Updating the Human Controller Model

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AeroAstro Department, Massachusetts Institute of Technology
Motivation
The Human Controller
Case Study
Motivation
What is the problem?

Human controller ≠ Automated controller
What is the problem?

What is the problem?

Example of **human controller** related safety constraints

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How can hazard analyses of the human controller be improved?
The Goal

To enhance the causal factor analysis of the human controller
The Human Controller
Process Model Variables

The “train door” example

Process Model Variables

Leveson, N., Thomas, J. “An STPA Primer Version 1,” August 2013

simplified train door controller

...with the door controller’s process models
**“Open door” control action**

<table>
<thead>
<tr>
<th>Process Model Variable</th>
<th>1. Train Motion (moving/stopped)</th>
<th>2. Train Position (aligned/not aligned)</th>
<th>3. Emergency (no/evacuation required)</th>
</tr>
</thead>
</table>
| Lower-level Process Model Variables | | | 3.1 Smoke present  
3.2 Fire present  
3.3 Toxic gas present |
| Feedback | 1. Train motion  
- Speed sensor #1  
- Speed sensor #2  
- Speed sensor #3 | 2. Train position  
- Left platform sensor  
- Right platform sensor | 3. Emergency  
3.1 Smoke present  
- Ionization smoke sensor  
- Optical smoke sensor  
3.1 Fire present  
- Engine compartment fire sensor  
- Passenger compartment fire sensor sensor  
3.1 Toxic gas present  
- Toxic gas sensor |
For the human operator, accurate understanding of the PMV's is necessary for system safety.
The Current Human Controller Model

An Updated Human Controller Model

Step 2 Causal Factors

Step 2 Causal Factors

Case Study
In-Trail Procedure (ITP)
In-Trail Procedure (ITP)

Enables flight level changes on a more frequent basis to improve flight efficiency
ITP Example Maneuver

ITP Following-Climb

Required equipment:
- **ADS-B** IN and OUT
- **ITP Equipment**
In-Trail Procedure (ITP)

**RTCA** analysis of ITP

**STPA** analysis of ITP

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Foundation

System Definition

Step 1

UCA’s

Step 2

Casual Factors
The UCA’s for this example stem from the **Execute ITP** control action

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Process Model Variables

**PMV 1:** ITP criteria

**PMV 2:** ATC clearance

**PMV 3:** Airspace model
## Process Model Variables

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<tr>
<th>High-level Process Model Variable</th>
<th>1. ITP criteria <em>(met or not)</em></th>
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<tr>
<td>Lower-level Process Model Variables</td>
<td>1.1 Climb/Descent rate <em>(Y/N)</em></td>
<td>None</td>
<td>3.1 Weather clear for ITP <em>(Y/N)</em></td>
</tr>
<tr>
<td></td>
<td>1.2 ITP distance <em>(Y/N)</em></td>
<td></td>
<td>3.2 Clear of other traffic <em>(Y/N)</em></td>
</tr>
<tr>
<td></td>
<td>1.3 Ground speed differential <em>(Y/N)</em></td>
<td></td>
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<td>1.4 Mach differential <em>(Y/N)</em></td>
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<td>1.5 Reference a/c maneuvering or expected to <em>(Y/N)</em></td>
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<td>1.6 Vertical distance reqs <em>(Y/N)</em></td>
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<td>1.7 Ownship data integrity <em>(Y/N)</em></td>
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<td>1.8 Reference a/c data integrity <em>(Y/N)</em></td>
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<td>1.9 Same track criteria <em>(Y/N)</em></td>
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<td>1.10 Requested flight level correct <em>(Y/N)</em></td>
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*Planned to be calculated by ITP equipment*
## Unsafe Control Actions

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<th>ATC Clearance</th>
<th>Airspace Model</th>
<th>Hazardous</th>
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<tr>
<td>Execute ITP</td>
<td>Met</td>
<td>Approved</td>
<td>Clear for ITP</td>
<td>No</td>
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<td>Execute ITP</td>
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Therefore, executing ITP is hazardous when either:

- The **ITP criteria (PMV 1)** is not met
  or
- **ATC clearance (PMV 2)** is not valid
  or
- The **Airspace model (PMV 3)** is not clear for ITP
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<td>ITP executed when <strong>ITP criteria not satisfied</strong></td>
<td>ITP executed too soon before approval</td>
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**Initiation or continuation?**

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Execute ITP

- Initiate ITP
- Continue ITP
- Terminate ITP

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| **Initiate ITP** | ITP initiated when **ITP criteria (PMV 1)** has not been met  
ITP initiated when **ATC approval (PMV 2)** is not valid  
ITP initiated when **Airspace model (PMV 3)** is not clear |  
| **Continue ITP** | ITP continued with inappropriate **ITP criteria (PMV 1)**  
ITP continued with revoked **ATC clearance (PMV 2)**  
ITP continued with **Airspace model (PMV 3)** that no longer permits ITP |  
|  |  | ITP executed too soon before approval  
ITP executed too late |  
|  |  | ITP continued past requested flight level  
ITP stopped before requested flight level |  |
## UCA Comparison

