Updating the Human Controller Model

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2014 STAMP Conference, Cambridge, Massachusetts
Massachusetts Institute of Technology

Motivation

The Human Controller

Case Study

[Motivation]

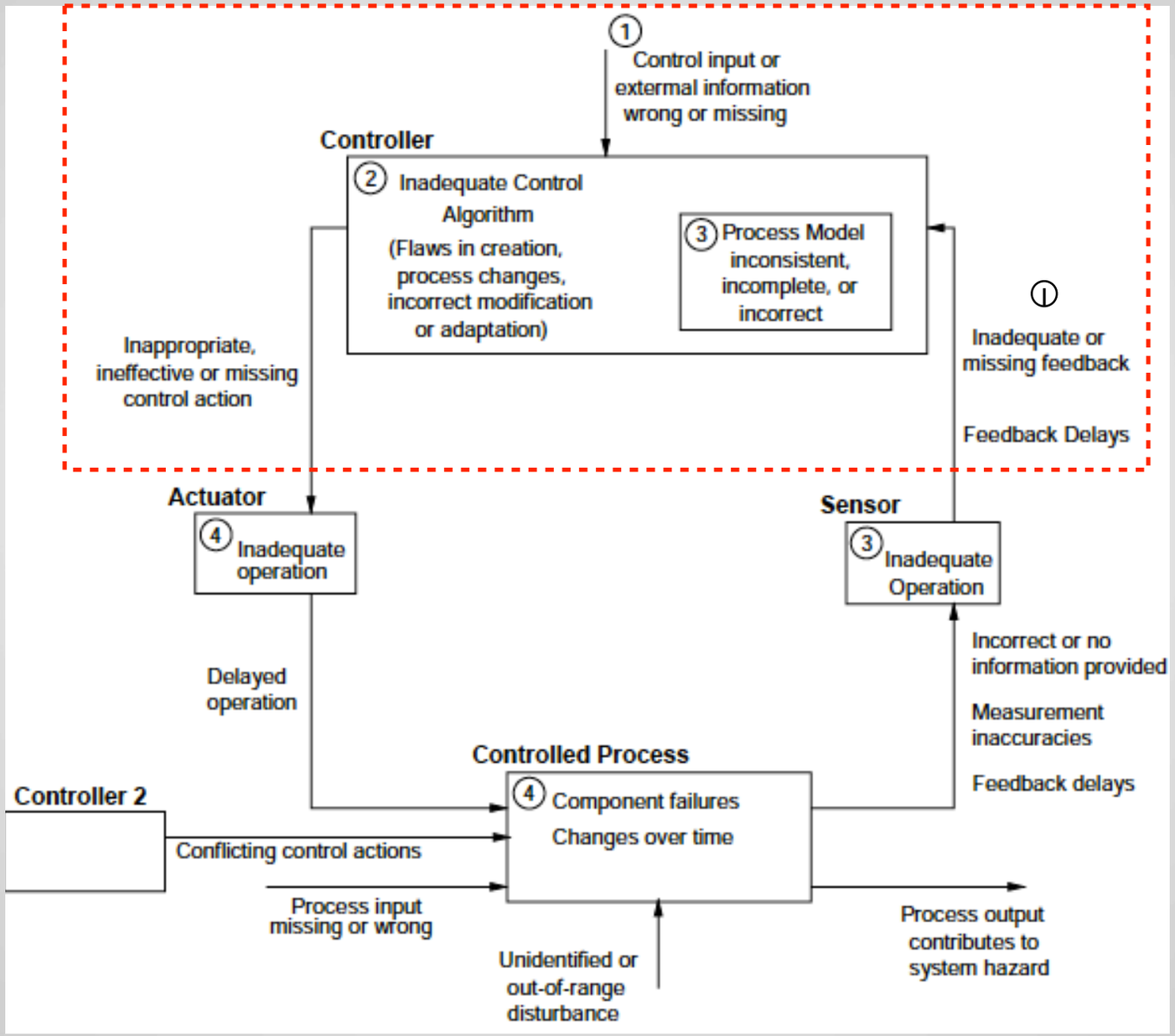
What is the problem?

Human controller

≠

Automated controller

What is the problem?



[2] Leveson, Nancy G. (2011), Engineering a Safer World. Massachusetts Institute of Technology, MIT Press, Cambridge, MA. pp 223.

What is the problem?

STPA-F.15T.1.1.2 The design of user interfaces must not contribute to ATC, flight crew, or airline operator error. (Allocated to: ERAM, FIM Automation, Other ATC or Operator Interfaces)

STPA-F.15T.1.1.3 User interfaces must provide a clear, consistent means for entering aircraft data. (Allocated to: ERAM, FIM Automation, Other ATC or Operator Interfaces)

Example of **human controller** related safety constraints

[6] Fleming C., Placke, S., Leveson, N. “STPA Analysis of NextGen Interval Management Components,” SSRL September 2013.

My Question

How can **hazard analyses** of the human controller be **improved**?

The Goal

To enhance the causal factor analysis
of the **human controller**

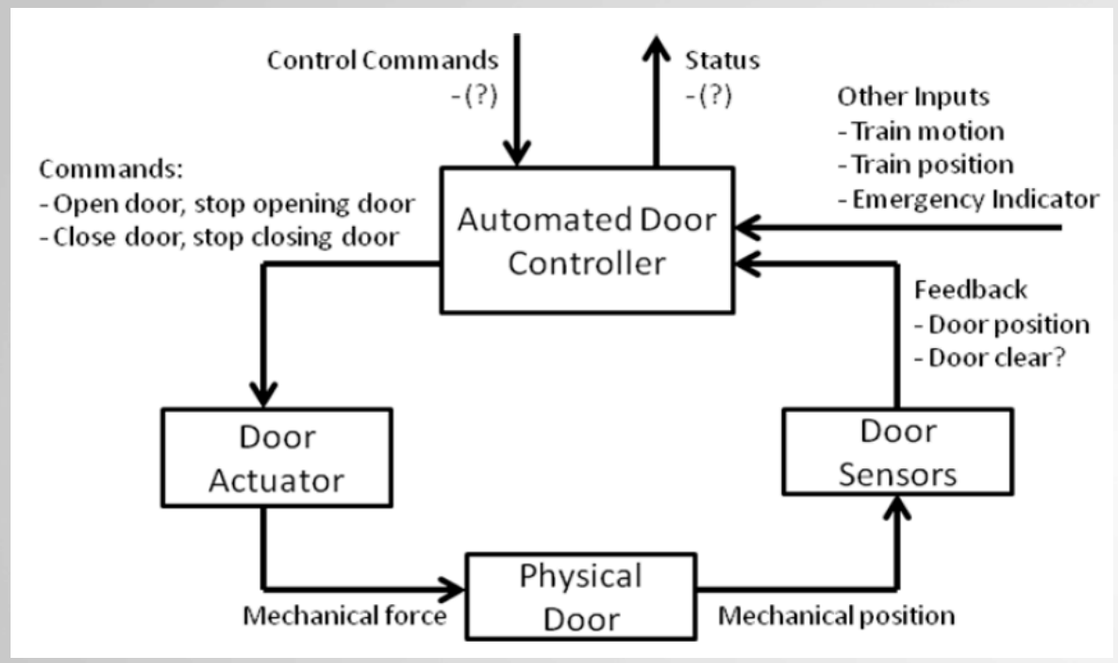
[The Human Controller]

Process Model Variables

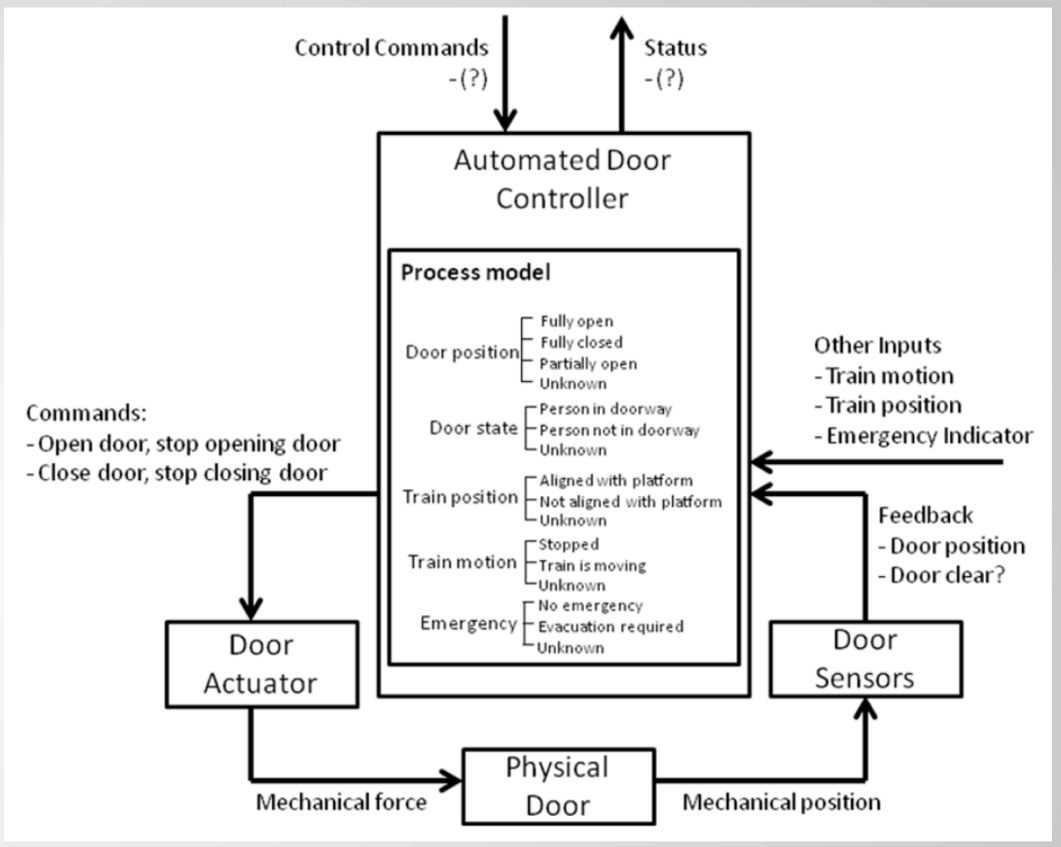
The “train door” example

[2] Lin, J. (2009). *Why is it so expensive to run the MBTA?* Retrieved from http://thetransitpass.files.wordpress.com/2009/10/red-line-to-alewife.jpg

