Aligned with your needs.

Black Swans & Lumberjacks:

The role of complacency, automation bias and cognitive tunneling in human interaction with highly reliable automation

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Asiana Flight 214 Accident

- 2013 Approach to San Francisco Airport
- Pilots set a mode of the flight management system (aircraft automation)
- They did not realize that this mode **turned off** the auto-throttle (thereby giving speed control to the pilot).

- But, not themselves controlling speed, the plane lost speed and altitude on descent, as the pilots **did not monitor** these variable, until too late. Pilots still assumed that automation was doing the speed control.
- The crash followed on this "unstable approach"

- A high degree of automation, and the automation "failed" (to do the job that was expected of it).

- Too much Automation?

Too much automation? What I will cover.

- A taxonomy of **degree of automation** within which "too much" may be quantified.
- Describe the "Lumberjack Analogy": the higher the trees, the harder they fall. Automation in nominal and failure modes.
- The role of **Situation Awareness** in mediating this fall.
- The biases in human cognition that thwart automation awareness and fault management.
- Five Remedies and cures to address the problems: Five paths to **resilience** in Human- Automation Interaction

Recent approaches to automation have characterized it by **Stages & Levels**

(Parasuraman Sheridan & Wickens, 2000).

Stages: Automation assists human performance at 4 stages of information processing

1. Attention & Noticing. Collecting Information

The alarm system

2. Understanding & Diagnosing: Situation Assessment

The diagnostic assistant.
The weather forecast model

3. Deciding what to do. What action to carry out.

The decision aid: Traffic collision avoidance system (TCAS)

4. Doing it: Action Execution

The auto infusion pump.
The electric can opener.

Levels within Stages:

Within each stage, automation can take on more (higher level) or less (lower level) authority and responsibility for computation.

- Correspondingly the human does more (lower automation level) or less (higher level) perceptual, cognitive and motor “work”.
- Higher level of automation, lower human workload.

Stage:	1	2	3	4
High **Level**				
Low				

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Stage:	1	2	3	4
High **Level**			Automation does, unless human vetoes	
Low			Automation suggests action	

