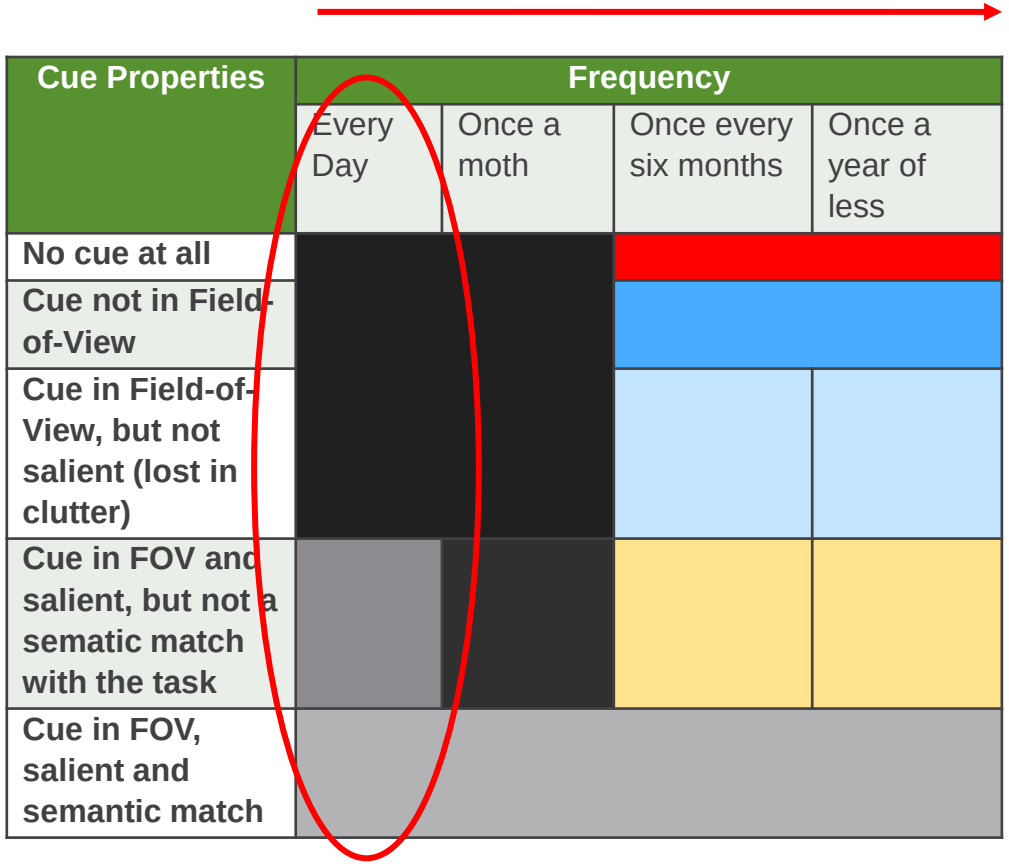
19- Asses: Is PBT left tail < Zero?

20- Redesign the SOP and the user-interface and run again until the SOP satisfies that PFtC criteria.

Step 15

15- Assess Operator Actions Performance.

- Operator actions are assessed based on 2 factors:
  - Frequency of an action
  - Saliency of the cue
- Frequency:
  - Frequent actions, happen every flight
  - Infrequent actions, may happen every now and then
  - Rare Events
- Cue Saliency:
  - Cue present, in Operator's Field of View (FOV), Salient, and Semantically similar to action.
  - Cue present, not in Operator's FOV, lost in the clutter, not semantically similar to action
  - No cue present



Step 16

16- Assign Time Distributions to all Actions from the Human Performance Time Distribution (HPTD) Database.

- Based on cue assessment and action frequency in step 15, assign each operator action a distribution.

Cue Properties	Frequency			
	Every Day	Once a moth	Once every six months	Once a year of less
No cue at all	**Triang (0.03, 1,9)**		Triang (0.03, 51, 120)	
Cue not in Field-of-View			Triang (0.03, 44, 110)	
Cue in Field-of-View, but not salient (lost in clutter)			Triang (0.03, 13, 25)	Triang (0.03, 44, 62)
Cue in FOV and salient, but not a sematic match with the task	Traing (0.03, 0.08, 2)	Triang (0.03, 1, 2)	Triang (0.05, 3.5, 62)	Triang (0.06, 121, 350)
Cue in FOV, salient and semantic match	Triang (0.03, 0.08, 1.5)			

Step 16

16- Assign Time Distributions to all Actions from the Human Performance Time Distribution (HPTD) Database.

- Based on cue assessment and action frequency in step 15, assign each operator action a distribution.

Cue Properties	Frequency			
	Every Day	Once a moth	Once every six months	Once a year of less
No cue at all	**Triang (0.03, 1,9)**		Triang (0.03, 51, 120)	
Cue not in Field-of-View			Triang (0.03, 44, 110)	
Cue in Field-of-View, but not salient (lost in clutter)			Triang (0.03, 13, 25)	Triang (0.03, 44, 62)
Cue in FOV and salient, but not a sematic match with the task	Traing (0.03, 0.08, 2)	Triang (0.03, 1, 2)	Triang (0.05, 3.5, 62)	Triang (0.06, 121, 350)
Cue in FOV, salient and semantic match	Triang (0.03, 0.08, 1.5)			

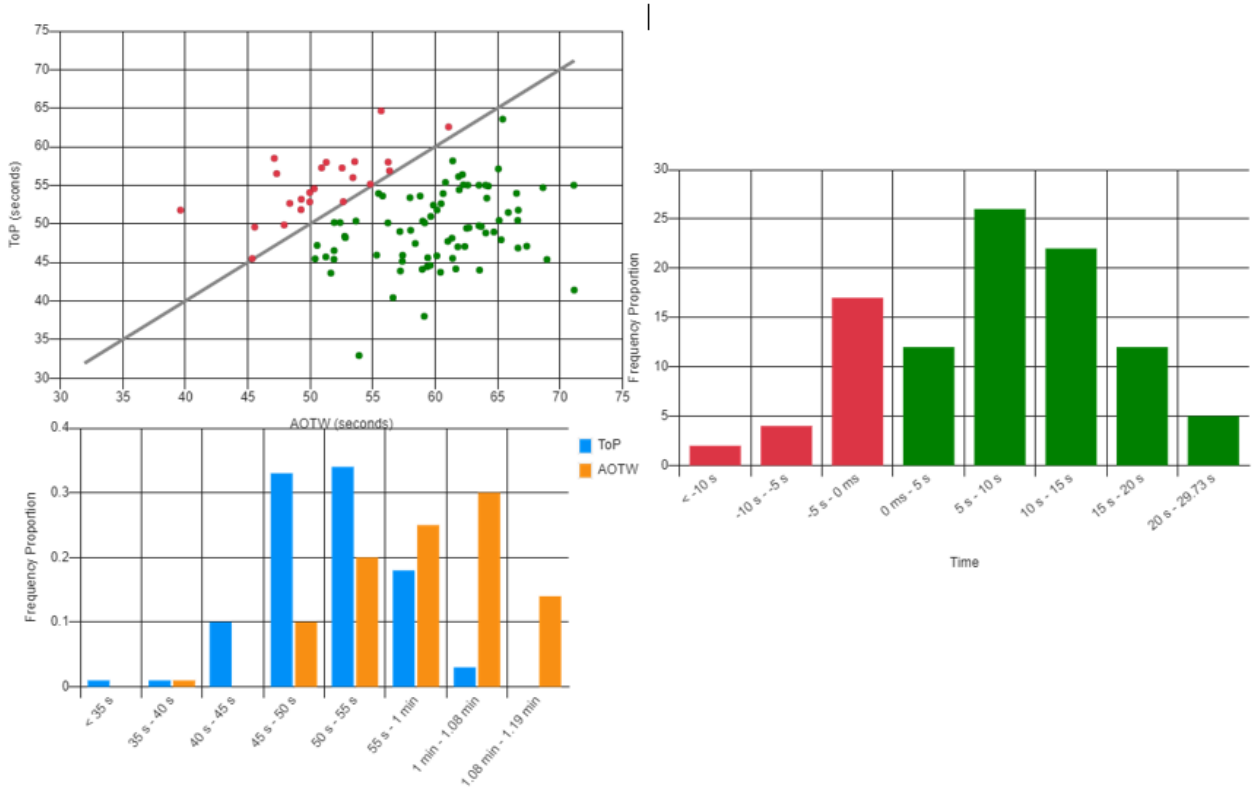
Step 17 and Step 18

17- Assign allowable operational time window (AOTW) Distribution Thresholds (5th percentile).