Process Model Variables



simplified train door controller



...with the door controller's process models

“Open door” control action

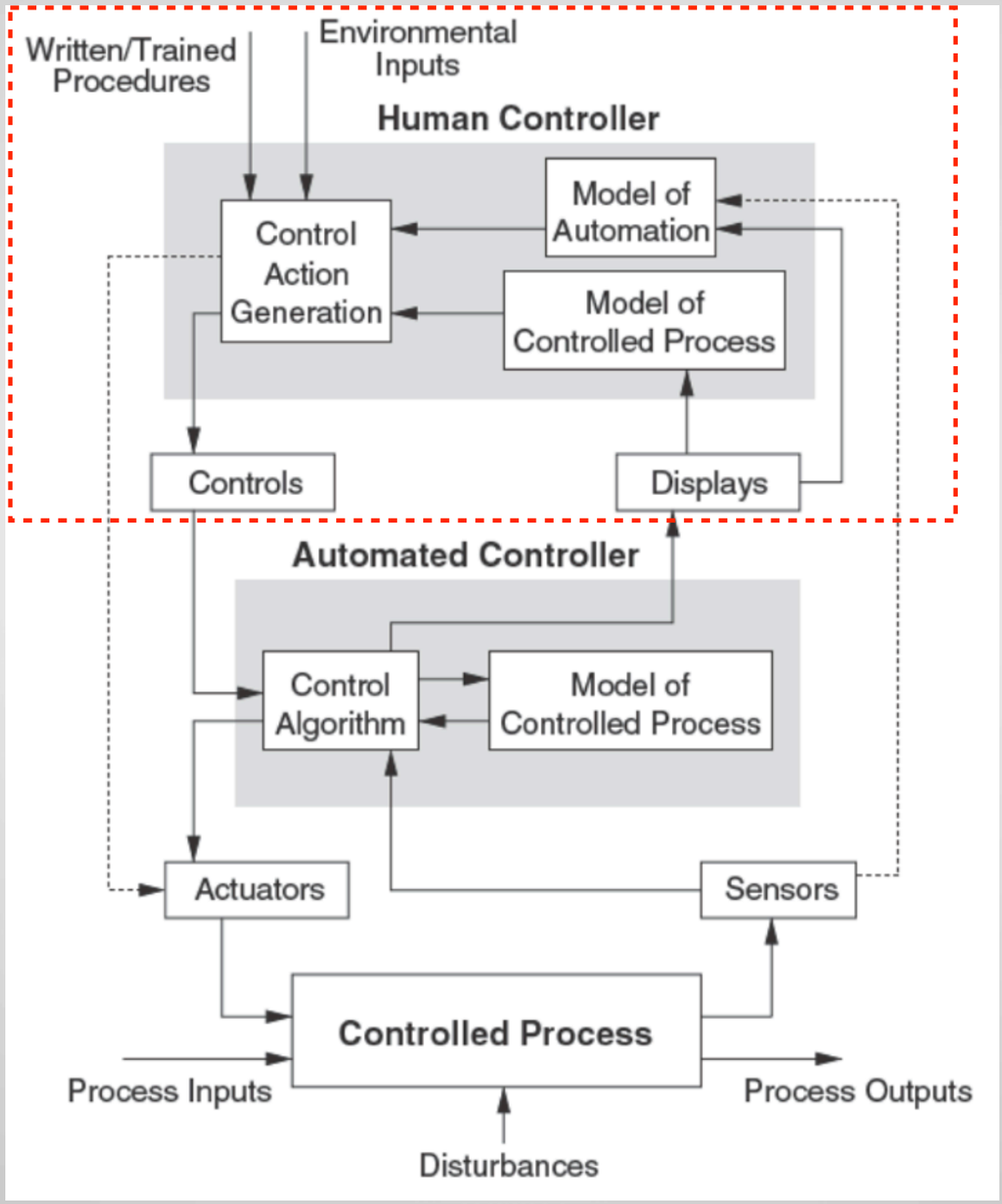
Process Model Variable	**1. Train Motion** (moving/ stopped)	**2. Train Position** (aligned/ not aligned)	**3. Emergency** (no/ evacuation required)
Lower-level Process Model Variables			**3.1 Smoke present** **3.2 Fire present** **3.3 Toxic gas present**
Feedback	**1. Train motion** - Speed sensor #1 - 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

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

Process Model Variables

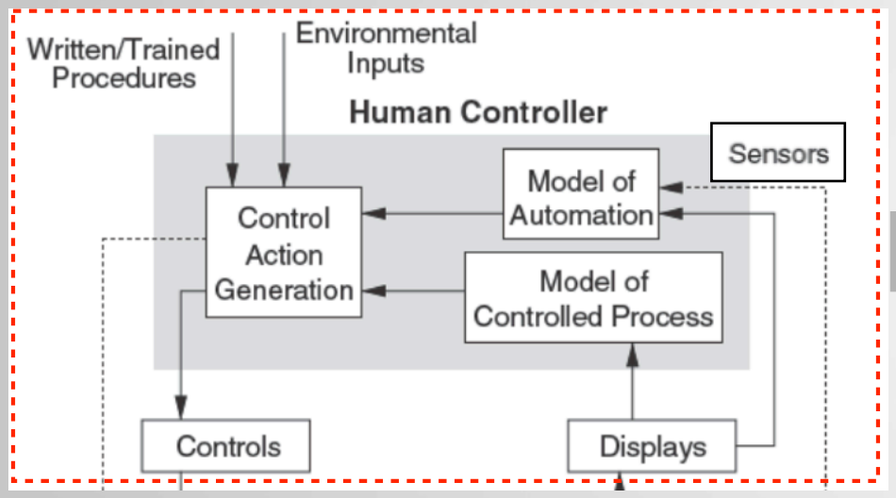
For the **human operator**, accurate understanding of the PMV's is **necessary** for **system safety**

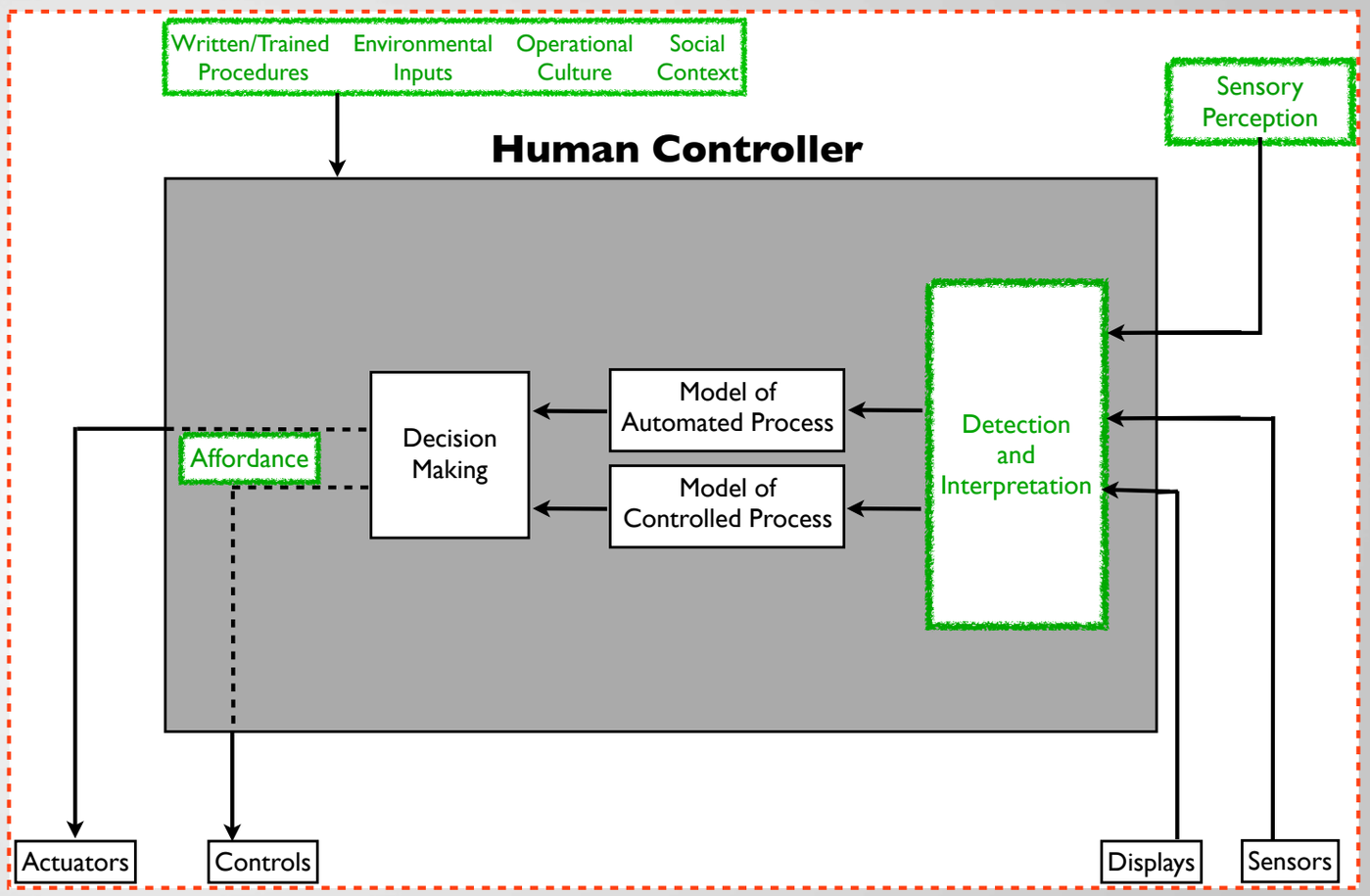
The Current Human Controller Model



[1] Leveson, Nancy G. (2011), Engineering a Safer World. Massachusetts Institute of Technology, MIT Press, Cambridge, MA. pp 228.