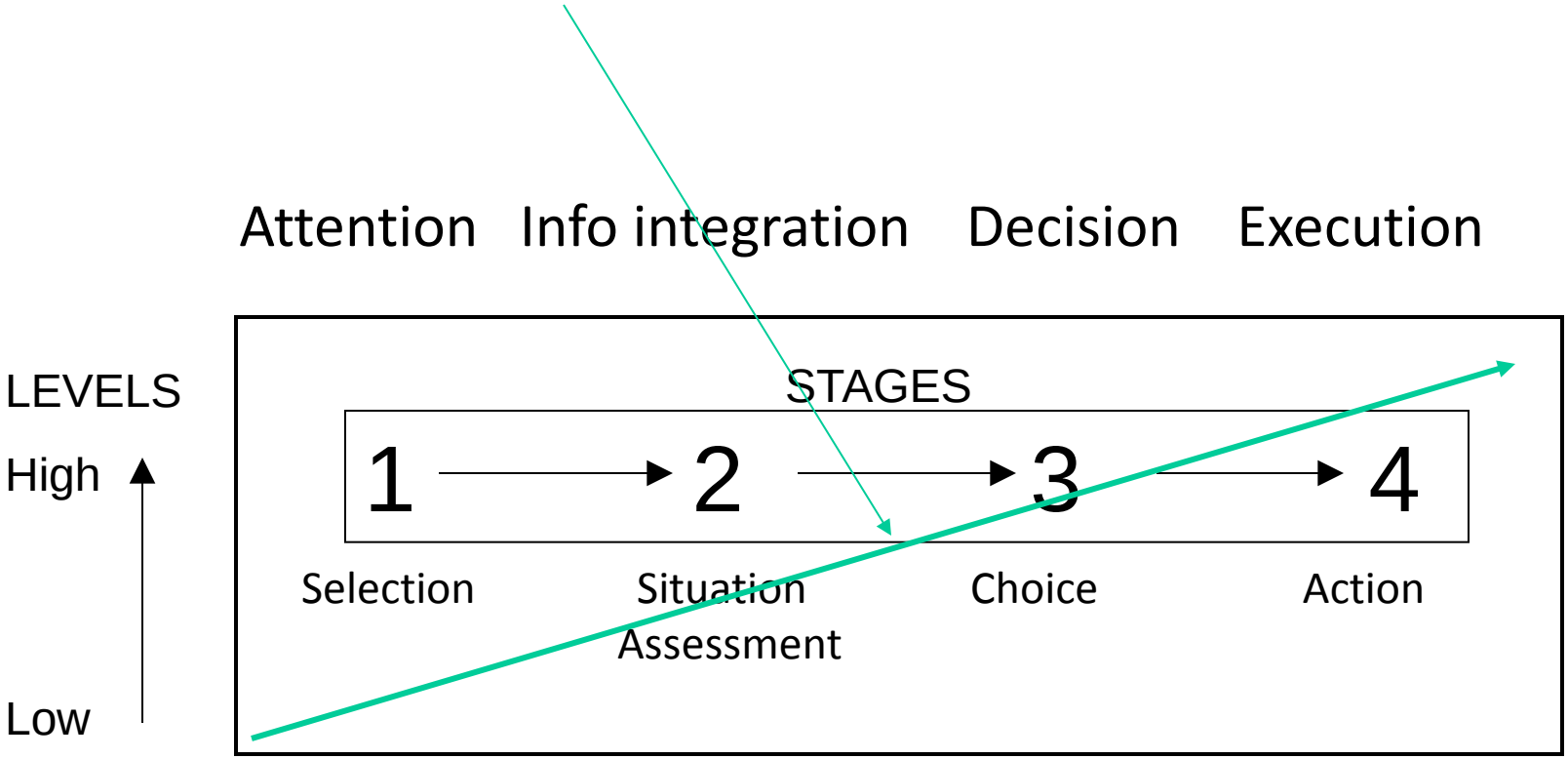
Stage:	1	2	3	4
Level High	All or none alert	Single forecast "Rainy"	Automation will Shut down the engine unless operator vetoes	Engine automatically shuts down
Low	Likelihood alert (2 levels)	Possible Forecasts "70% chance of rain" (30% clear)	Suggest that operator shuts down engine.	Operator presses button for shutdown

Applications to medical technology, aviation, process control, **statistical tests**, legal proceedings, business & finance, every day

Aps: **what is**, versus **what to do**.

Statistics package: p value (stage 2 inference) versus "reject hypothesis" decision rule: (stage 3 decision aid).

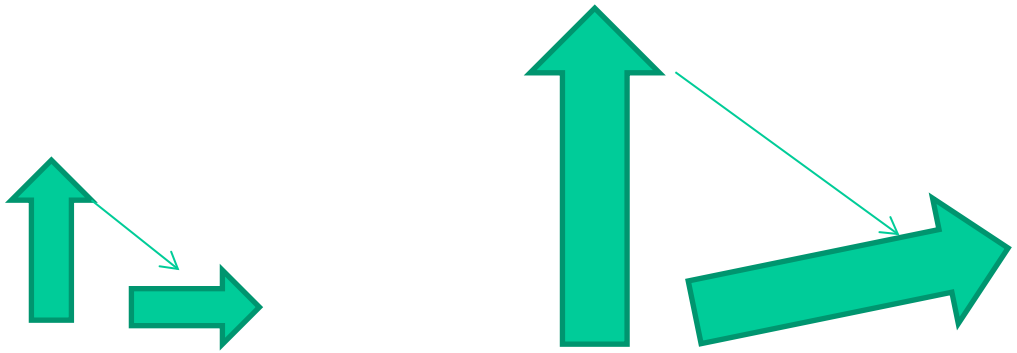
Higher **Degree of automation**: later stages and/or higher levels



The lumberjack analogy of automation dependence: The higher they are, the harder they fall.

