Human Factors Analysis using HMI Sequence Diagrams

Lance Sherry

Learning Objectives

Knowledge

- HMI
- HMI Steps (4)
- HMI- Loop
- Cueing
- Failure Modes in Cueing
- Operationally Allowable Time Window (OATW)

Skills

- Create an HMI Sequence Diagram
- Interpret an HMI Sequence Diagram

Human Factors

- Study of the ability of the Human-Machine "system" to deal with mission surprises

- Need to understand the interaction between Humans and Machines

Human-Machine Interaction (HMI)

- All machines (i.e. vehicles, processing plants, systems) are controlled/managed by human operators
- The success of the mission is therefore directly attributable to the ability of the human-machine "system" to achieve the mission goals in the presence of an uncertain operating environment
  - i.e. mission surprises
- Machine is vehicle/processing plant
  - Include automation

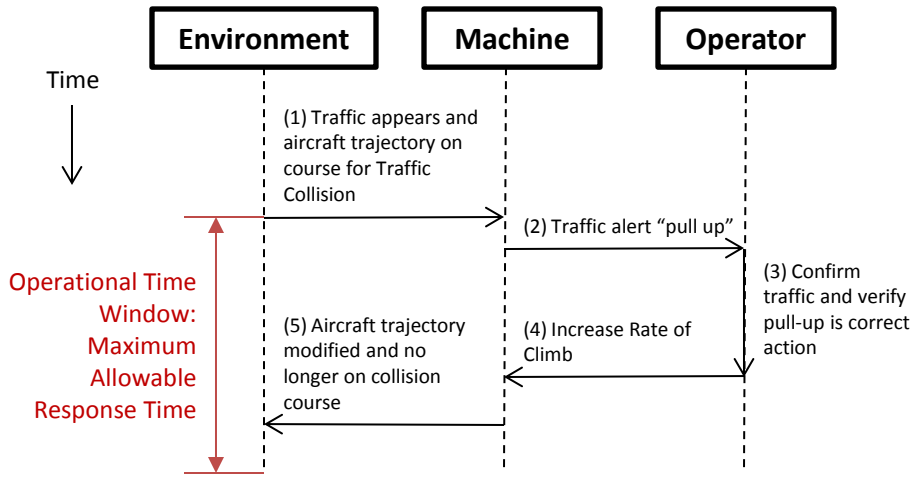
HMI

- “Machine” control/management is conducted through a cycle of interaction
  1. Observe the environment and the status of the machine
  2. Interpret the situation
  3. Decide on the next action(s)
  4. Act by manipulating parameters that control the machine

HME Interaction Loop

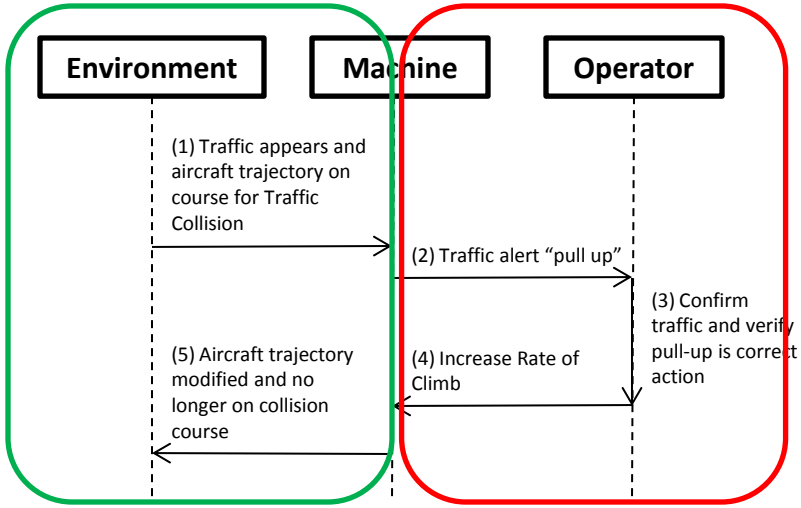
1. Change in environment is detected by machine sensors
2. Sensor information is processed and made available to **cue** the Operator
3. Operator interprets information and **decides** on appropriate action (if required)
4. Operator takes **action** by adjusting machine configuration
   - Most commands coordinated through automation
5. Machine results in change in environment

- HME Interaction loop must be completed within the Operational Time Window



HMI Design an Afterthought?