- PFtC Threshold

18- Run Action Diagram (MC Simulation) to generate distributions for AOTW, ToP, and PBT, and to calculate PFtC.

- AOTW: The total time of all Plant actions.
- ToP: The total time of all Operator actions.
- PBT = AOTW – ToP
- PFtC = P(PBT<0), when ToP is greater than AOTW



Step 19 and Step 20

19- Asses: Is PBT left tail < Zero?

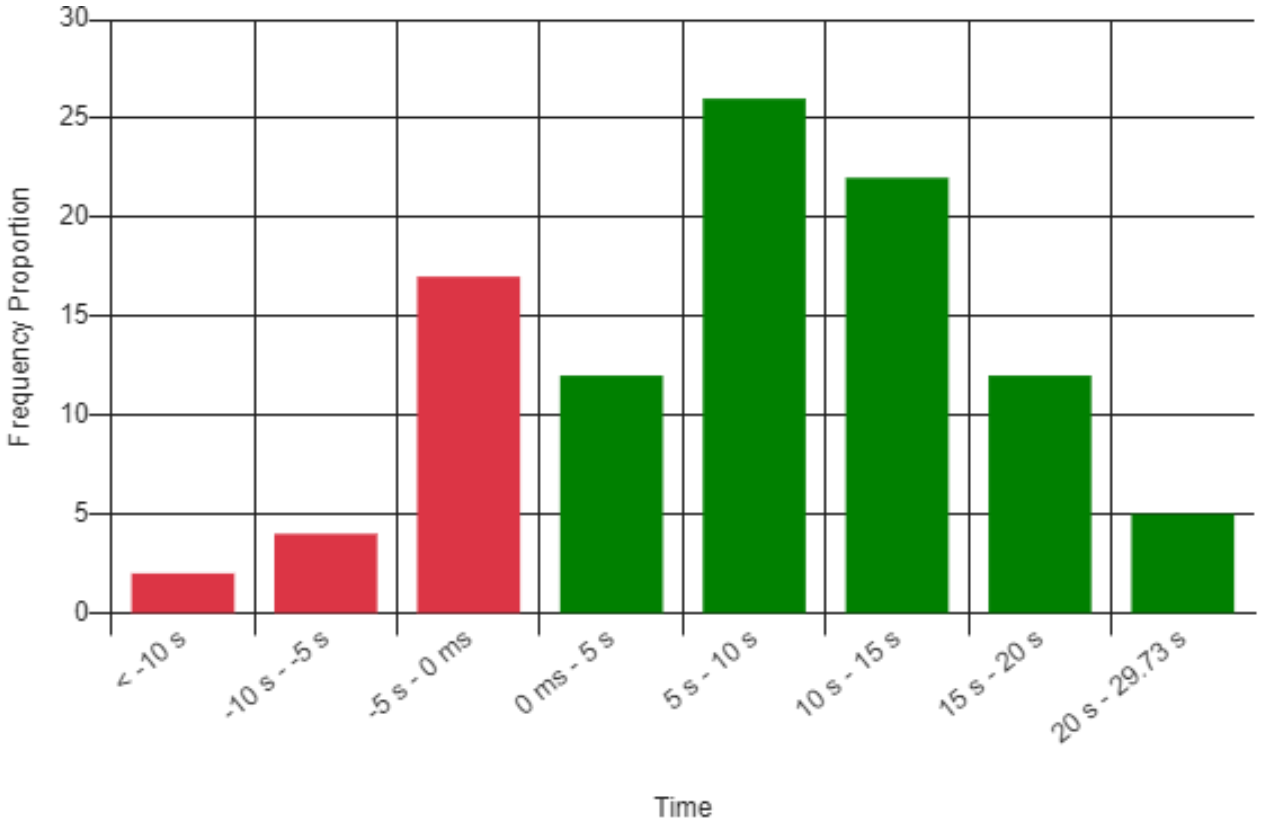
- If it is, what percent of runs did this happen.
- Greater than PFtC Threshold:

20- Redesign the SOP and the user-interface and run again until the SOP satisfies that PFtC criteria.

  - Redesign SOP
  - Redesign Input Device and Output Display
  - Go back to step 18.

- Less than PFtC Threshold:
  - Good

PFtC: 23%



Agenda

1. Introduction
2. Overview of Modelling Standard Operating Procedures (SOPs)
3. MBSE SOP
    1. Model an SOP Action Diagram from a Text SOP
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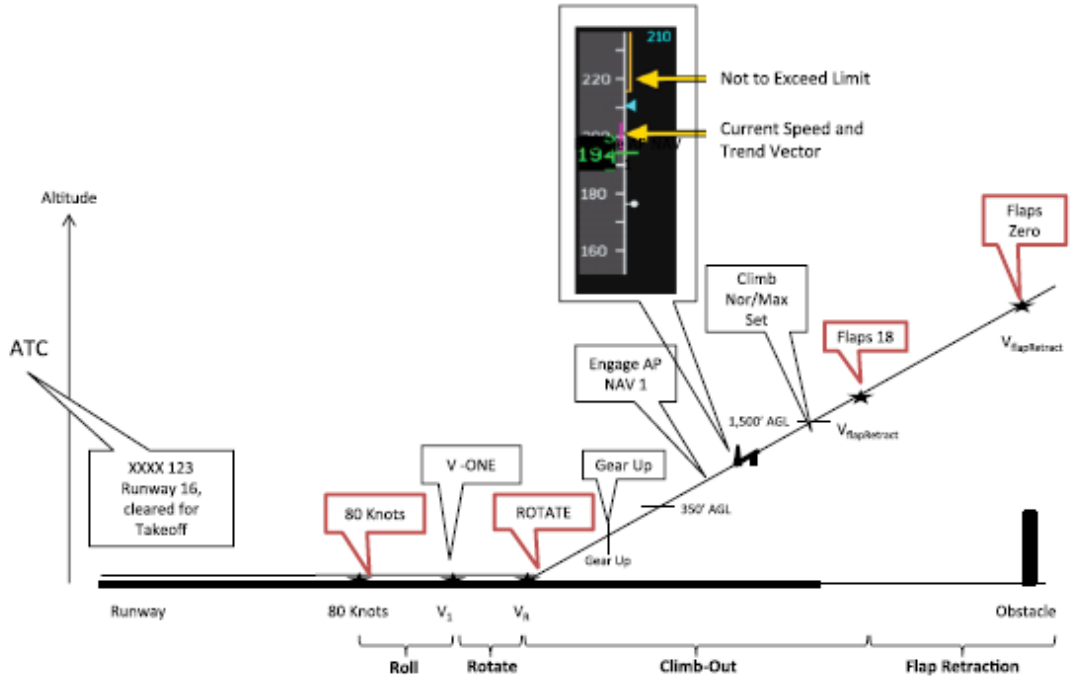
4. **Case Study: Takeoff SOP**
5. Conclusions & Future Work