An Updated Human Controller Model





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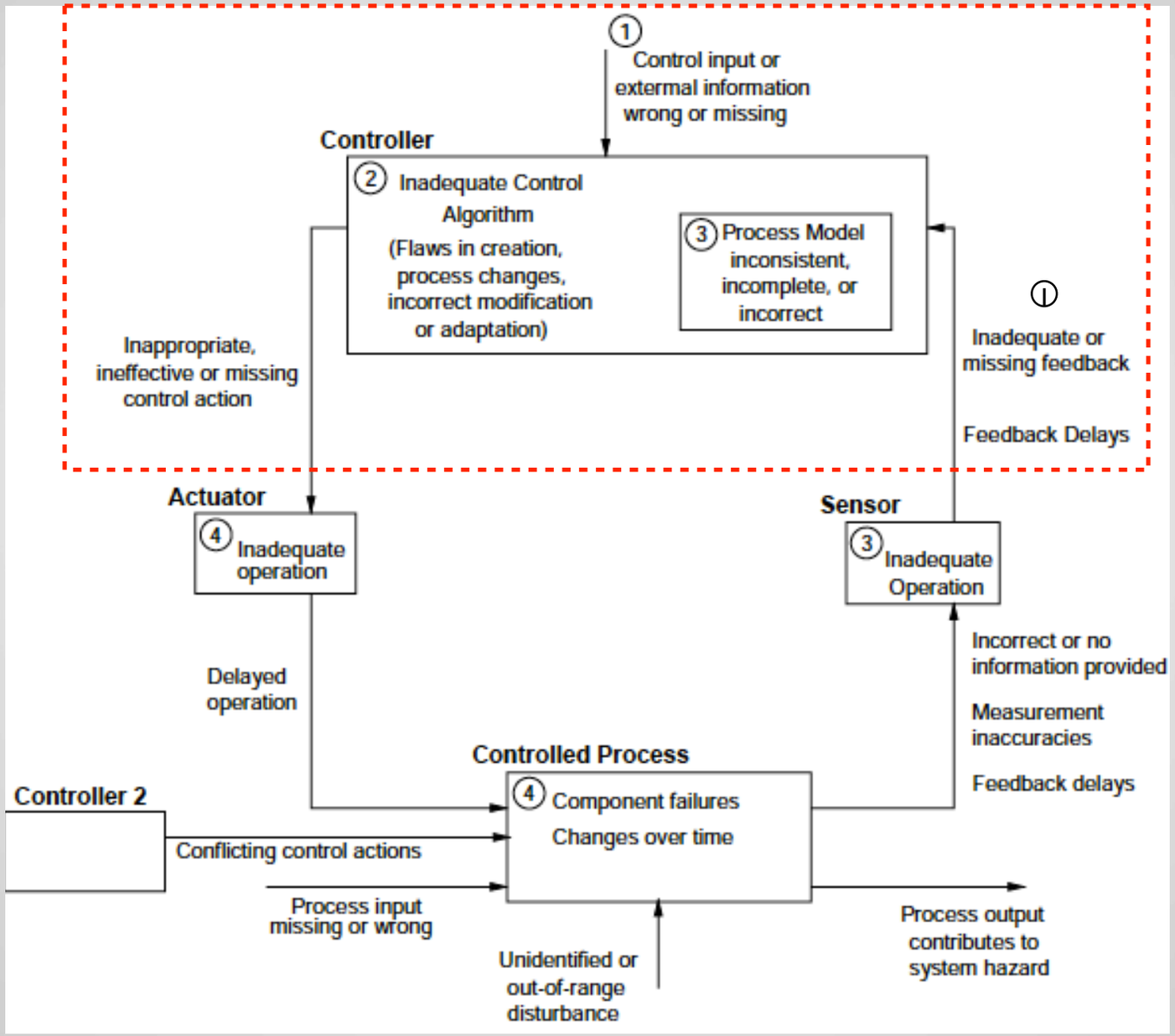
Step 2 Causal Factors



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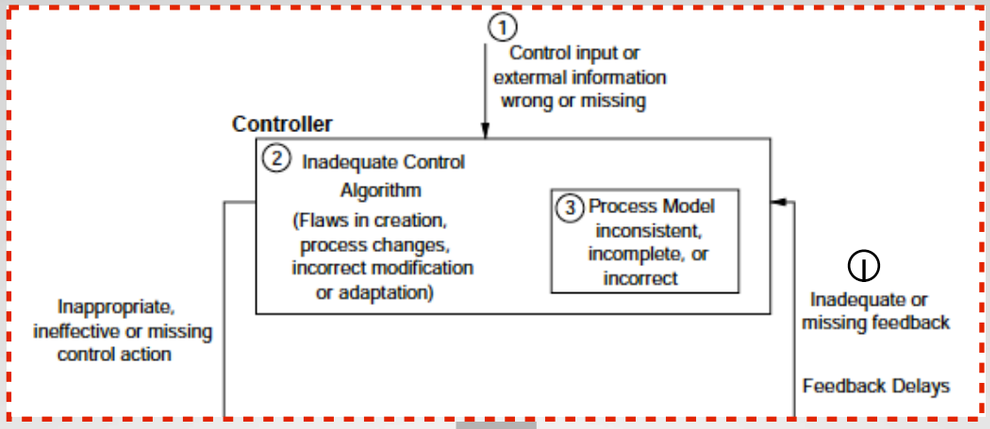

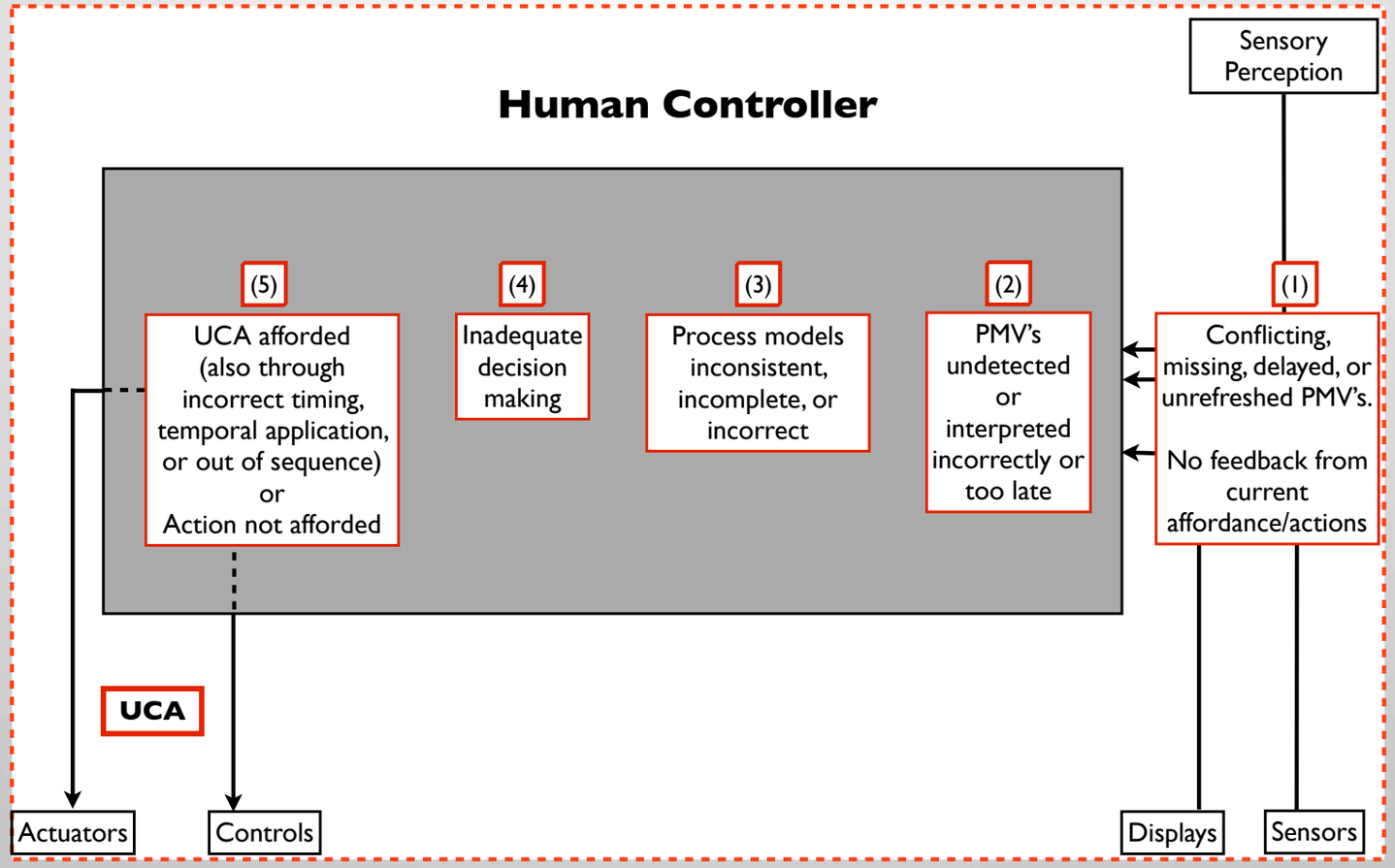

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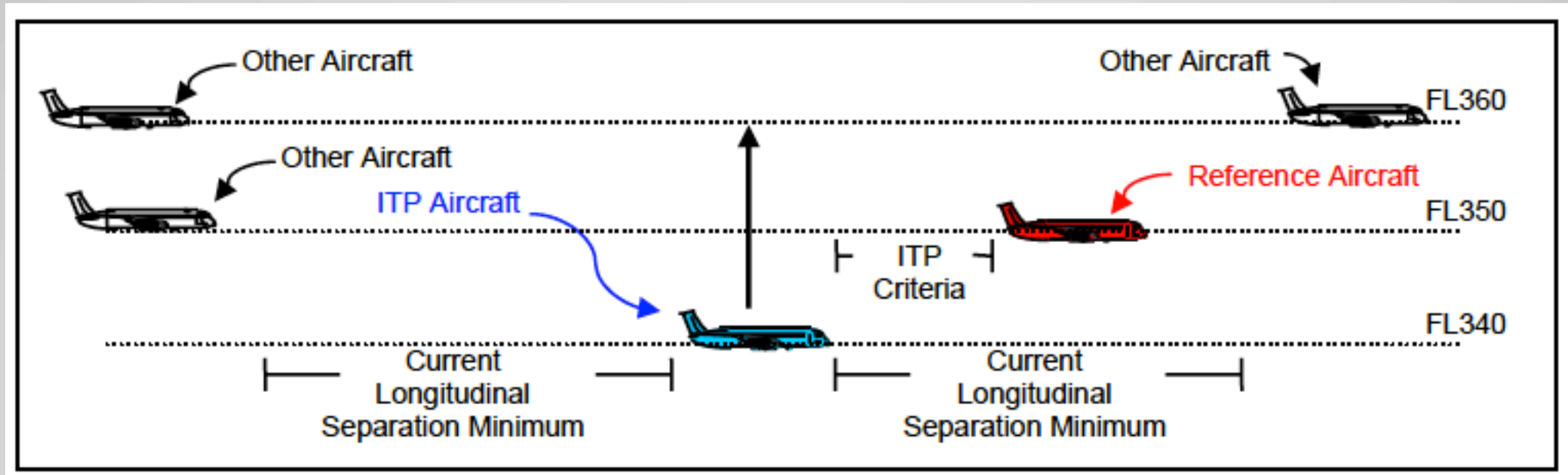
[Case Study]