- The "conventional wisdom" of human-automation interaction: Well designed automation helps human-system performance when all is well, but hurts under conditions of unexpected failures.

- The Higher the Degree of Automation (DOA), the greater benefit when it works: the greater cost **when** it "fails".



- Remember Asiana Airline accident

What is a “Failure”?

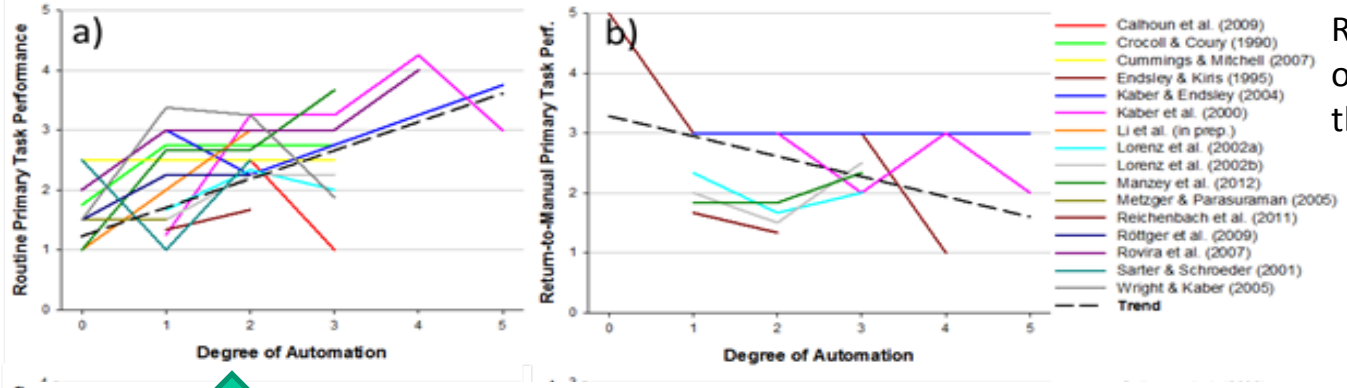
- Hardware or software “bug” (software reliability issues, with millions of lines of code. Power outages, stuck valves, Three Mile Island).
- Automation cannot perfectly perform its tasks in an uncertain world (alarm false alarms, incorrect weather forecasts; incorrect assumptions about a user’s word choice).
- Human “sets up” automation incorrectly. (KAL 007)
- Human does not fully understand implications (Asiana 214) and makes error in its use.

Where do the **Lumberjack data** come from? The meta-analysis.

Onnasch, Wickens, Manzey & Li, (2014)

Nominal Performance

Failure Performance



Results of a meta-analysis of studies that have varied the degree of automation

Degree of Automation

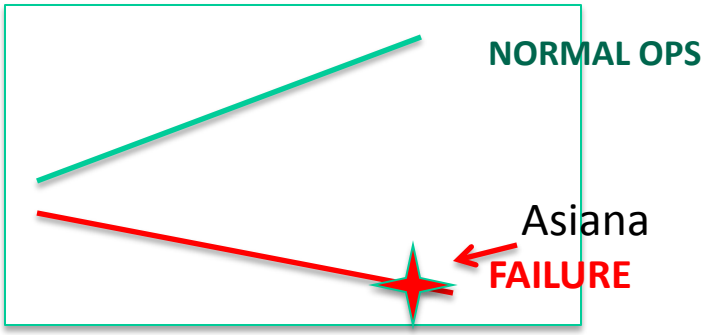
The higher they stand

The harder they fall

And they stand a lot

And they fall (or fail) rarely (but **unexpectedly**)