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STPA Analysis

Foundation
System Definition

Step 1
UCA’s

Step 2
Casual Factors
The differences

Hazard: H-1, H-2, H-4
Unsafe Control Action: 1) **ITP initiated** when any of **PMV 1-3** are not met, approved, or clear for ITP
2) **ITP continued** when any of **PMV 1-3** are no longer met, approved, or clear for ITP
Causal Factor Comparison

The **current** human controller model vs. The **updated** human controller model
The differences

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- ITP equipment give incorrect or ambiguous information  
- ATC approval not on communication channel that FC is monitoring |
| Inadequate or missing feedback              | - Change in own velocity/altitude/bearing not displayed to pilot  
- Change in the velocity/altitude/bearing of nearby ship not displayed to pilot  
- Proper aircraft identifier or nearby aircraft not displayed to pilot  
- FC does not receive communication from ATC  
- FC does not receive local traffic information from ADS-B |

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<td>ITP afforded</td>
<td>- Flight Crew affords the initiation of ITP or continues to afford ITP, through a slip or mistake, and isn’t made aware of this through feedback</td>
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The differences

Hazard: H-1, H-2, H-4

Unsafe Control Action: 1) **ITP initiated** when any of PMV 1-3 are not met, approved, or clear for ITP
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![Diagram of Human Controller and control actions]
Causal Factor Comparison

The **current** human controller model

**vs.**

The **updated** human controller model
# The differences

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| **ATC clearance (PMV 2):** | - Is incorrect or missing  
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| Either **Airspace model variable (PMV 3.1 or 3.2):** | - Is incorrect or missing  
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- Is in conflict which leads to an ambiguous **Airspace model (PMV 3)** |
| - There is a conflict between ITP criteria, ATC approval, and the airspace model (i.e. a conflict between **PMV 1, PMV 2,** and **PMV 3**)
- No feedback reaches Flight Crew that communication protocols are invalid
- There is no feedback to determine incorrect ITP affordance |

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| No traceability to current affordance/actions | - There is a conflict between ITP criteria, ATC approval, and the airspace model (i.e. a conflict between PMV 1, PMV 2, and PMV 3)  
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**Hazard: H-1, H-2, H-4**

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Causal Factor Comparison

The **current** human controller model

**vs.**

The **updated** human controller model

The current human controller model:

1. Control input or external information wrong or missing
2. Inadequate Control Algorithm (Flaws in creation, process changes, incorrect modification or adaptation)
3. Process Model inconsistent, incomplete, or incorrect
4. Inadequate or missing feedback
5. Feedback Delays

The updated human controller model:

- **UCA afforded** (also through incorrect timing, temporal application, or out of sequence) or Action not afforded
- Inadequate decision making
- Process models inconsistent, incomplete, or incorrect
- PMV's undetected or interpreted incorrectly or too late
- No traceability to current affordance/actions

Causal Factors:

- **Sensors**
- **PMV's**
- **Controls**
- **Displays**
- **Actuators**
- **Human Controller**

UCA vs.

- **Sensory Perception**
- **Conflicting, missing, delayed, or unrefreshed PMV's**
- **No traceability to current affordance/actions**
The differences

Hazard: H-1, H-2, H-4
Unsafe Control Action: 1) **ITP initiated** when any of PMV 1-3 are not met, approved, or clear for ITP  
2) **ITP continued** when any of PMV 1-3 are no longer met, approved, or clear for ITP

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Overall, the new human controller model improved the **clarity**, **structure**, and **organization** of the causal factor analysis.
The Way Forward

- Improve upon the decision making analysis
- Improve upon the links between affordance, action, and feedback (traceability)
RTCA Comparison

**Process Model Link** | **Cause**
--- | ---
Process Models inconsistent, incomplete, or incorrect | Flight Crew believes:
- ITP criteria (PMV 1) has been met when it is not
- ATC clearance (PMV 2) to be valid when it is not
- Airspace model (PMV 3) to be clear when it is not

Inadequate decision making | Flight Crew:
- Decides ITP is appropriate when it is not
- Does not accurately assess ITP criteria
- Does not select the appropriate flight level
- Does not initiate the correct communication protocols with ATC or other aircraft
- Does not accurately assess anything other than ATC approval
- Does not accurately verify ITP criteria

ITP afforded | Flight Crew affords the execution of ITP or continues to afford ITP, through a slip or mistake, and isn’t made aware of this through feedback

Conflicting, missing, delayed, or unrefreshed PMV’s. | Any of the ITP criteria (PMV 1, 1.1-1.10):
- Are incorrect or missing
- Aren’t refreshed in the appropriate amount of time
- Are in conflict which leads to an ambiguous ITP criteria (PMV 1)

ATC clearance (PMV 2):
- Is incorrect or missing
- Isn’t provided in the appropriate amount of time
- No longer remains valid (i.e. not refreshed in the appropriate amount of time)

Either Airspace model variable (PMV 3.1 or 3.2):
- Is incorrect or missing
- Isn’t refreshed in the appropriate amount of time
- Is in conflict which leads to an ambiguous Airspace model (PMV 3)

No traceability to current actions | There is a conflict between ITP criteria, ATC approval, and the airspace model (i.e. a conflict between PMV 1, PMV 2, and PMV 3)
- No feedback reaches Flight Crew that communication protocols are invalid
- There is no traceability to determine incorrect ITP affordance

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