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

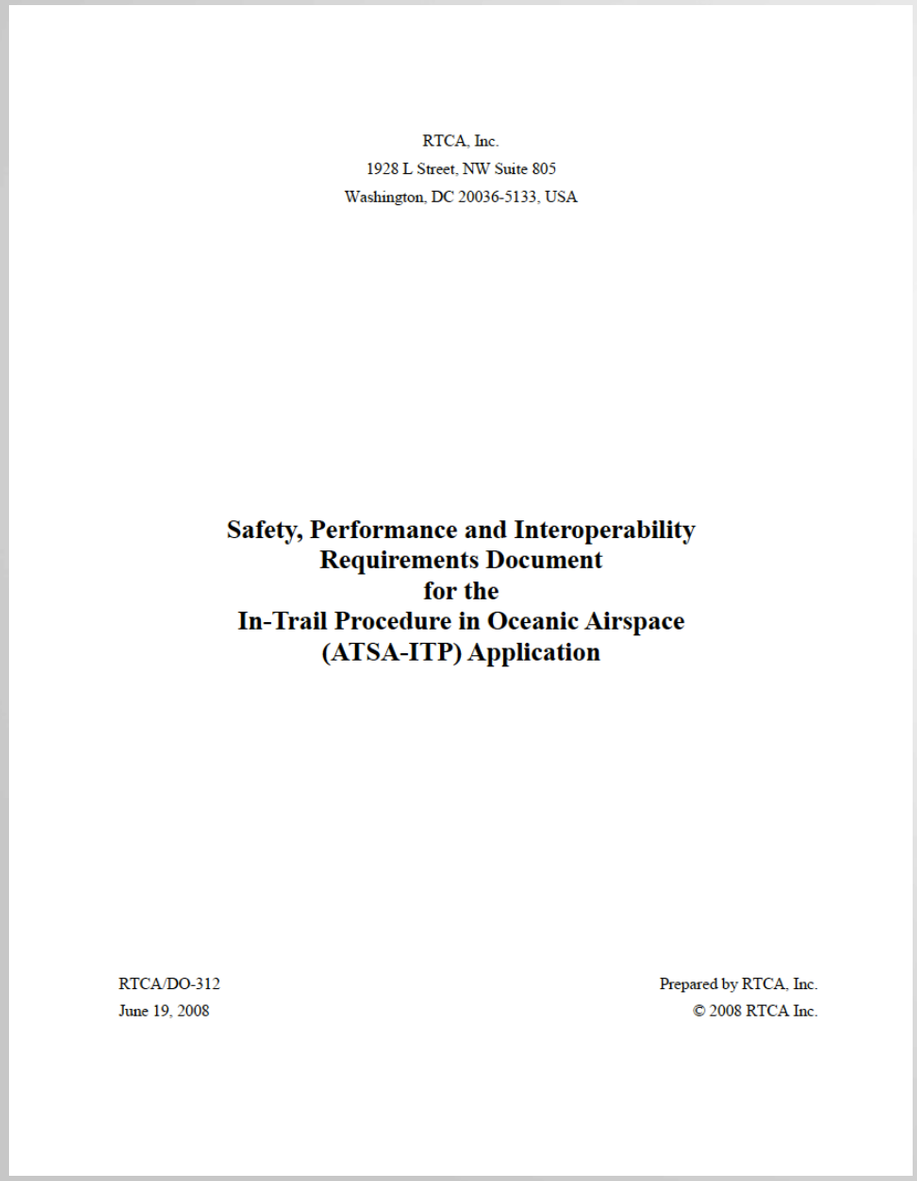
<u>Required equipment:</u>

- **ADS-B** IN and OUT
- **ITP Equipment**

[5] RTCA, "Safety, Performance and Interoperability Requirements Document for the In-Trail Procedure in the Oceanic Airspace (ATSA-ITP) Application," DO-312, Washington DC, June 19, 2008

In-Trail Procedure (ITP)

RTCA analysis of ITP



RTCA, Inc.
1928 L Street, NW Suite 805
Washington, DC 20036-5133, USA

Safety, Performance and Interoperability Requirements Document for the In-Trail Procedure in Oceanic Airspace (ATSA-ITP) Application

RTCA/DO-312
June 19, 2008

Prepared by RTCA, Inc.
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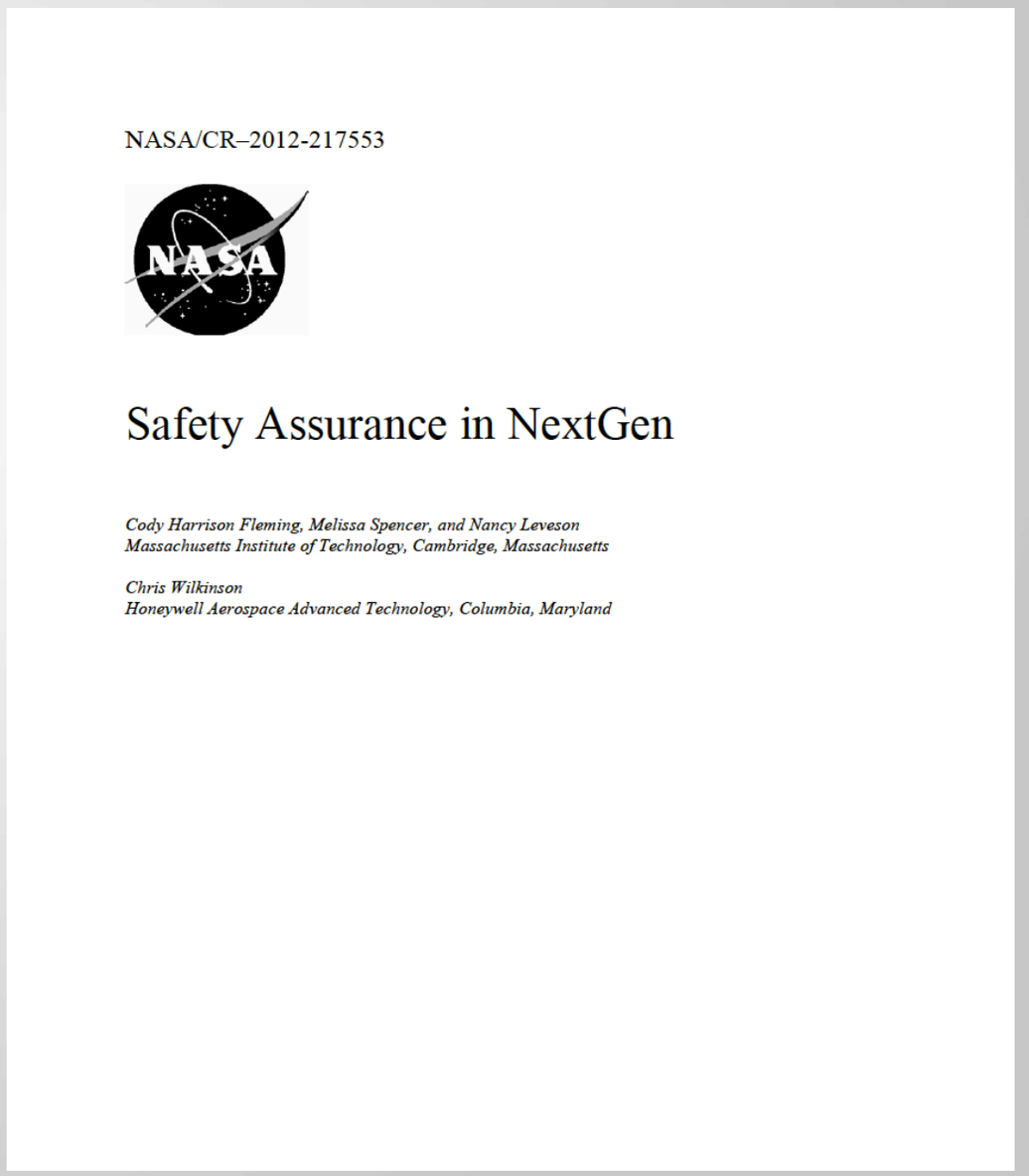
STPA analysis of ITP



NASA/CR–2012-217553

Safety Assurance in NextGen

Cody Harrison Fleming, Melissa Spencer, and Nancy Leveson
Massachusetts Institute of Technology, Cambridge, Massachusetts

Chris Wilkinson
Honeywell Aerospace Advanced Technology, Columbia, Maryland

[5] RTCA, "Safety, Performance and Interoperability Requirements Document for the In-Trail Procedure in the Oceanic Airspace (ATSA-ITP) Application," DO-312, Washington DC, June 19, 2008
[6] Fleming C., Spencer, M., Leveson, N., Wilkinson, C. “Safety Assurance in NextGen,” NASA, Langley Research Center, March 2012.

Foundation

System Definition

Step 1

UCA's

Step 2

Casual Factors

The UCA's for this example stem from the **Execute ITP** control action

Control Action	Not Providing Causes Hazard	Providing Causes Hazard	Wrong Timing/ Sequence Causes Hazard	Stopped Too Soon or Applied Too Long Causes Hazard
Execute ITP	...	...	...	...