- Emphasis on System/Machine Design
  - Long history of engineering methods leading to robust integrated designs
  - Model-based design practices
- HM Interaction Design is afterthought
  - Short history of piece-meal approaches



System/Machine Design
- System/Mission
- Hardware
- Software

HM Interaction Design
- Ergonomics
- Human Factors
- Procedures
- Training

Formal Method for HMI Design

1. Is the HMI feasible
   - Machine is designed for Ease-of-Use
     - supports Cue – Decide – Act Operator Actions
2. Is the HMI reliable
   - HMI can be performed within operational time limits under all expected circumstances
3. Is the HMI robust to disruptions
   - HMI can be performed reliably in the presence of disruptions
4. Comparing Alternate Procedures
   - Utility Analysis

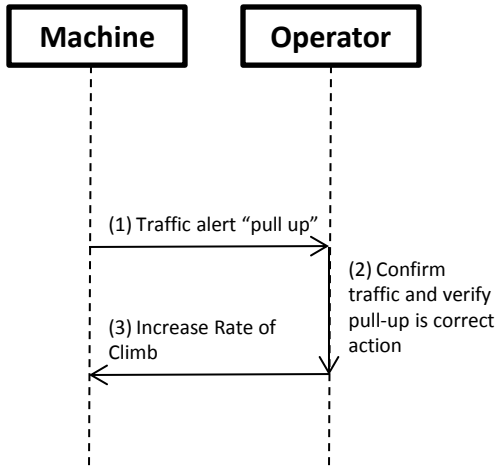
Organization

1. HMI Sequence Diagram
   - HMI-loop
2. Ease-of-Use Evaluation
   - Cueing, Decision, Action
3. Reliability Analysis
   - Hazards and Operational Time Windows
   - HMI Sequence Simulations
4. Robust to Disruptions
   - Disruption Analysis

HMI Sequence Diagram

- Operator Actions:

1. Cue
2. Decide on appropriate action(s)
3. Execute action(s)



1. Ease-of-Use Analysis

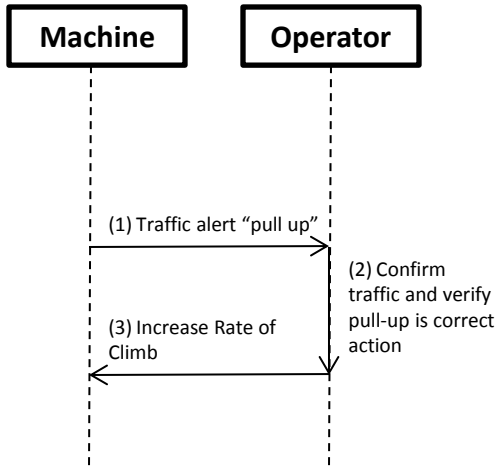
- How seamless is HMI-loop?

- Direct cues/prompts to the next Operator action provide for seamless operation

HMI-loop

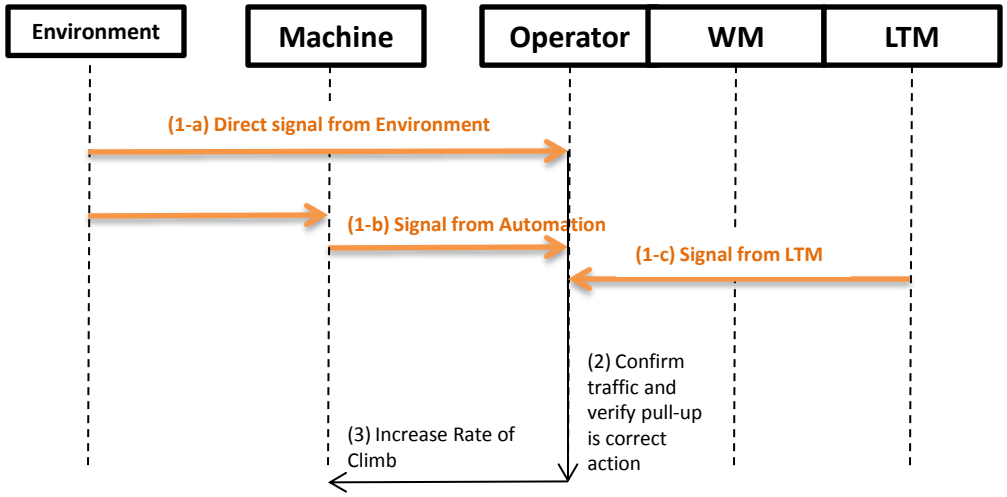
- Operator Actions:

1. Cue
2. Decide on appropriate action(s)
3. Execute action(s)



Cueing

- (1-a) Direct signal from Environment
  - Visual
  - Tactile
  - Aural
- (1-b) Signal from Automation
  - Visual
  - Tactile
  - Aural
- (1-c) Signal from Long-term Memory
  - Memorized