Case Study: Takeoff Procedure

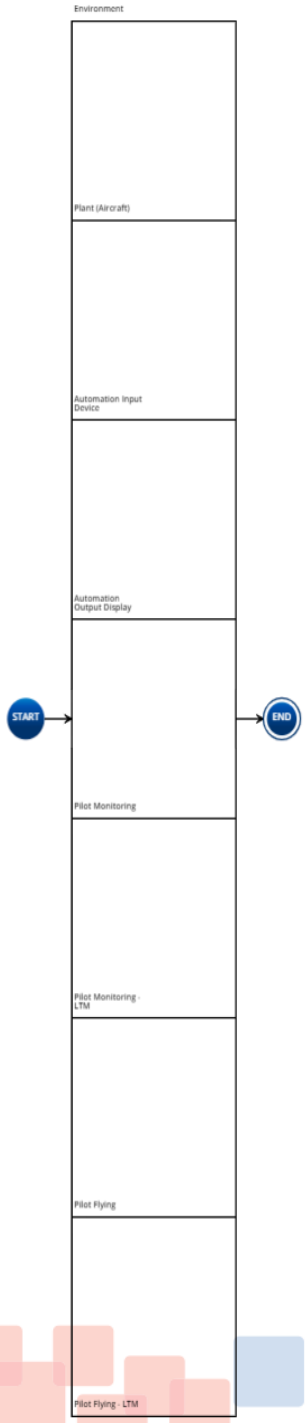
- SOP



Task Initiation Cue	Pilot Flying Action	Pilot Monitoring Actions
Positive airspeed indication		Call, “Airspeed alive”
PM calls, “Airspeed alive.”	Verify airspeed.	
At 80 KIAS		Verify 80 knots indicated on both PF and PM airspeed indicators. Call, “80 knots cross-checked.”
PM calls, “80 knots crosschecked”	Move left hand from nose steering to control yoke and call, “My yoke”.	
PF calls, “My yoke”.		Release control yoke.
At V1		Call, “V1.”
PM calls, “V1.	Move right hand to control yoke	
At VR		Call, “Rotate.”
PM calls, “Rotate.”	Rotate aircraft to pitch attitude per AFM.	

1-Identify and create branches for the action diagram.

- Actors:
  - External Environment
  - Plant
  - Automation Input Device
  - Automation Output Display
  - Pilot Monitoring
  - Pilot Monitoring – LTM
  - Pilot Monitoring - WM
  - Pilot Flying
  - Pilot Flying – LTM
  - Pilot Flying – WM



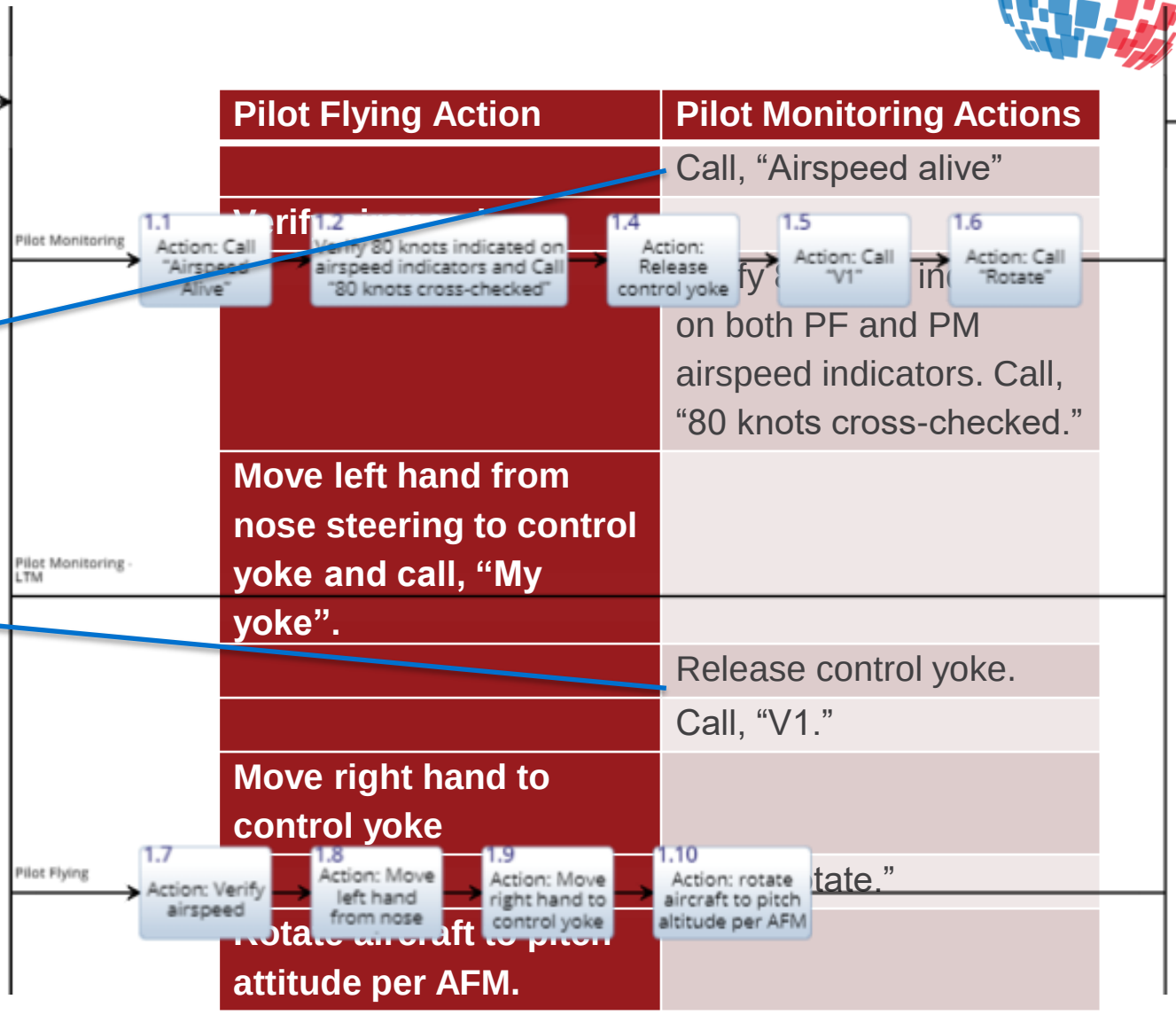
2- For each operator, insert operator actions.

Pilot Monitoring Actions:

- Action: Call “Airspeed Alive”
- Action: Verify 80 knots indicated on airspeed indicators and Call “80 knots cross-checked”
- Action: Release control yoke
- Action: Call “V1”
- Action: Call “Rotate”

Pilot Flying Actions:

- Action: Verify airspeed
- Action: Move left hand from nose steering to control yoke and call “My yoke”
- Action: Move right hand to control yoke
- Action: rotate aircraft to pitch altitude per AFM



3-For each operator action, add a “See and Decide” or “Hear and Decide” or “remember and Decide” action.

Pilot Monitoring Actions:

- See and Decide: Call “Airspeed Alive”
- See and Decide: Verify 80 knots indicated on airspeed indicators and Call “80 knots cross-checked”
- Hear and Decide: Release control yoke
- See and Decide: Call “V1”
- See and Decide: Call “Rotate”

Pilot Flying Actions:

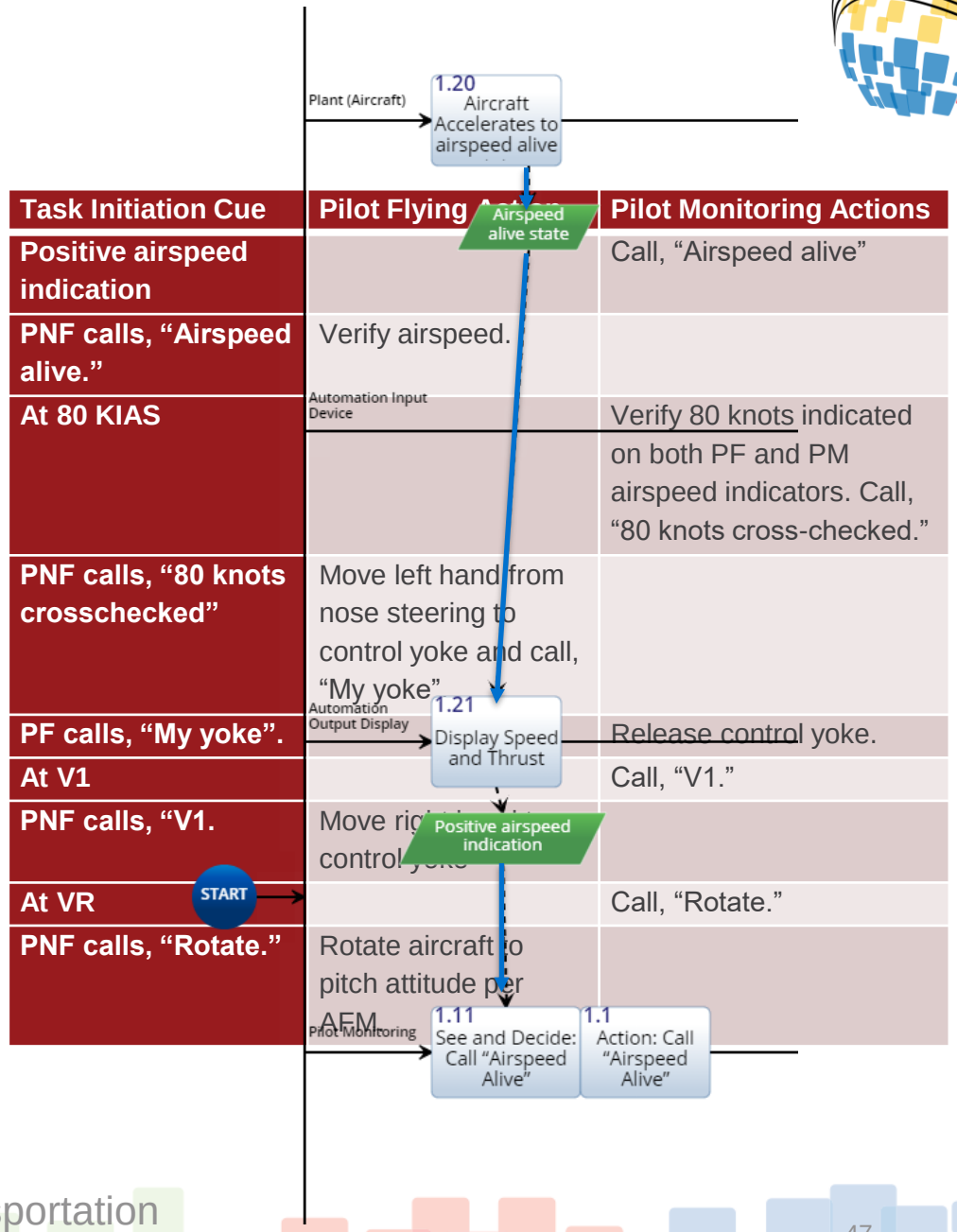
- Hear and Decide: Verify airspeed
- Hear and Decide: Move left hand from nose steering to control yoke and call “My yoke”
- Hear and Decide: Move right hand to control yoke
- Hear and Decide: rotate aircraft to pitch altitude per AFM

Task Initiation Cue	Pilot Flying Action	Pilot Monitoring Actions
Positive airspeed indication		Call, “Airspeed alive”
PNF calls, “Airspeed alive.”	Verify airspeed.	
At		V ots i on both PF and PM airspeed indicators. Call, “80 knots cross-checked.”
PNF calls, “80 knots crosschecked”	Move left hand from nose steering to control yoke and call, “My yoke”.	
PF calls, “My yoke”.		Release control yoke.
PNF calls, “V1.	Move right hand to control yoke	
At VR		Call, “Rotate.”
PNF calls, “Rotate.”	Rotate aircraft to pitch attitude per AFM.	

4- Add the initiation action and cue of the SOP.

- Initiating Action:

Machine action: Aircraft Accelerates to airspeed alive state
Cue: Airspeed alive state
Automation Output Display action: Display Speed and Thrust
Cue: Positive airspeed indication



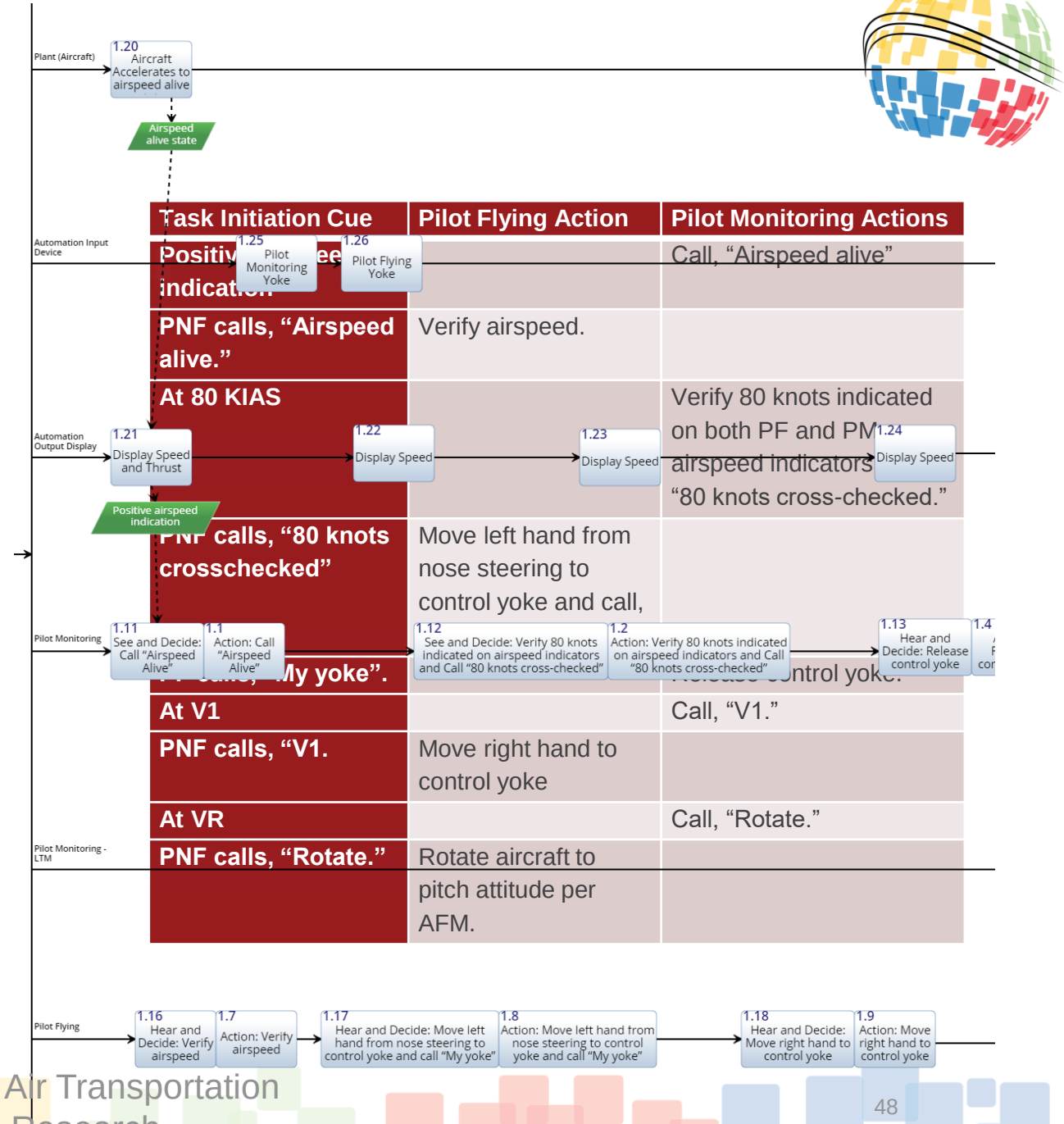
5- Insert Automation Output Display and Automation Input Device actions

Automation Output Display:

- Display Speed and Thrust
- Display Speed
- Display Speed
- Display Speed

Automation Input Device:

- Pilot Monitoring Yoke
- Pilot Flying Yoke



6-Identify the cues of the SOP, and identify the type of each cue; visual, aural, memory.