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Process Model Variables

PMV 1: ITP criteria

PMV 2: ATC clearance

PMV 3: Airspace model

Process Model Variables

High-level Process Model Variable	**1. ITP criteria** (met or not)	**2. ATC clearance** (yes or no)	**3. Airspace model** (clear or not)

Process Model Variables

High-level Process Model Variable	**1. ITP criteria** (met or not)	**2. ATC clearance** (yes or no)	**3. Airspace model** (clear or not)
Lower-level Process Model Variables	**1.1 Climb/Descent rate** (Y/N) **1.2 ITP distance** (Y/N) **1.3 Ground speed differential** (Y/N) **1.4 Mach differential** (Y/N) **1.5 Reference a/c maneuvering or expected to** (Y/N) **1.6 Vertical distance reqs** (Y/N) **1.7 Ownship data integrity** (Y/N) **1.8 Reference a/c data integrity** (Y/N) **1.9 Same track criteria** (Y/N) **1.10 Requested flight level correct** (Y/N)	None	**3.1 Weather clear for ITP** (Y/N) **3.2 Clear of other traffic** (Y/N)

*Planned to be calculated by ITP equipment

Unsafe Control Actions

Control Action	ITP Criteria	ATC Clearance	Airspace Model	Hazardous
Execute ITP	Met	Approved	Clear for ITP	No
Execute ITP	Met	Approved	Not clear for ITP	**Yes**
Execute ITP	Met	Not approved	Clear for ITP	**Yes**
Execute ITP	Met	Not approved	Not clear for ITP	**Yes**
Execute ITP	Not met	Approved	Clear for ITP	**Yes**
Execute ITP	Not met	Approved	Not clear for ITP	**Yes**
Execute ITP	Not met	Not approved	Clear for ITP	**Yes**
Execute ITP	Not met	Not approved	Not clear for ITP	**Yes**

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

Previous UCA's

Control Action	Not Providing Causes Hazard	Providing Causes Hazard	Wrong Timing/ Sequence Causes Hazard	Stopped Too Soon or Applied Too Long Causes Hazard
Execute ITP		ITP executed when **not approved by ATC** ITP executed when **ITP criteria not satisfied** ITP executed with **incorrect climb rate, final altitude, etc.**	ITP executed too soon before approval ITP executed too late	

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Initiation or continuation?

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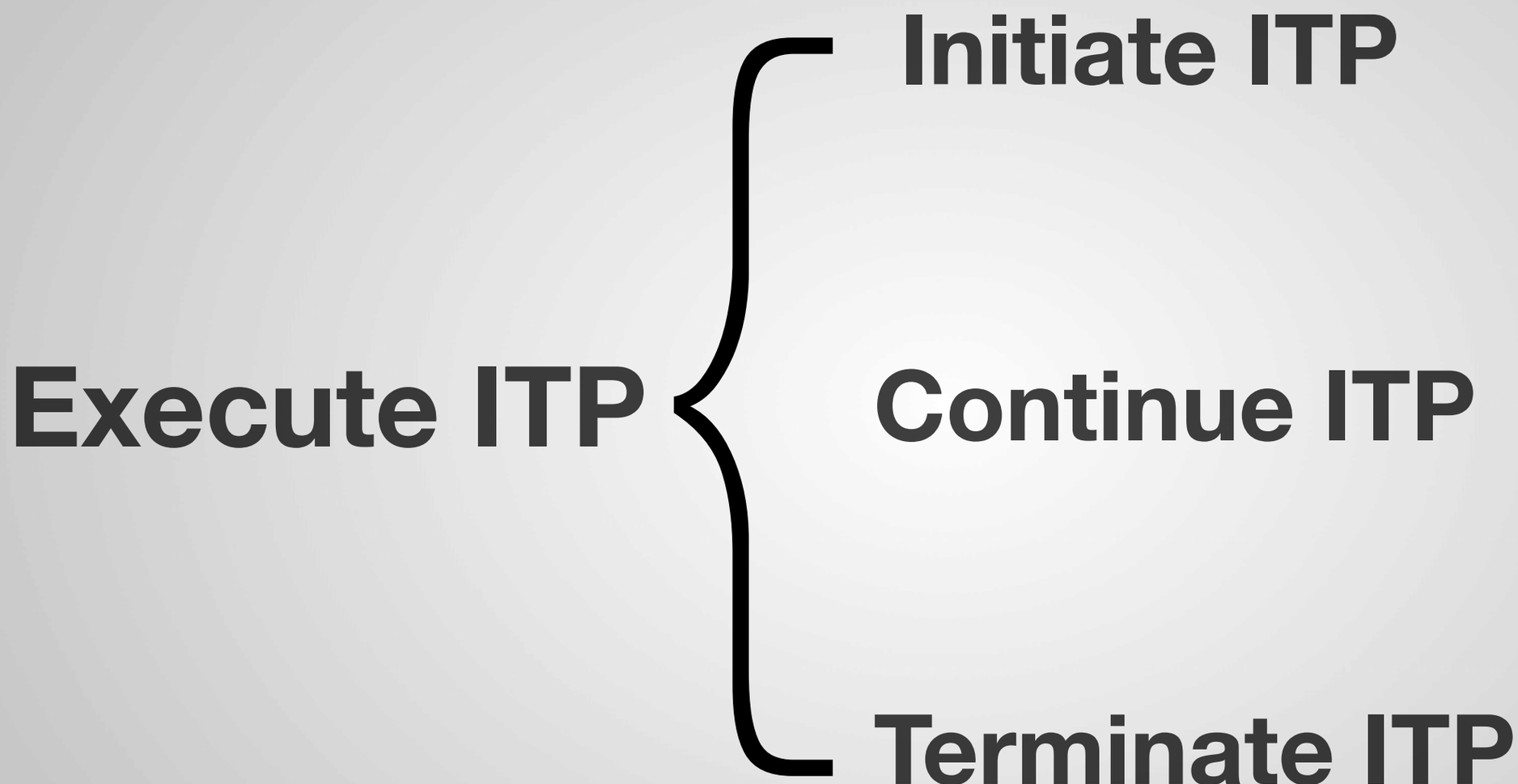

[6] Fleming C., Spencer, M., Leveson, N., Wilkinson, C. “Safety Assurance in NextGen,” NASA, Langley Research Center, March 2012.

Updated UCA's

Control Action	Not Providing Causes Hazard	Providing Causes Hazard	Wrong Timing/ Sequence Causes Hazard	Stopped Too Soon or Applied Too Long Causes Hazard
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	ITP executed too soon before approval ITP executed too late	
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 continued past requested flight level ITP stopped before requested flight level

UCA Comparison

Control Action	Previous UCA's	Updated UCA's
Initiate ITP	ITP executed when **not approved by ATC** ITP executed when **ITP criteria not satisfied** ITP executed with **incorrect climb rate, final altitude, etc.**	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
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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
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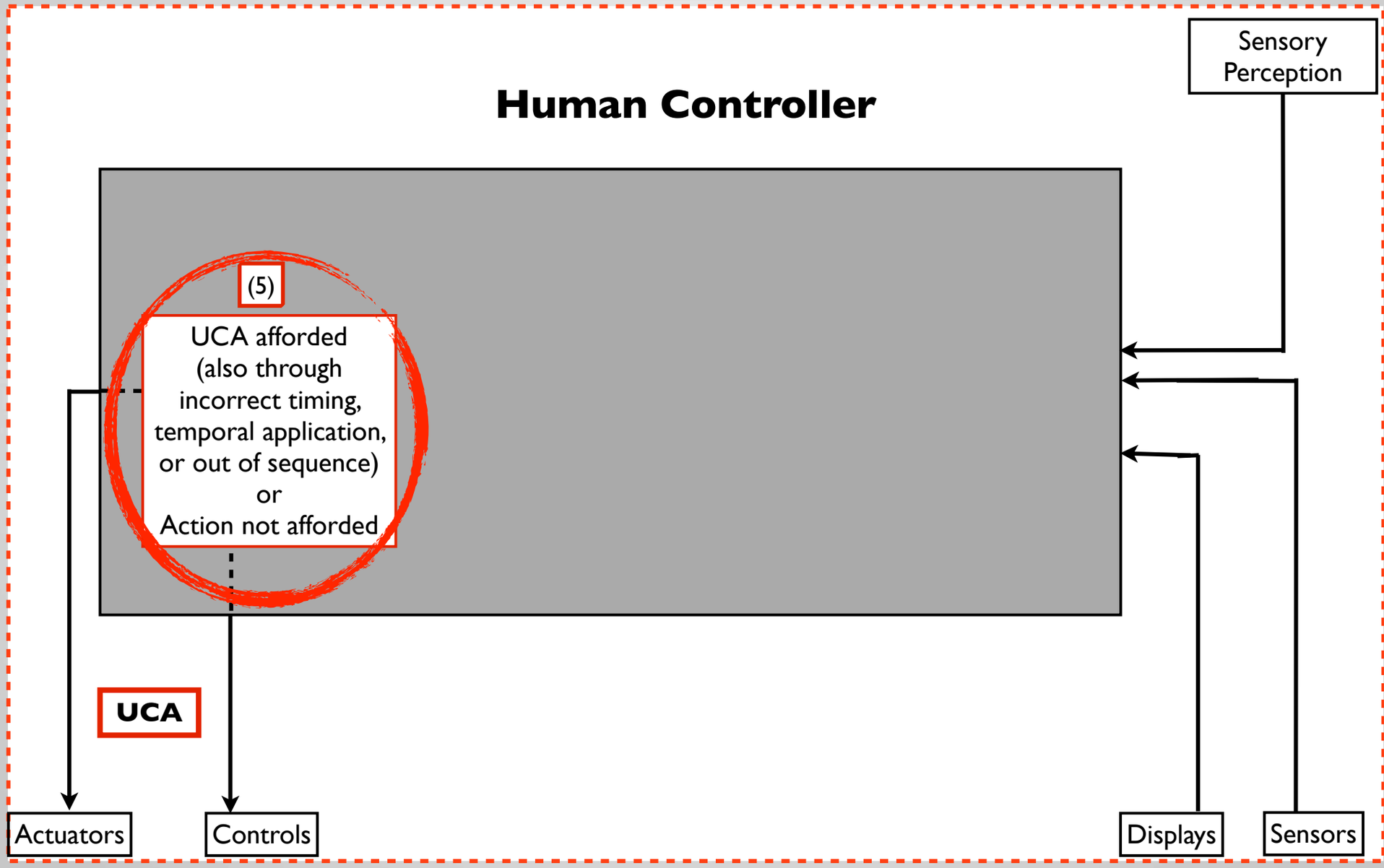
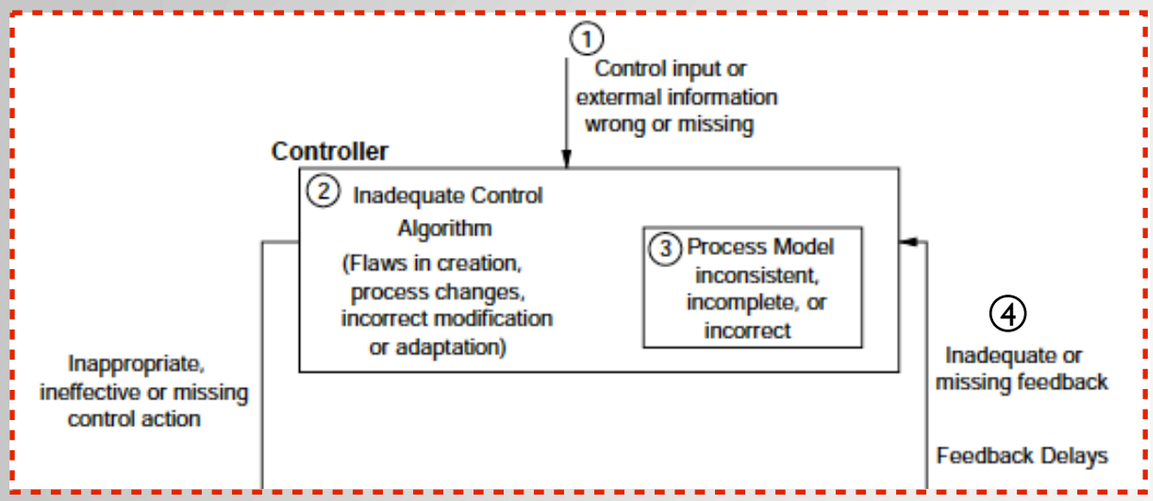
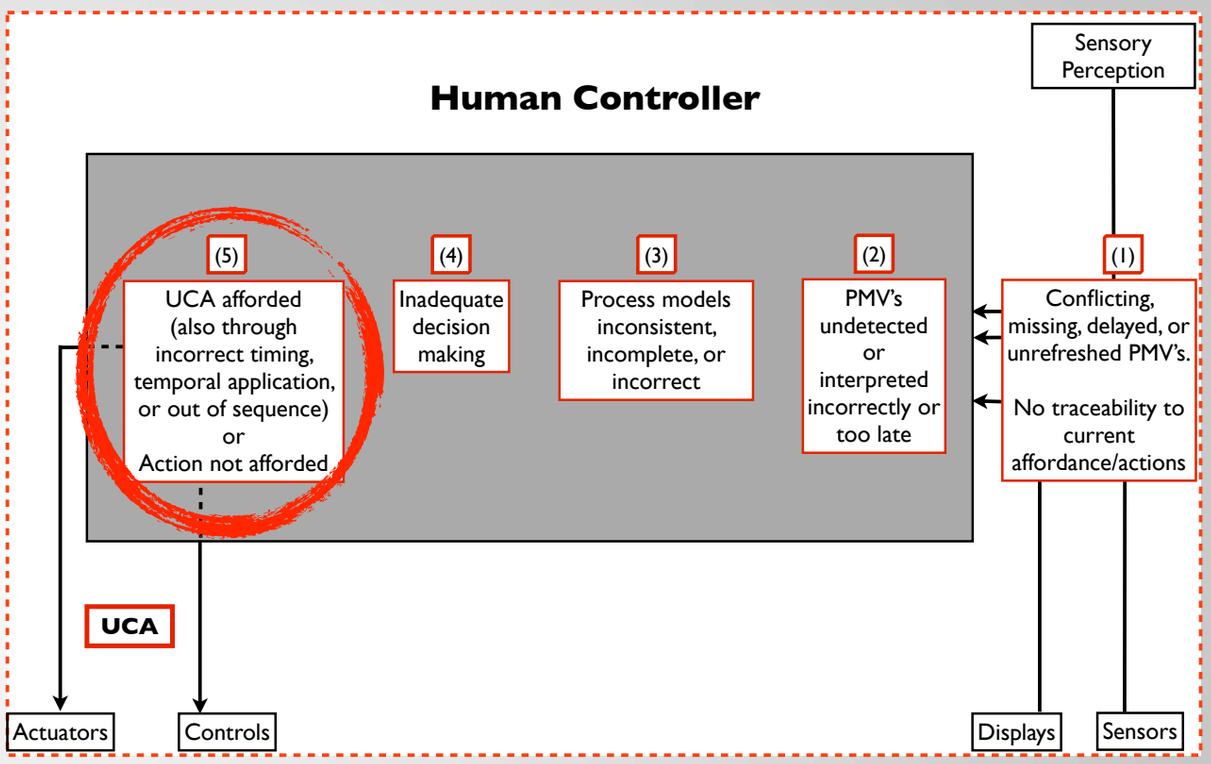