Failure Modes in Cueing

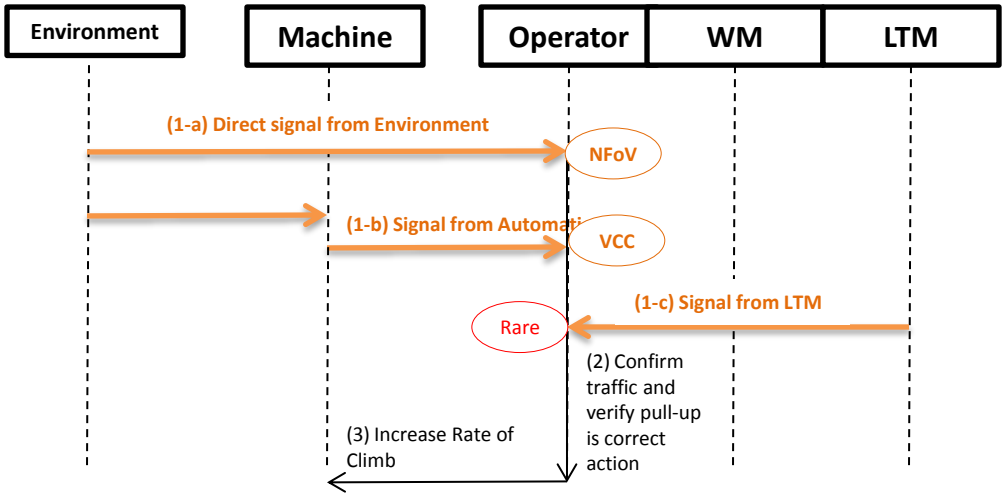
- Visual
  - No visual cue **(NVC)**
  - Visual cue present, but not in field of view **(NFoV)**
  - Visual cue present and in field of view, but lost in clutter **(CVC)**
    - i.e. competing visual cues
  - Salient cue, but semantics of cue do not match semantics of action **(VCSem)**
    - Cues button push with cue that does not match button label
  - Salient and Semantically similar OR Frequent **(S&S, Freq)**
- Tactile/Aural
  - No cue **(NTC, NAC)**
  - Cue present, but not in tactile/aural range for human sensory perception **(NTR, NAR)**
  - Cue present and in range, but lost in noise **(CTC, CAC)**
  - Salient cue, but cannot be interpreted **(TCSem, ACSem)**

Failure Modes in Cueing

- Long-term Memory **(Freq) (Inf) (Rare)**
  - Works fine for frequent events
  - Is subject to failure for infrequent/rare events

- Note: Long-term Memory is the “back-up” for failures in Visual/Tactile/Aural cues