- Cue: “Airspeed alive”
  - Aural
- Cue: 80 KIAS
  - Visual
- Cue: “80 knots cross-checked”
  - Aural
- Cue: “My yoke”
  - Aural
- Cue: V1 KIAS
  - Visual
- Cue: “V1”
  - Aural
- Cue: Vr KIAS
  - Visual
- Cue: “Rotate”
  - Aural

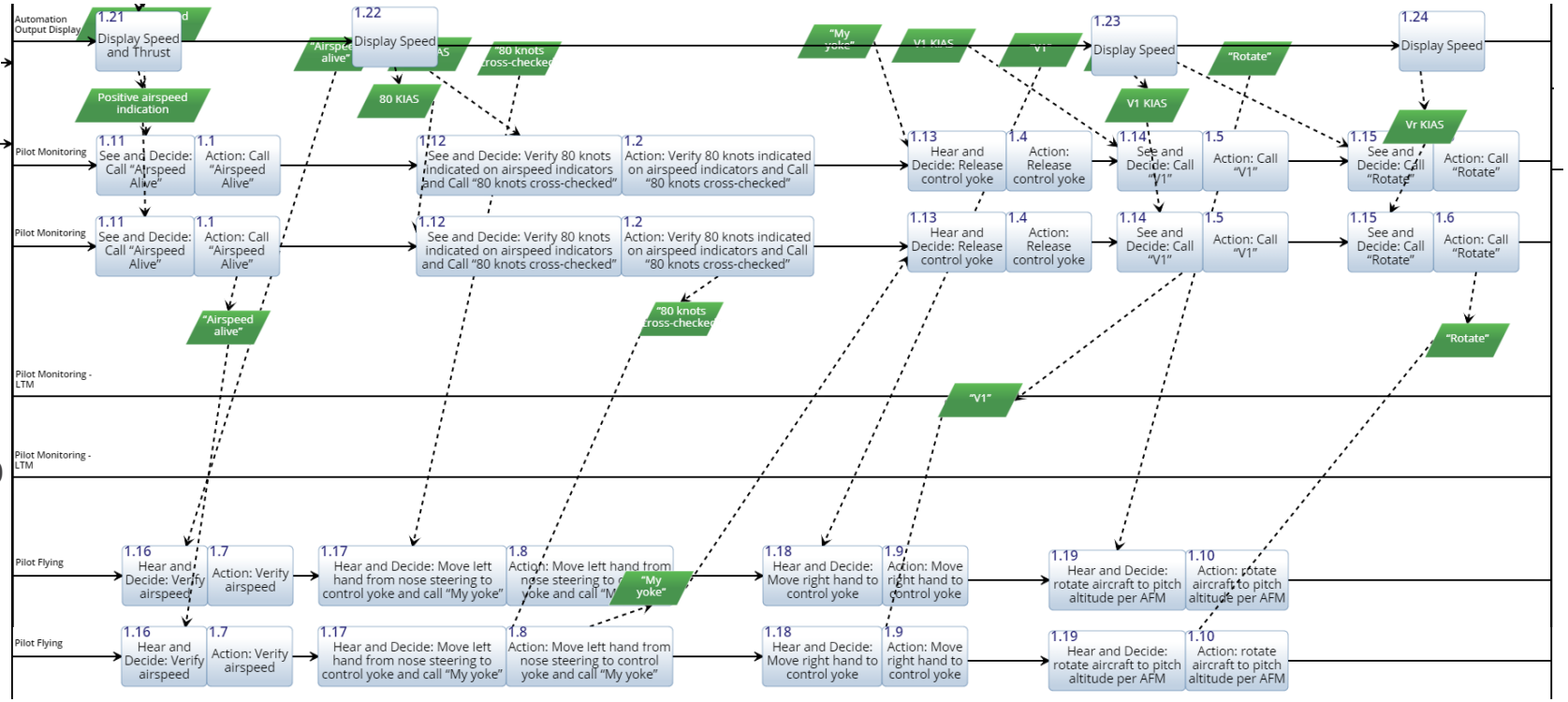
Task Initiation Cue	Pilot Flying Action	Pilot Monitoring Actions
Positive airspeed indication		Call, “Airspeed alive”
PNF calls, “Airspeed alive.”	Verify airspeed.	
At 80 KIAS		Verify 80 knots indicated on both PF and PM airspeed indicators. Call, “80 knots cross-checked.”
PNF calls, “80 knots crosschecked”	Move left hand from nose steering to control yoke and call, “My yoke”.	
PF calls, “My yoke”.		Release control yoke.
At V1		Call, “V1.”
PNF calls, “V1.	Move right hand to control yoke	
At VR		Call, “Rotate.”
PNF calls, “Rotate.”	Rotate aircraft to pitch attitude per AFM.	

7-Identify the source action/actor of each cue identified in step 6.

Cue	Source Action	Source Actor
“Airspeed alive”	Action: Call “Airspeed Alive”	Pilot Monitoring
80 KIAS	Display Speed	Automation Output Display
“80 knots cross-checked”	Action: Verify 80 knots indicated on airspeed indicators and call “80 knots cross-checked”	Pilot Monitoring
“My yoke”	Action: Move left hand from nose steering to control yoke and call “My yoke”	Pilot Flying
V1 KIAS	Display Speed	Automation Output Display
“V1”	Action: Call “V1”	Pilot Monitoring
Vr KIAS	Display Speed	Automation Output Display
“Rotate”	Action: Call “Rotate”	Pilot Monitoring

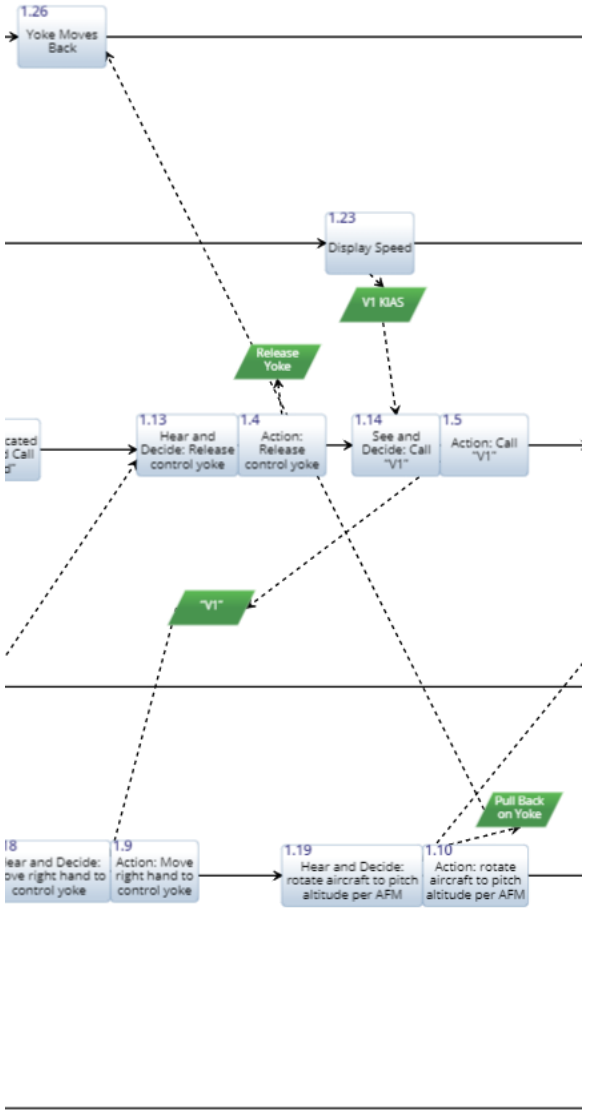
Step 8, 9, 10

- 8- Using table generated in Step 7, add the cues to the diagram and make sure to connect a cue to each See/Hear & Decide Action
- 9- Using table generated in Step 7, connect each cue to its source action.
- 10- Rewrite Cues as necessary