Causal Factor Comparison





The **current** human controller model

VS.

The **updated** human controller model

The differences

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

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Previous Causal Factors

Process Model Link	Cause
Inadequate sensor operation	- Flight Crew does not understand or correctly apply ITP data from ITP equipment
Control input or external information wrong or missing	- Flight crew lacking information from ATC - 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

Updated Causal Factors

Process Model Link	Cause
ITP afforded	- 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

[6] Fleming C., Spencer, M., Leveson, N., Wilkinson, C. "Safety Assurance in NextGen," NASA, Langley Research Center, March 2012.

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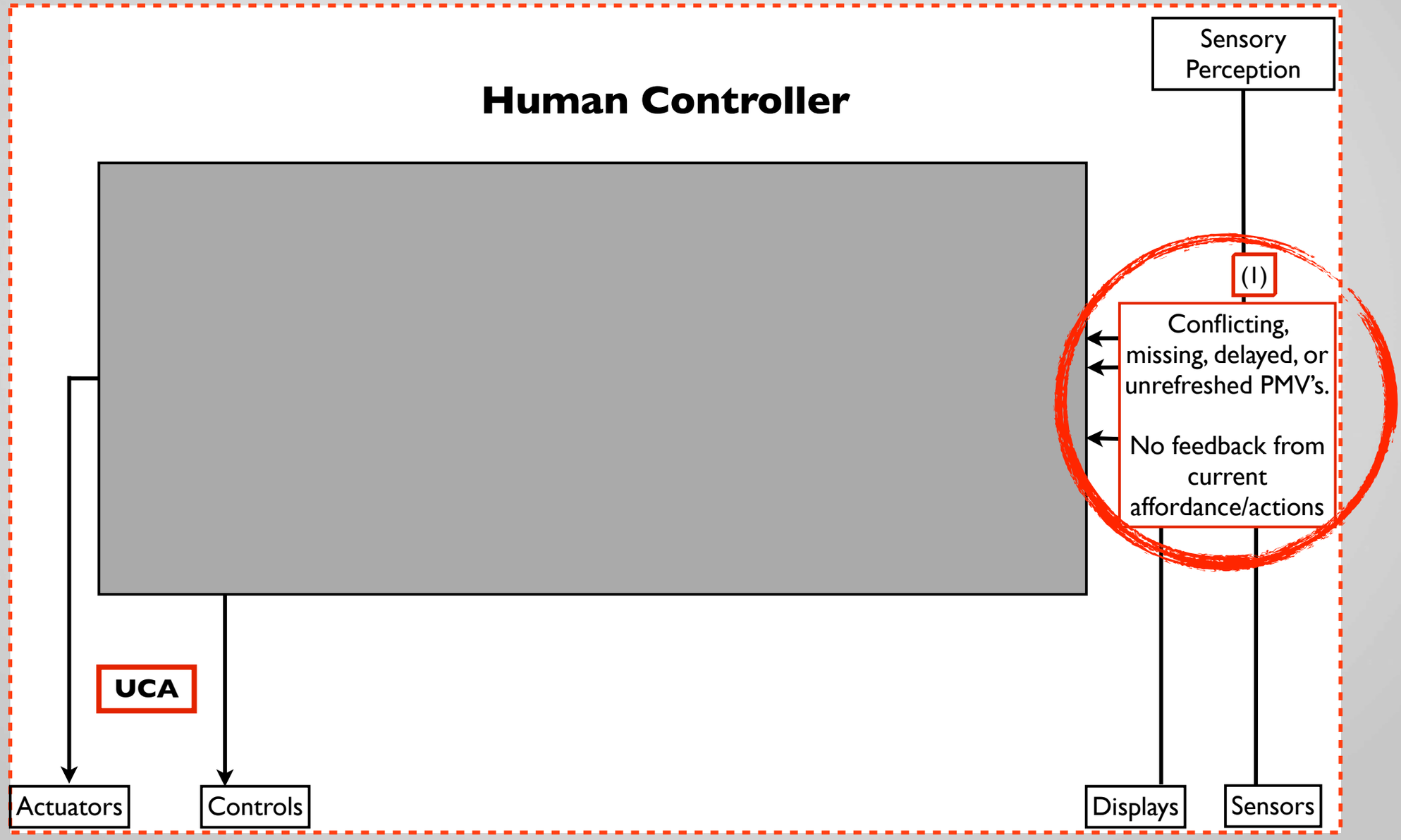
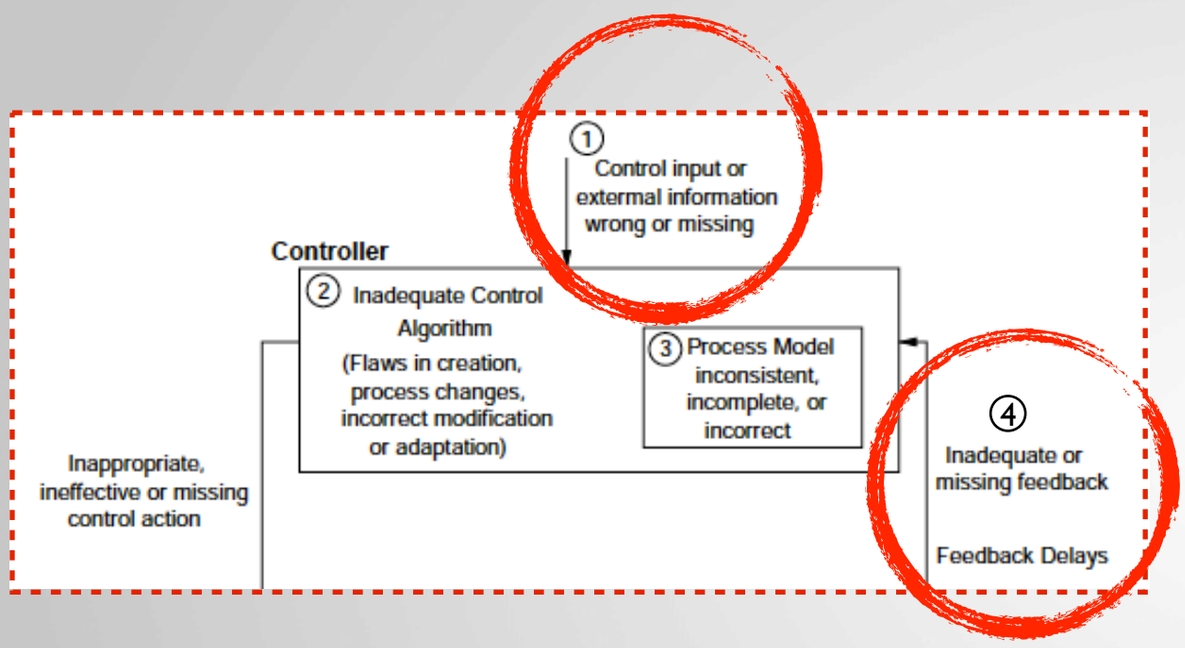
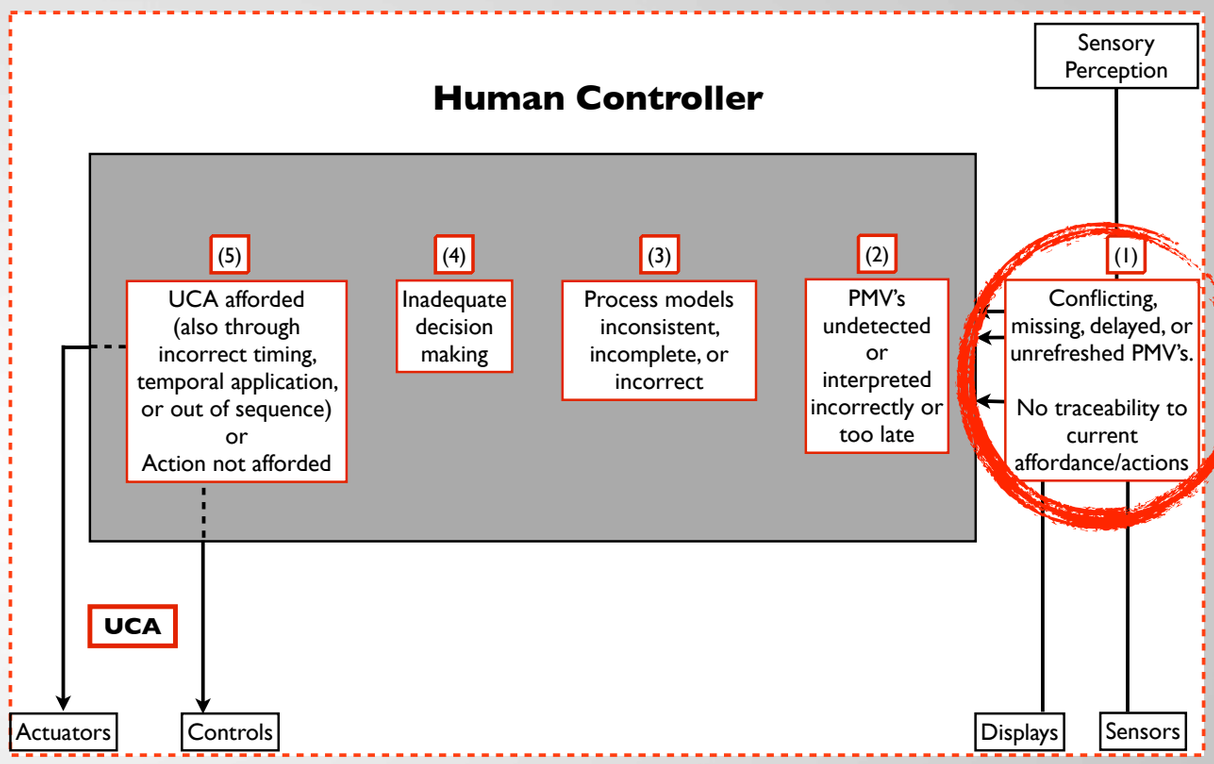