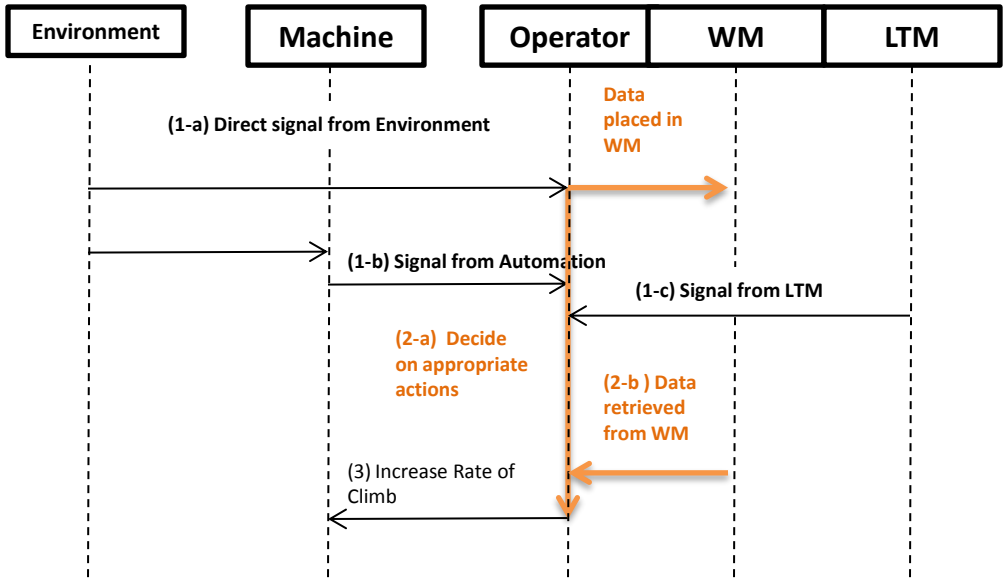
Failure Modes in Cueing



Decision-making

(2-a) Decide on appropriate actions

(2-b) Decide based on retrieval from Working Memory



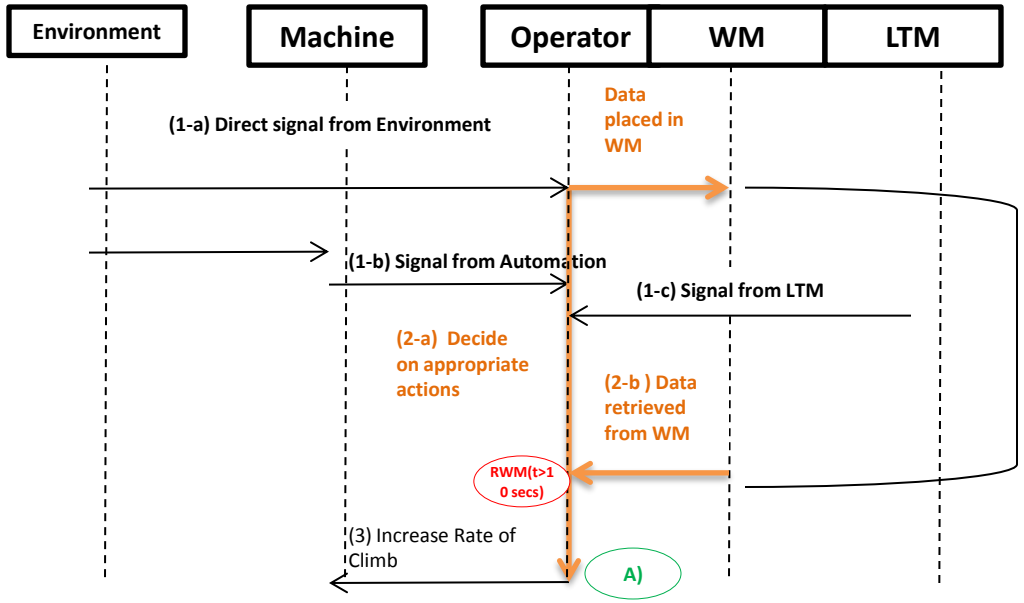
Failure Modes in Decision-making

(2-a) Decide on appropriate actions

1. Automaticity **(A)**
   - Procedure is well-defined (i.e. no gaps)
   - Procedures/Habit/Practiced
   - *Fast and reliable*
   - *Subject to (inadvertent) "slips"*
2. Rule-based **(RB, T&E)**
   - Procedure requires operator to fill in gaps
   - Needs some thinking based on memorized rules
   - "thinking" is generally done by Trial-and-Error **(T&E)**
   - *Slower and less reliable*
   - *Subject to "mistakes"*
3. Reasoning **(R)**
   - No procedure
   - Needs deep thinking based on information gathering and mental model trial-and-error
   - *Very slow and poor reliability*
   - *Subject to deep errors in how things work (i.e. response to stimulus)*

(2-b) Decide based on retrieval from Working Memory **(RWM(t>10 secs))**

- Data in WM decays in matter of seconds (7-10 secs)


Environment
Machine
Operator
WM
LTM
Data placed in WM
(1-a) Direct signal from Environment
(1-b) Signal from Automation
(1-c) Signal from LTM
(2-a) Decide on appropriate actions
(2-b) Data retrieved from WM
RWM(t>10 secs)
(3) Increase Rate of Climb
A)

[μ = 7 secs, σ = 1.2]