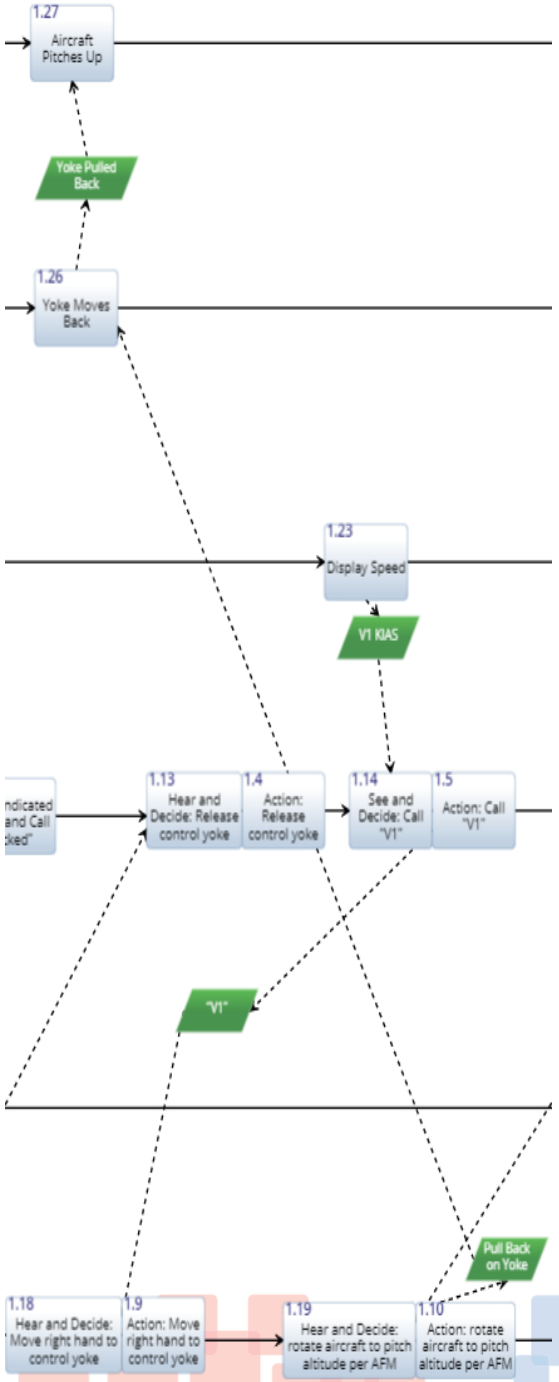
11- For each operator action, add a Automation Input Display action as appropriate.

- Operator “physical” actions:
  - Move left hand from nose steering to control yoke
  - Release control yoke
  - Move right hand to control yoke
  - Rotate aircraft to pitch altitude
- Not all physical actions require an input device action
  - Moving left hand to yoke
  - Releasing control yoke



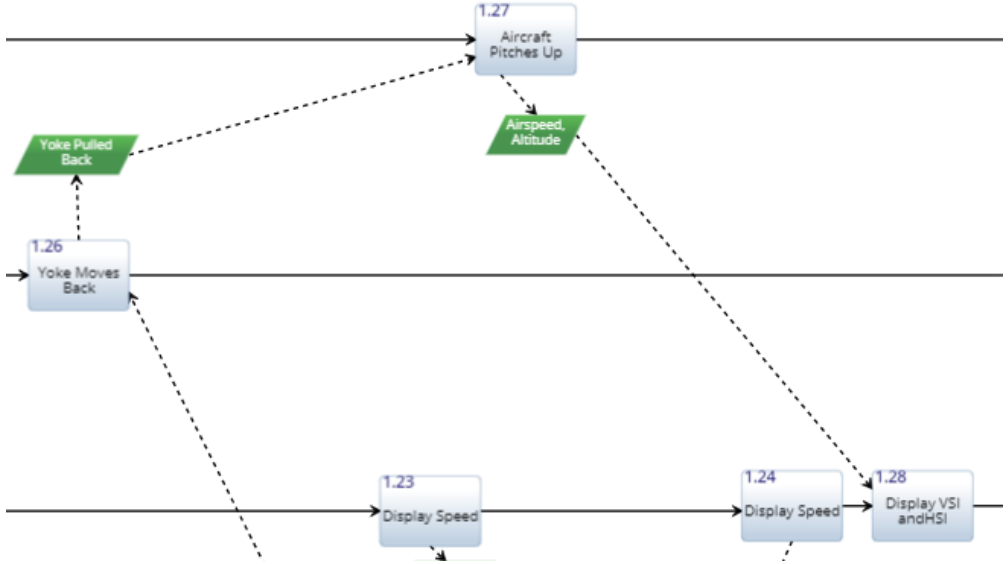
12- For each Automation Input Device action, add an output to a Machine Action and add I/Os as appropriate.

- Automation Input Device Action: Yoke Moves Back
  - Machine action: Aircraft Pitches up