Causal Factor Comparison



The **current** human controller model

VS.



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Updated Causal Factors

Process Model Link	Cause
Conflicting, missing, delayed, or unrefreshed PMV's. No traceability to current affordance/actions	Any of the **ITP criteria (PMV 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)** - 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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Updated Causal Factors

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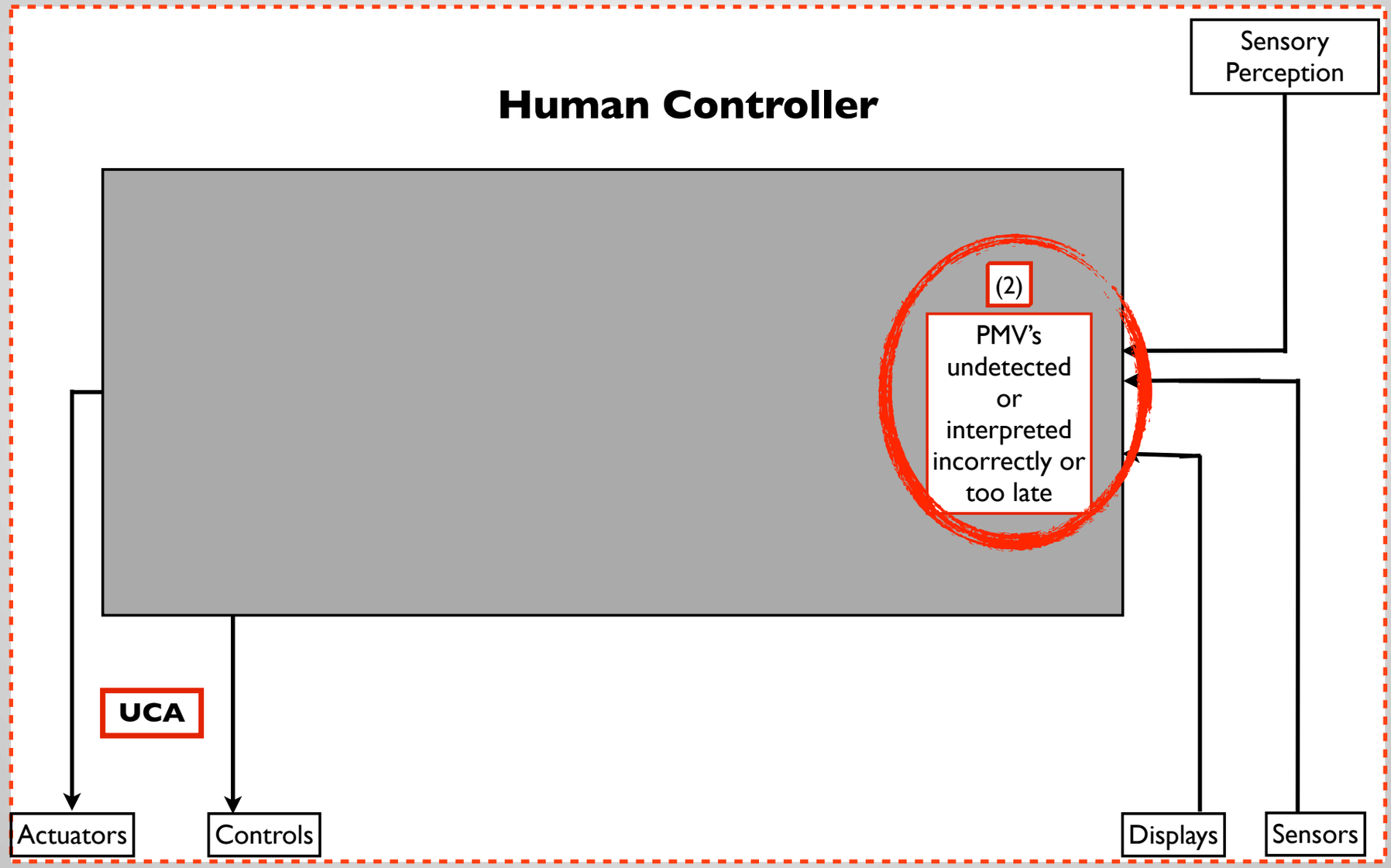
Conflicting, missing, delayed, or unrefreshed PMV's. No traceability to current affordance/actions	Any of the **ITP criteria (PMV 1.1-1.10)**: - Are incorrect or missing - Aren't refreshed in the appropriate amount of time - Are in conflict which leads to an ambiguous **ITP criteria (PMV 1)** **ATC clearance (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)** - 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

[6] Fleming C., Spencer, M., Leveson, N., Wilkinson, C. "Safety Assurance in NextGen," NASA, Langley Research Center, March 2012.