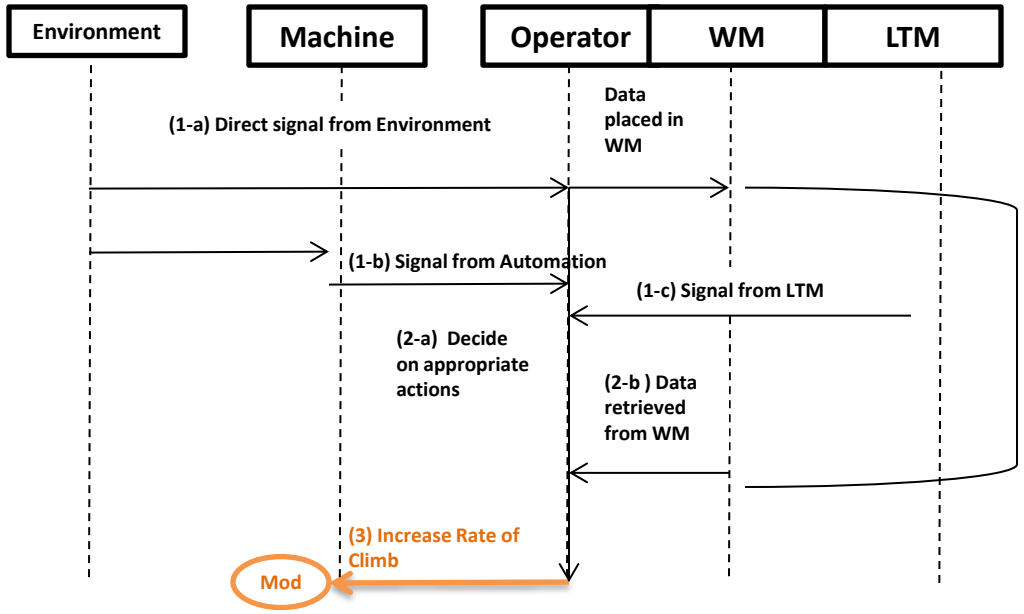
Actions

- Manipulate Input Device
  - Lever
  - Button
  - Knob
  - Data Entry
    - Keyboard
    - Selection
    - Cursor (point-and-click)

Failures in Actions

- Failure Modes
  - Input device not in range (to reach) **(NiR)**
  - Input device manipulation error (e.g. direction) **(ME)**
  - Input device moded (i.e. works differently in different situations) **(Mod)**
  - Input device manipulation not acknowledged **(NAck)**

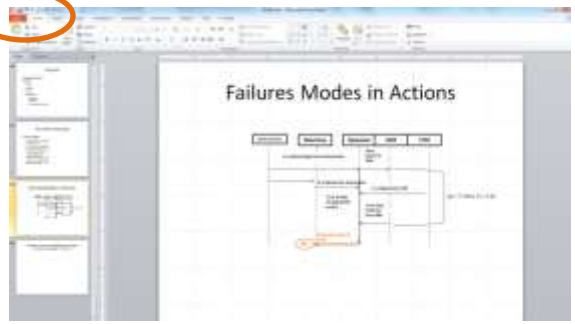
Failures Modes in Actions



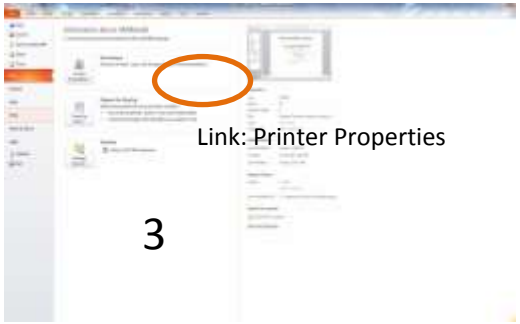
[μ = 7 secs, σ = 1.2]