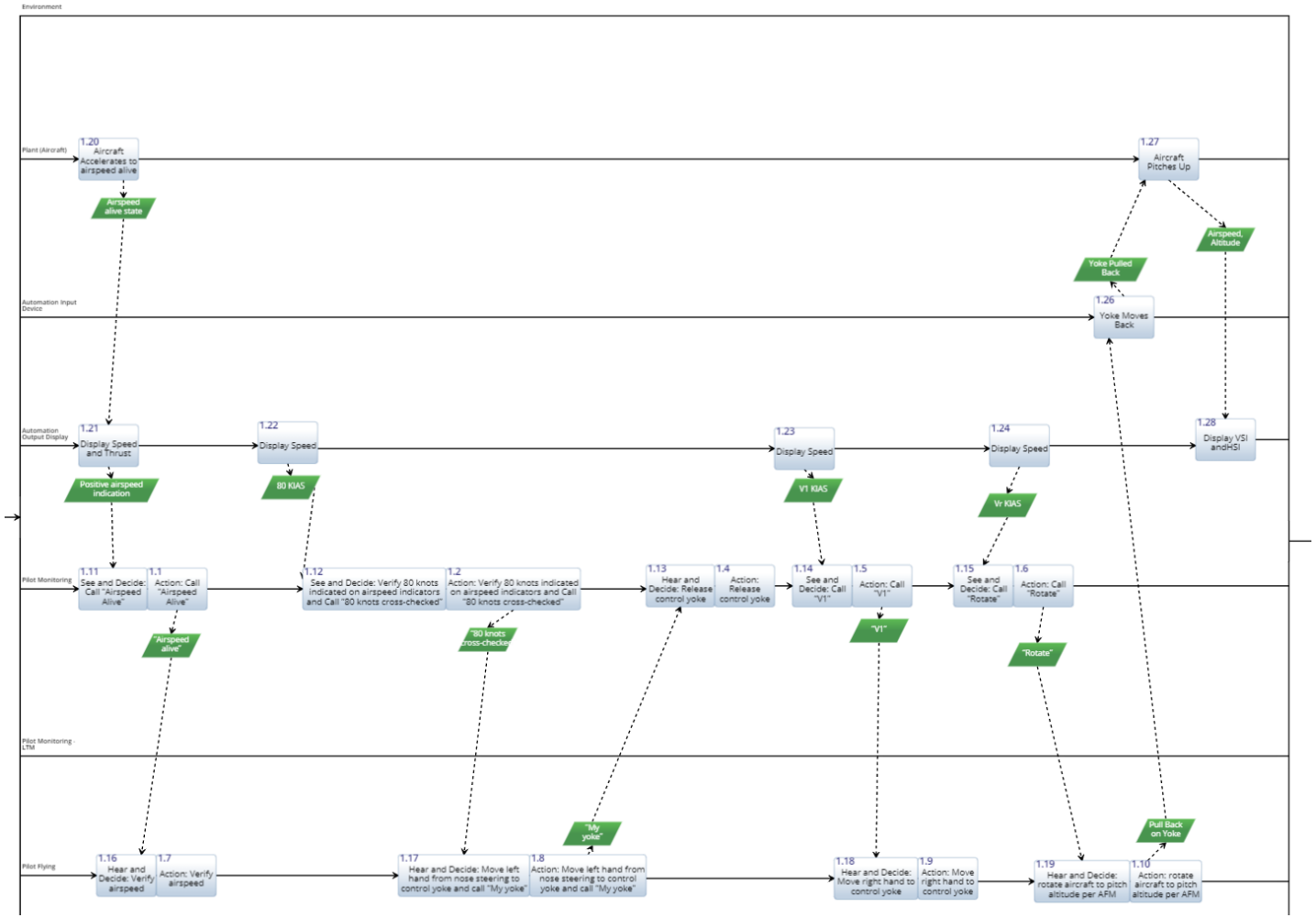


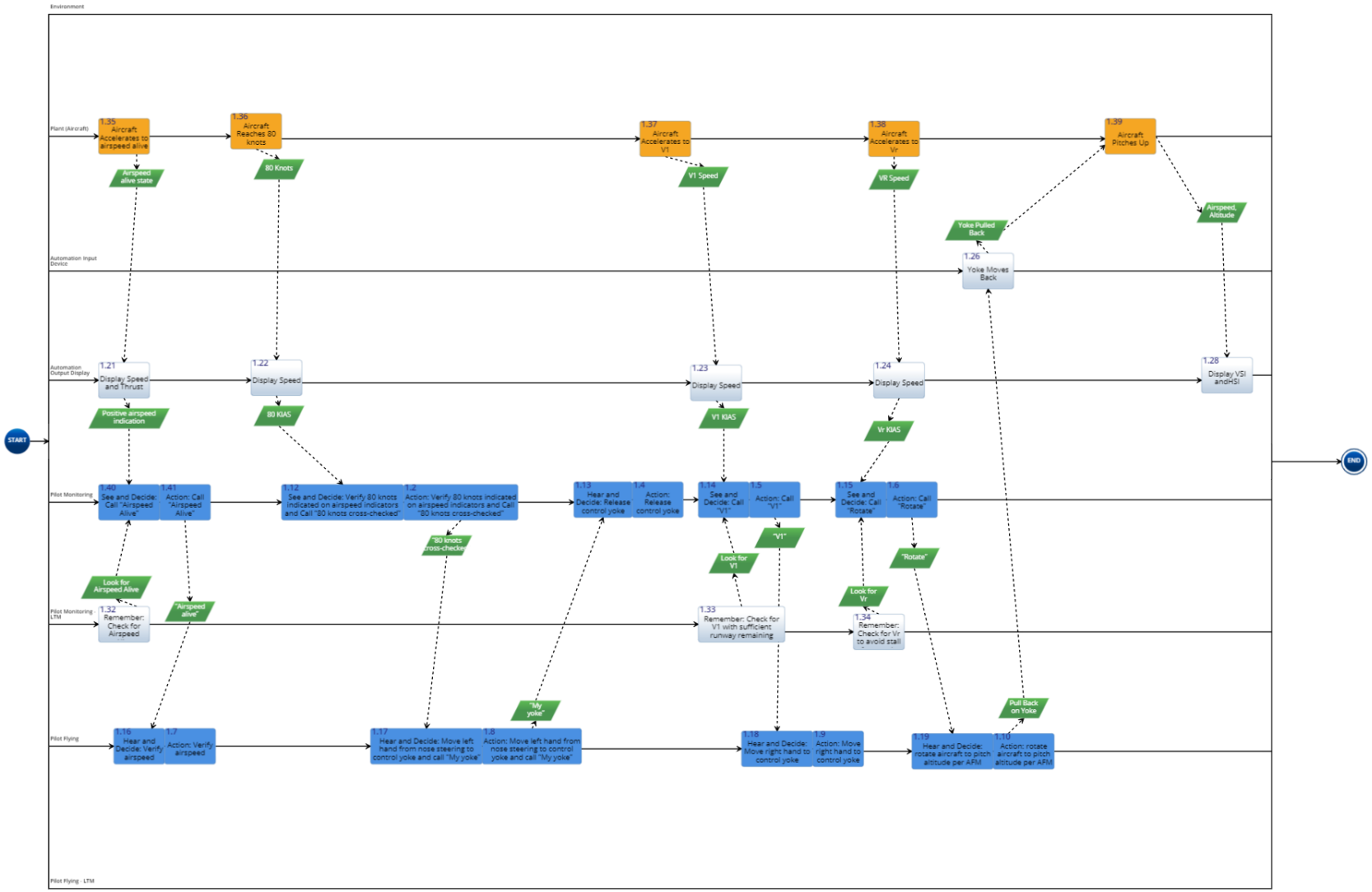
13- For each Machine action, add an Automation Output Display action and I/O as appropriate.

- Machine action: Aircraft Pitches Up
  - Automation output display action: VSI and HSI



End of First Iteration





14- Compare SOP to action diagram, go back to step 5 as appropriate.

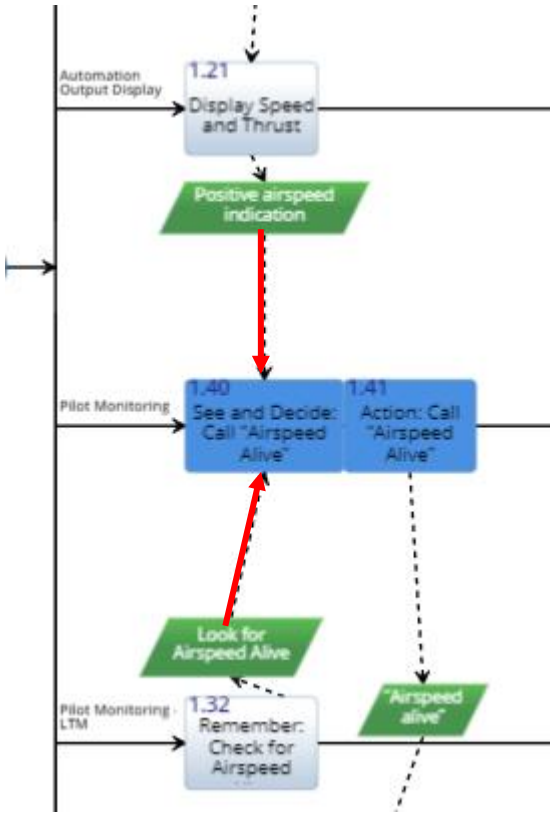
2 iterations to get a complete SOP Action Diagram.

15- Assess Operator Actions Performance.

Cue Propertiesasx	Frequency			
	Every Day	Once a moth	Once every six months	Once a year of less
No cue at all				
Cue not in Field-of-View				
Cue in Field-of-View, but not salient (lost in clutter)				
Cue in FOV and salient, but not a sematic match with the task				
Cue in FOV, salient and semantic match				

- 9 See /Hear & Decide – Action Pairs”
  - Pilot Monitoring
    - See and Decide: Call “Airspeed Alive”
    - See and Decide: Verify 80 knots indicated on airspeed indicators and Call “80 knots cross-checked”
    - Hear and Decide: Release control yoke
    - See and Decide: Call “V1”
    - See and Decide: Call “Rotate”
  - Pilot Flying:
    - Hear and Decide: Verify airspeed
    - Hear and Decide: Move left hand from nose steering to control yoke and call “My yoke”
    - Hear and Decide: Move right hand to control yoke
    - Hear and Decide: rotate aircraft to pitch altitude per AFM

15- Assess Operator Actions Performance



See and Decide: Call "Airspeed Alive"

Visual cue – Positive airspeed indication (salient, in FoV, Semantically unambiguous)