PERFORMANCE



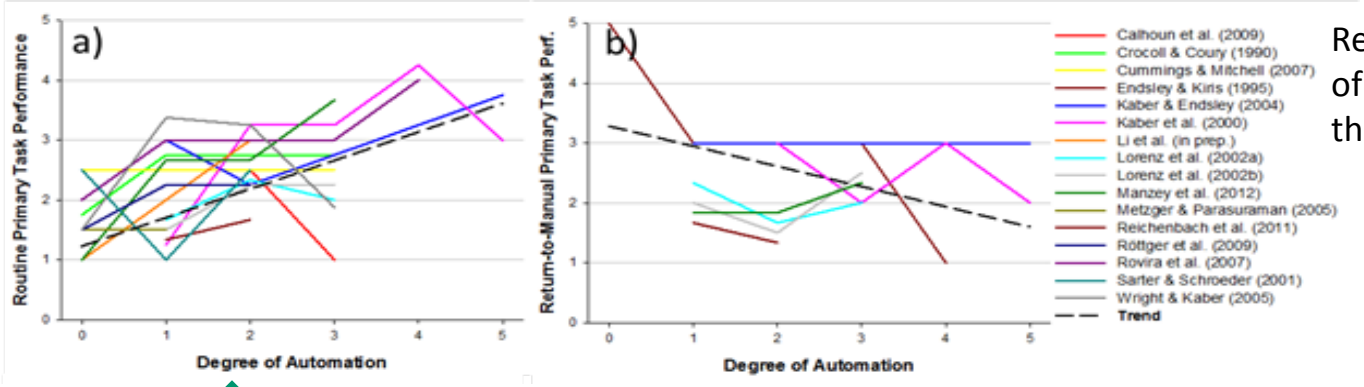
THE PROTOTYPE:

DEGREE OF AUTOMATION

Onnasch, Wickens, Manzey & Li, (2014)

Nominal Performance

Failure Performance



Results of a meta-analysis of studies that have varied the degree of automation

Degree of Automation

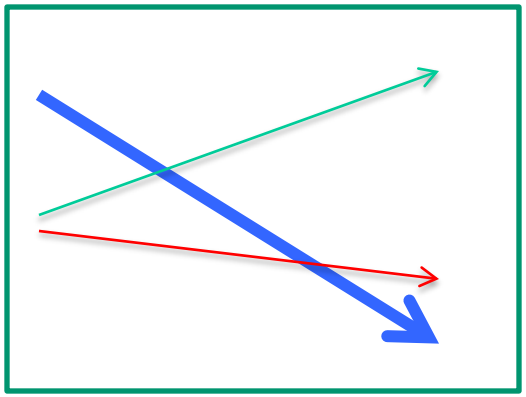
The higher they stand

The harder they fall

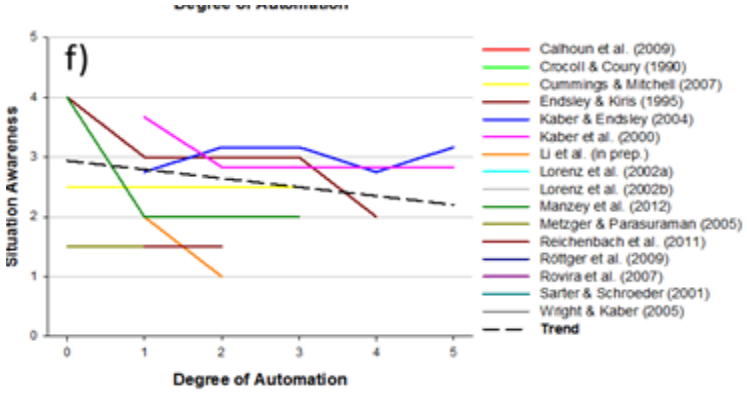
What underlies this increased cost, at higher degree of automation, when automation "fails"?