Example: Print from Powerpoint but Change Orientation Landscape to Portrait

1



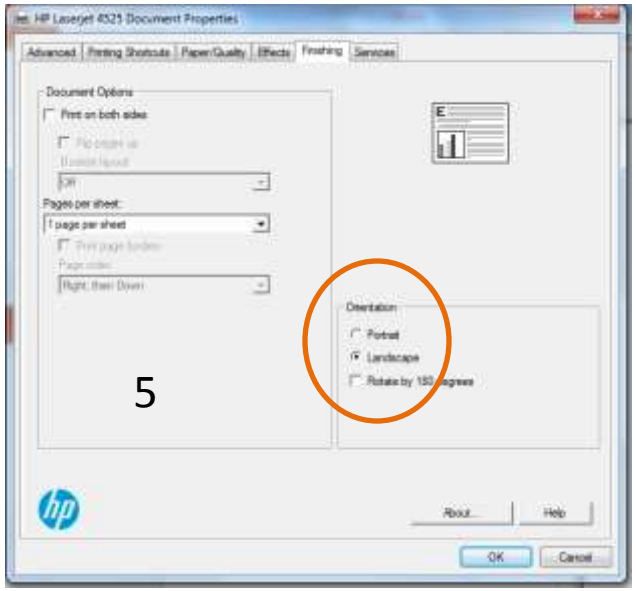
2



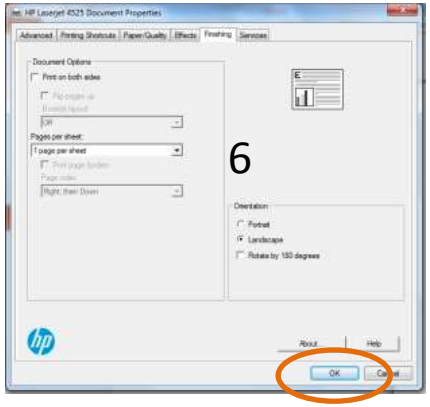
Link: Printer Properties

3

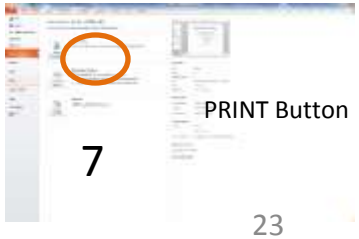
4



5



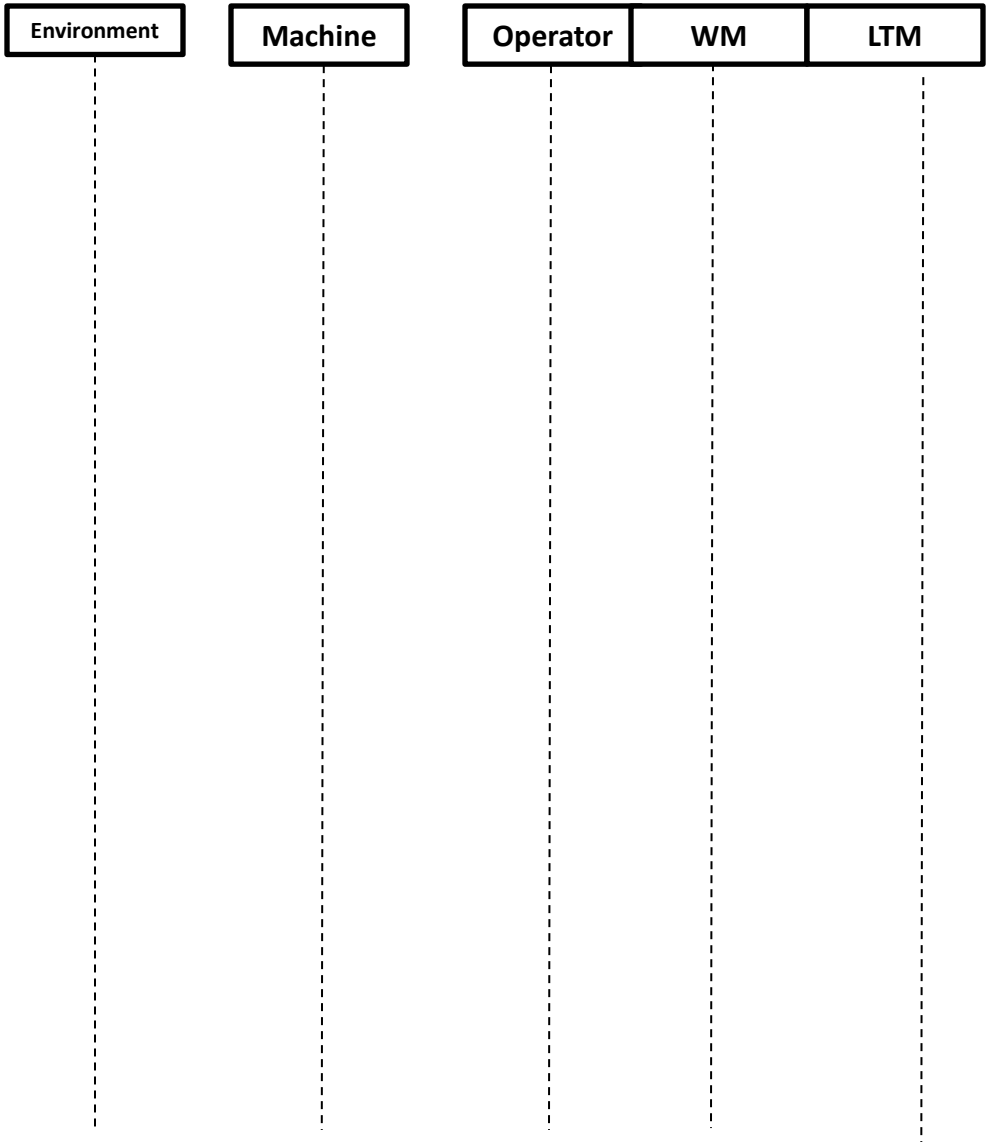
6



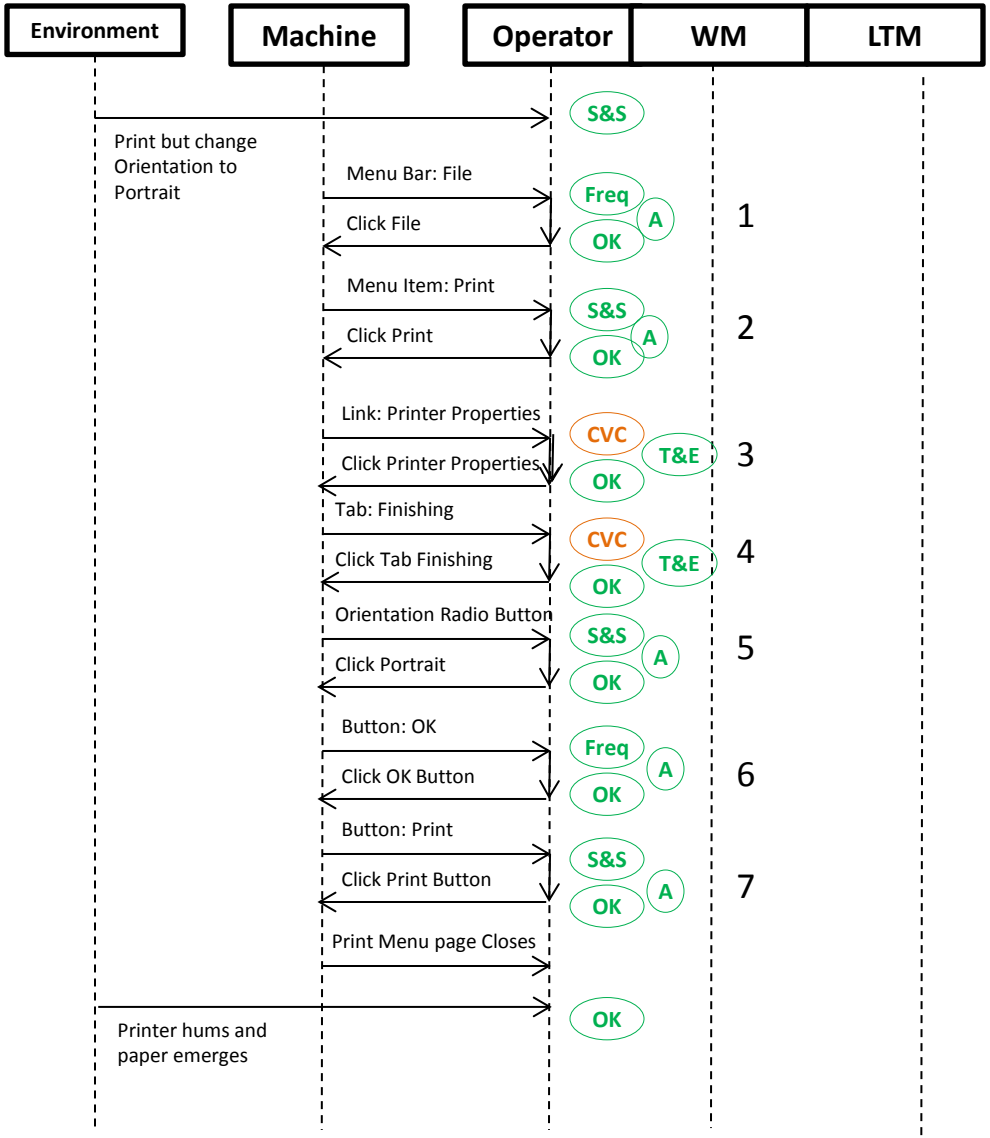
7

PRINT Button

Task Print from Powerpoint but Change Orientation Landscape to Portrait
(1) Draw an HMI Sequence Diagram, (2) Assign Failure Modes to each Operator Action



Print from Powerpoint but Change Orientation Landscape to Portrait



- Where are the likely ***failure points*** in the chain of HMI loops?
- How would you fix these?