Memory item - Always

Cue Properties	Frequency			
	Every Day	Once a moth	Once every six months	Once a year of less
No cue at all	**Triang (0.03, 1,9)**		Triang (0.03, 51, 120)	
Cue not in Field-of-View			Triang (0.03, 44, 110)	
Cue in Field-of-View, but not salient (lost in clutter)			Triang (0.03, 13, 25)	Triang (0.03, 44, 62)
Cue in FOV and salient, but not a sematic match with the task	Traing (0.03, 0.08, 2)	Triang (0.03, 1, 2)	Triang (0.05, 3.5, 62)	Triang (0.06, 121, 350)
Cue in FOV, salient and semantic match	Triang (0.03, 0.08, 1.5)			

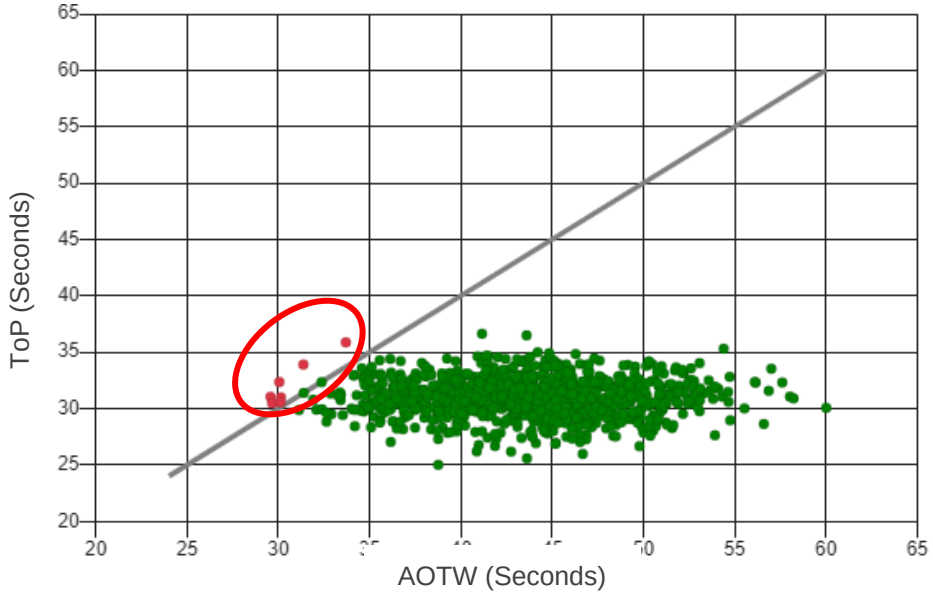
Dashboard – Statistics and Distributions

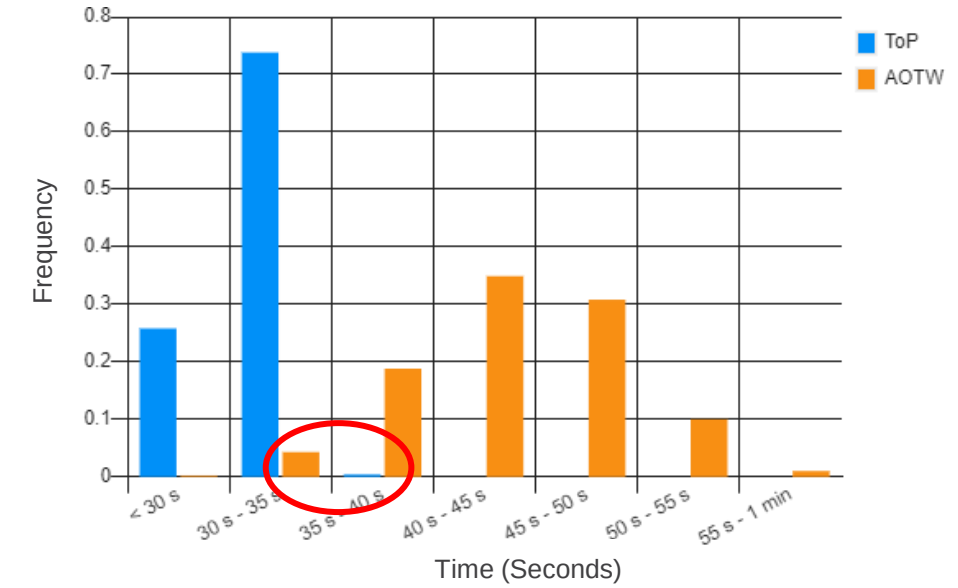
- See and Decide/Action Pairs triggered by:
  - LTM Only (No Cue): 0
  - Visual Only: 1
    - Visual Cue: in FoV, Not lost in clutter, Semantically unambiguous
  - Aural Only: 5
    - Aural Cue: in range of human sensory, not lost in noise and semantically unambiguous
  - Memory and Visual: 3
    - Visual Cue: in FoV, Not lost in clutter, Semantically unambiguous
    - Memory: Frequent

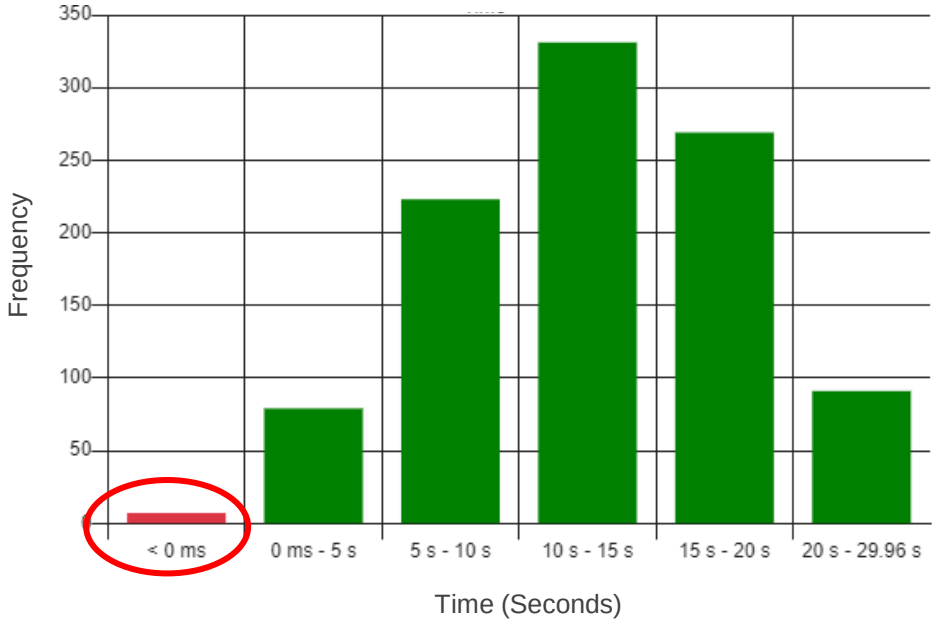
Step 16 & Step 17

- Step 16: Add distributions from HPTD Database
- Step 17: assigned threshold: 1%
- Step 18: Run MC Simulation
  - Each run:
    - Sum of ToP
    - Sum of AOTW
    - PBT

Results







PFtC: 0.7%

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Conclusions

- SOPs are critical for safe and efficient operations under different conditions of plant, operator, and environment must be taken into consideration
  - ToP and AOTW exhibit variance
  - ToP and AOTW follow triangular distributions
- Quantitively evaluating SOP can be done using MBSE Method to Model & Analyze SOP
  - Accounts for AOTW & ToP Variance
- Integration of ToP and AOTW: Probability of Failure to Complete (PFtC)
  - Helps designers improve the design of SOP early in development life-cycle

Future Work

- SOP Action Diagram Hierarchical Models.
  - Abstract complex diagrams into simpler diagrams
- Simultaneous SOPs/Multi-tasking
  - Performing multiple SOPs at the same time
  - How is this modelled/analyzed.
- Sequential SOPs
  - How to model/analyze
- Using MBSE to analyze aviation accidents
- Using NLP to automatically convert text SOPs to SOP Action Diagram.
  - Nasa Funding – Spec Innovations

References

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