Loss of Situation Awareness at higher degree of automation

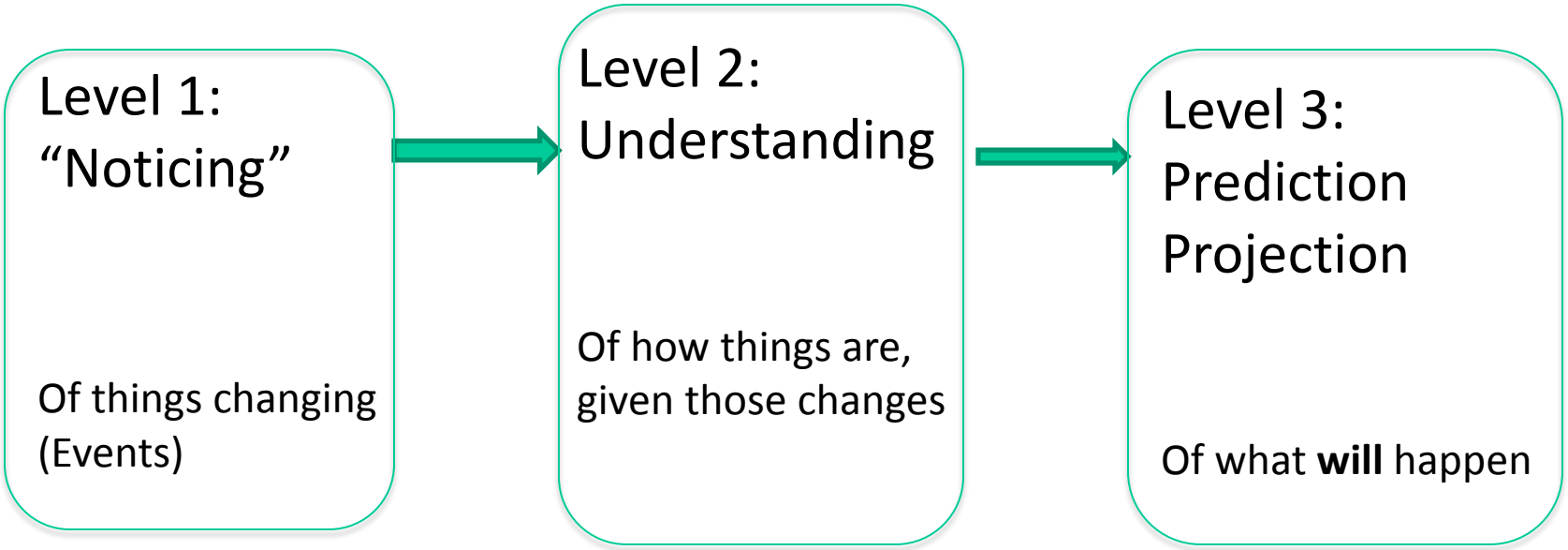
Situation Awareness



degree of automation



Situation Awareness: Mica Endsley's useful and well established taxonomy: 3 "levels" of SA. (distinguished from the multiple levels of automation and the 4 stages of automation).



Situation Awareness: Mica Endsley's useful and well established taxonomy: 3 "levels" of SA. (distinguished from the multiple levels of automation and the 4 stages of automation).

Level 1: "Noticing" → Level 2: Understanding → Level 3: Prediction Projection

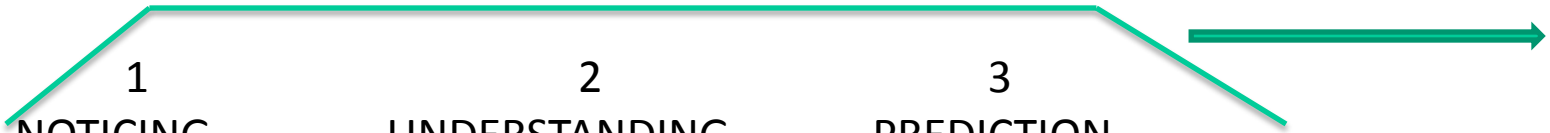
Humans with full processing resources should perform well at all three levels. BUT, they are susceptible to biases.

What can go wrong in human cognition?

Five Heuristics & Biases in Decision making.