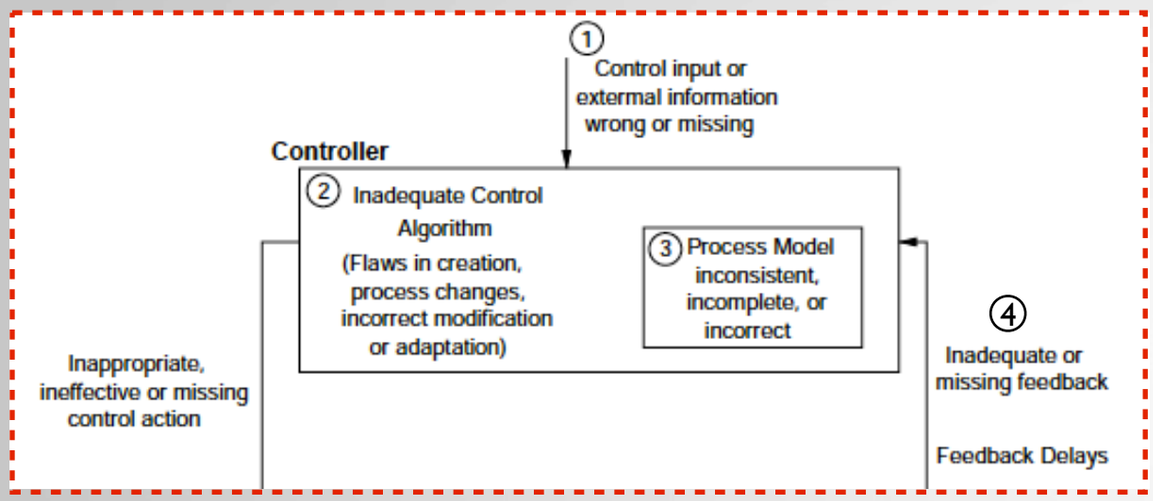
The differences

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

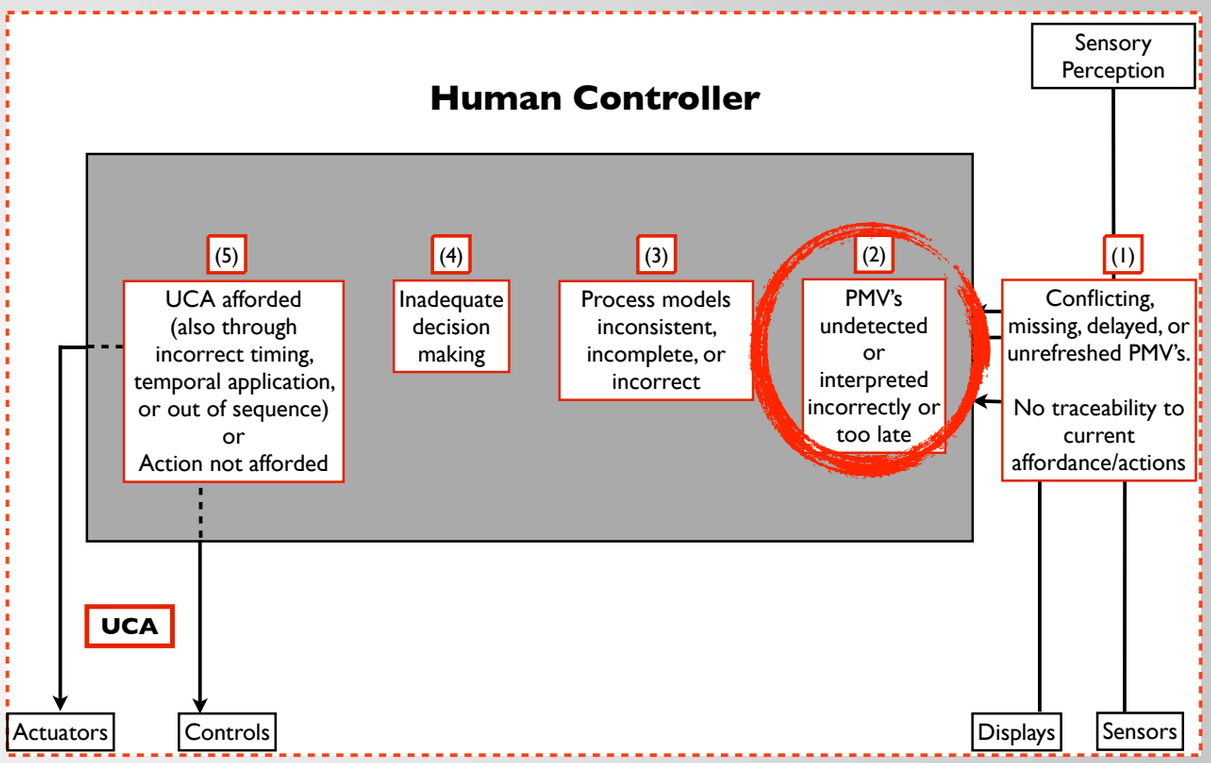


Causal Factor Comparison



The **current** human controller model

VS.



The **updated** human controller model

The differences

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Previous Causal Factors

Process Model Link	Cause
Inadequate sensor operation	- Flight Crew does not understand or correctly apply ITP data from ITP equipment
Control input or external information wrong or missing	- Flight crew lacking information from ATC - 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

Updated Causal Factors

Process Model Link	Cause
PMV's undetected or interpreted incorrectly or too late	Any of **ITP criteria** (**PMV 1.1 - PMV 1.10**) OR their changes/updates: - Are not detected - Are not interpreted correctly (hello, mode confusion) and leads to inaccurate or conflicting understanding of the **ITP criteria (PMV 1)** - Take too long to detect and interpret correctly - Require too much attentional demand to detect and interpret correctly **ATC clearance (PMV 2)** or any change or update: - Anything but ATC clearance is detected and interpreted as a clearance - A revoke of ATC clearance is not detected and interpreted correctly Either **Airspace variable (PMV 3.1 or 3.2)**: - Is not detected - Is not interpreted correctly and leads to inaccurate or conflicting understanding of the **Airspace (PMV 3)** - Takes too long to detect and interpret correctly - Requires too much attentional demand to detect and interpret correctly

[6] Fleming C., Spencer, M., Leveson, N., Wilkinson, C. "Safety Assurance in NextGen," NASA, Langley Research Center, March 2012.

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The differences

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[6] Fleming C., Spencer, M., Leveson, N., Wilkinson, C. "Safety Assurance in NextGen," NASA, Langley Research Center, March 2012.

ITP Example

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

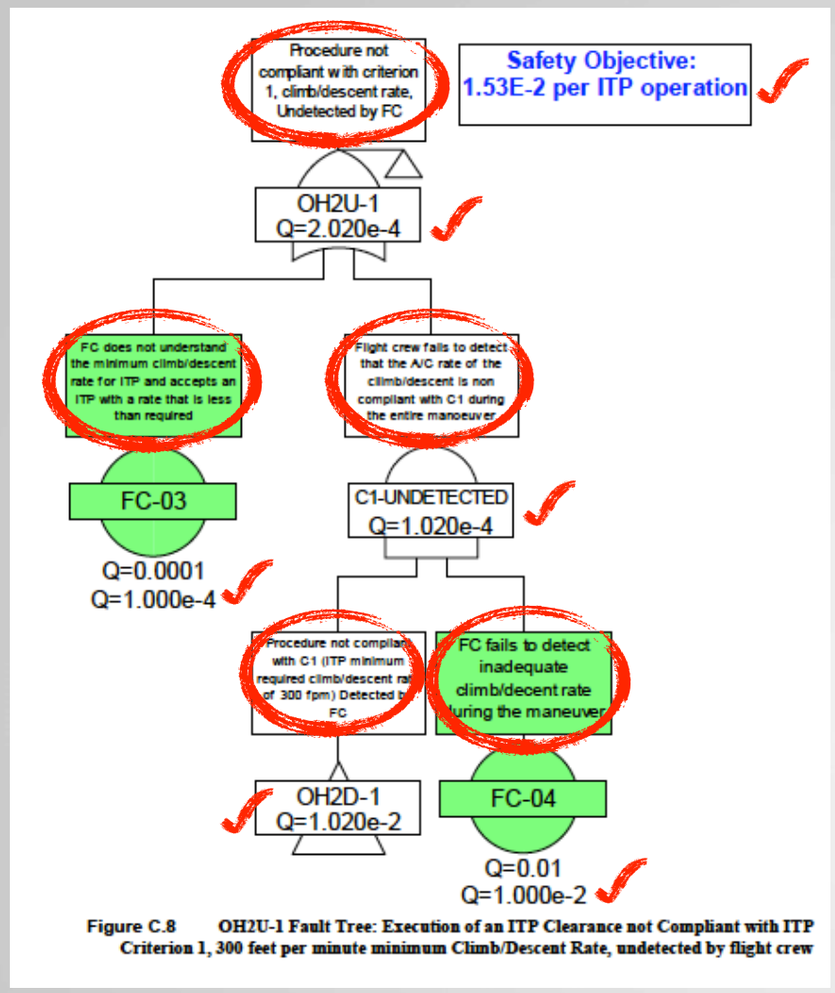

Figure C.8 OH2U-1 Fault Tree: Execution of an ITP Clearance not Compliant with ITP Criterion 1, 300 feet per minute minimum Climb/Descent Rate, undetected by flight crew

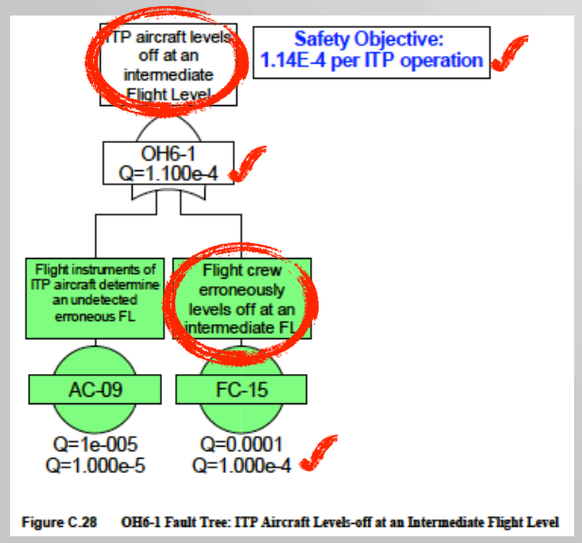

Figure C.28 OH6-1 Fault Tree: ITP Aircraft Levels-off at an Intermediate Flight Level

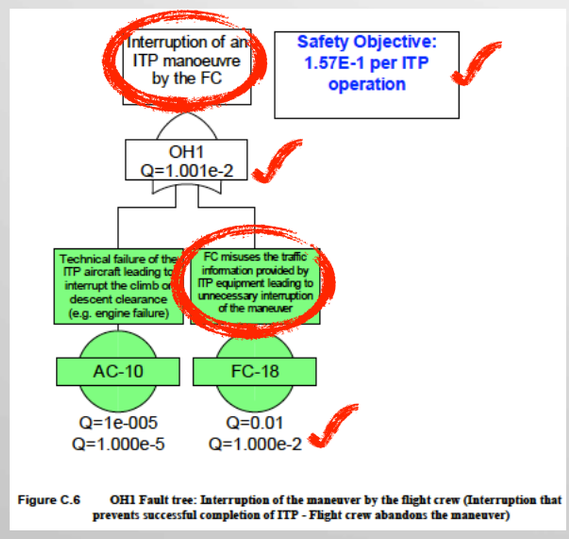

Figure C.6 OH1 Fault tree: Interruption of the maneuver by the flight crew (Interruption that prevents successful completion of ITP - Flight crew abandons the maneuver)

VS.

Process Model Link	Cause
Process Models inconsistent, incomplete, or incorrect	Flight Crew believes: - **ITP criteria** (**PMV 1**) has been met when it has 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. No traceability to current actions	Any of the **ITP criteria (PMV 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)** - 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
PMV's undetected or interpreted incorrectly or too late	Any of **ITP criteria** (**PMV 1.1** - **PMV 1.10**) OR their changes/ updates: - Are not detected - Are not interpreted correctly (hello, mode confusion) and leads to inaccurate or conflicting understanding of the **ITP criteria (PMV 1)** - Take too long to detect and interpret correctly - Require too much attentional demand to detect and interpret correctly **ATC clearance (PMV 2)** or any change or update: - Anything but ATC clearance is detected and interpreted as a clearance - A revoke of ATC clearance is not detected and interpreted correctly Either **Airspace variable (PMV 3.1 or 3.2)**: - Is not detected - Is not interpreted correctly and leads to inaccurate or conflicting understanding of the **Airspace (PMV 3)** - Takes too long to detect and interpret correctly - Requires too much attentional demand to detect and interpret correctly

[5] RTCA, "Safety, Performance and Interoperability Requirements Document for the In-Trail Procedure in the Oceanic Airspace (ATSA-ITP) Application," DO-312, Washington DC, June 19, 2008

Cameron Thornberry clthorn@mit.edu