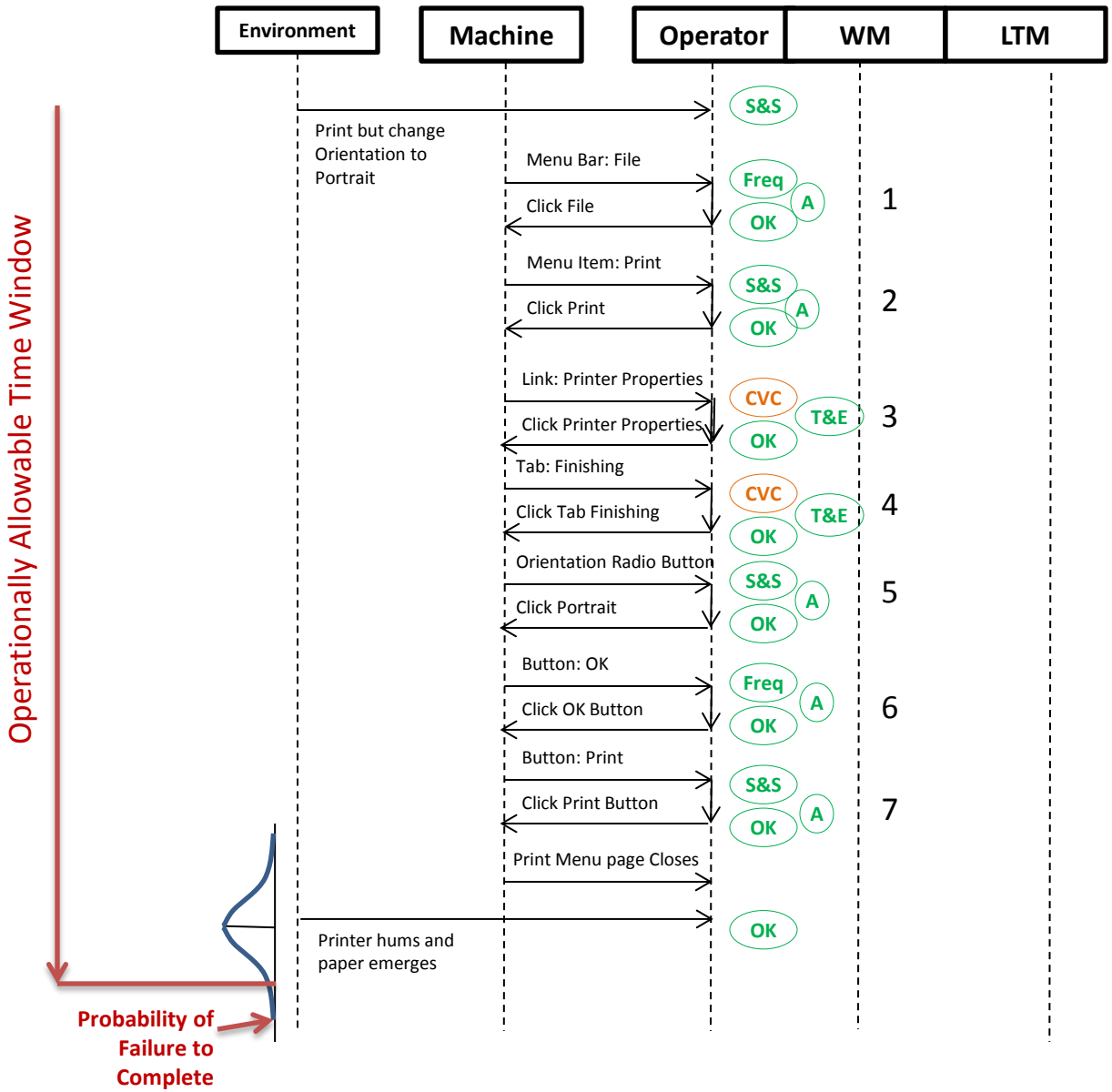
2. Reliability Analysis

- How reliably, over a population of users can the Procedure be completed with an Operationally Allowable Time Window (OATW) ?

Defining the OATW

- OATW defined by:
  - Hazards (in a dynamic system – e.g. collisions, performance envelope, energy limitations, …)
  - Efficiency goals

Print from Powerpoint but Change Orientation Landscape to Portrait



- Where are the ***time consuming steps in the*** chain of HMI loops?
- How would you fix these?

Accident Investigation

- AF 447
  - Automation sends deluge of “faults”
    - Competing cues
    - Conflicting cues
    - No cues on what actions to take to resolve
- TK 1951
  - Automation autonomously changes control model (i.e. to a Land Mode despite the aircraft being airborne)
  - Hides true intent (not to control speed) with **functionally overloaded** label (“RETARD”)
- OZ214
  - Automation changes control mode based on pilot action
  - Hides true intent (not to control speed) with **functionally overloaded** label (“HOLD”)

Accident Investigation

- Flight crew included on flight deck to:
  1. Communicate with outside world (via voice)
  2. Oversee systems that are not (yet) integrated
  3. **Intervene if systems behavior inappropriately (for the current situation)**
- Intervention:
  - Monitor equipment designed to 10-5 to intervene to achieve safety target of 10-9
  - Is the best design?
    - Asking humans to monitor for rare events that occur 10-4.
- Should pilots be held liable for not intervening in a 10-4 scenario?
- Who is/should be responsible for solving this problem?