WHAT CAN GO WRONG?

FAILURE OF: SITUATION AWARENESS ACTION



WHAT CAN GO WRONG?

FAILURE OF: SITUATION AWARENESS → ACTION

1 **NOTICING** → 2 UNDERSTANDING → 3 PREDICTION

1. CHANGE BLINDNESS

Pilots failure to notice unexpected "**black swan**" events.

Unexpected dangers (obstacles) on a cleared runway in simulated landings (Wickens, Hooey et al., 2009). 30% miss rate.

Change blindness amplified by:

- **Low salience** (not conspicuous) event
- **High workload**
- Away from forward field of view. (**Peripheral vision**) or out of sight

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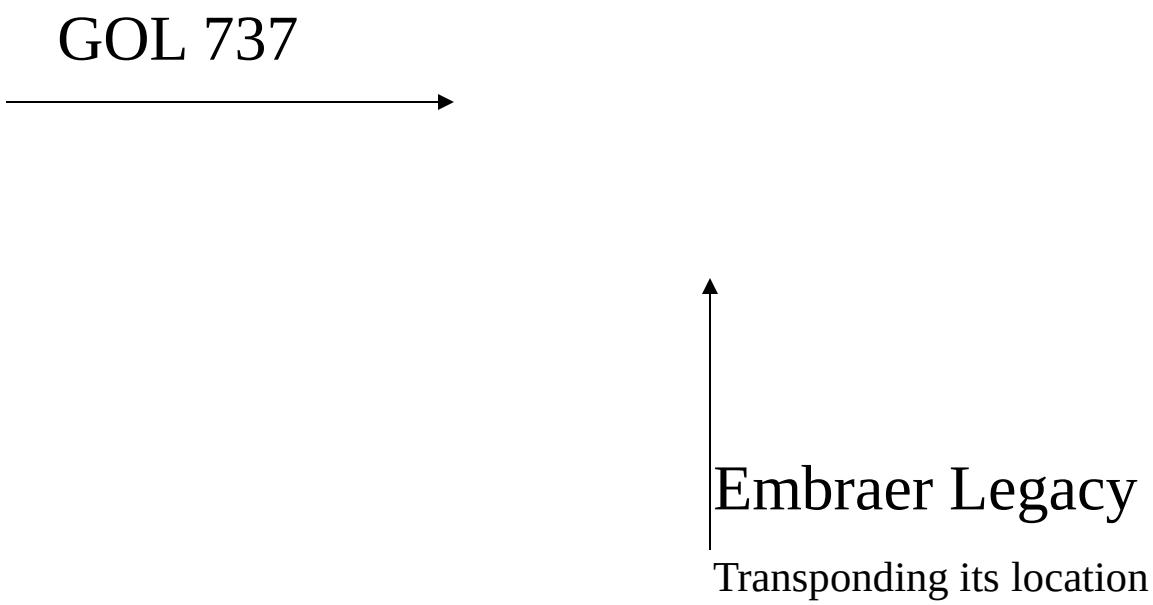
2006 Mid-Air Collision over Brazil



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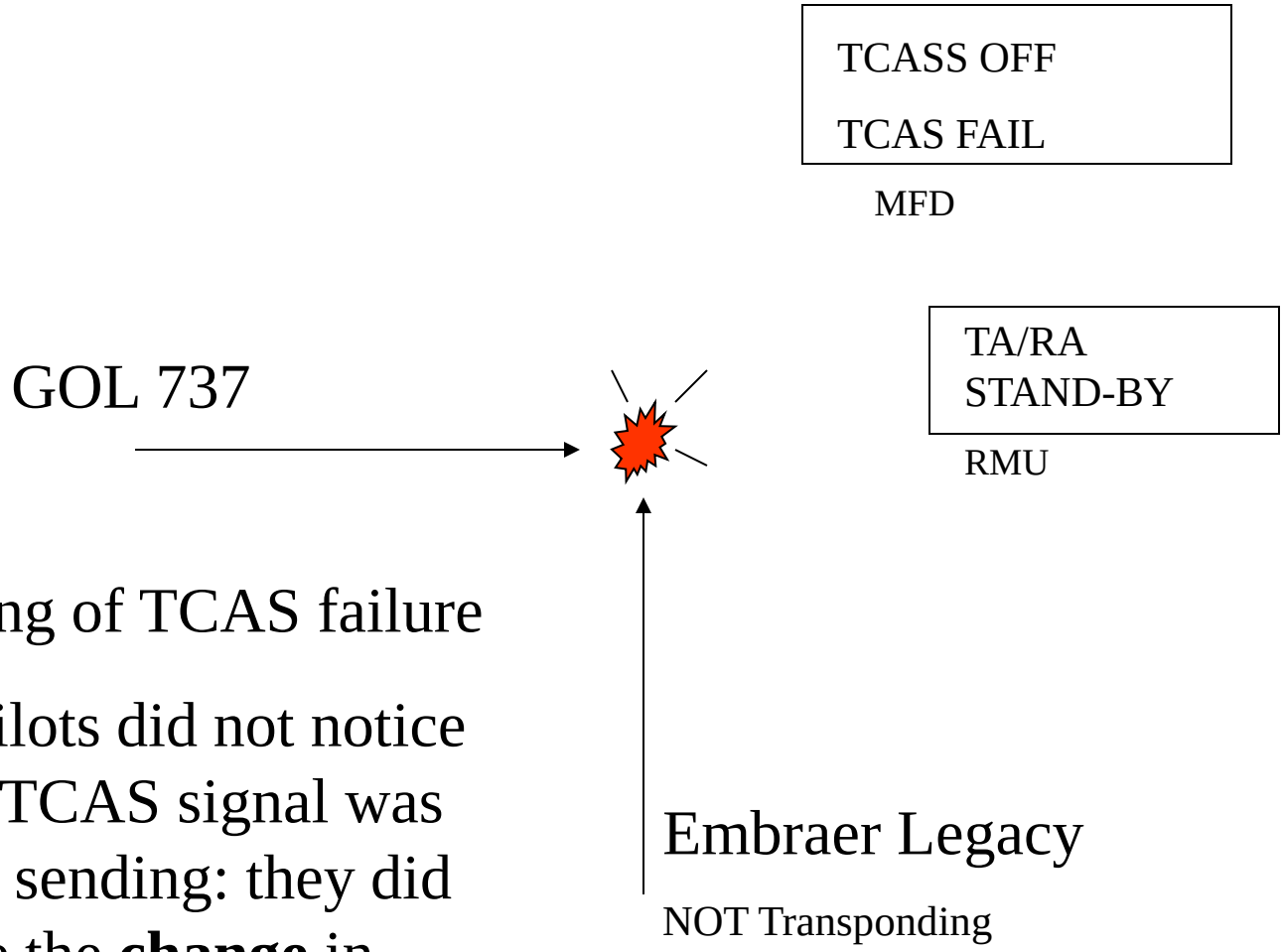

No flashing of TCAS failure

Legacy pilots did not notice that their TCAS signal was no longer sending: they did not notice the **change** in display state.

CHANGE BLINDNESS

We are poor at noticing unexpected changes in our environment that occur outside the momentary focus of attention:

Brazil Mid Air collision

Flying Monitoring

Ownship location transponder operating display

TIME

transponding

Gaze directed elsewhere.

(look down)

Not transponding

WHAT CAN GO WRONG?

FAILURE OF: SITUATION AWARENESS → ACTION

1 NOTICING

2 **UNDERSTANDING**

3 PREDICTION

CHANGE BLINDNESS

2. COMPLACENCY

Poor monitoring → poor understanding (Parasuraman & Manzey, 2010).

3. THE GENERATION EFFECT

We remember events and changes better when we actively cause them than when we passively watch another agent (automation) causing them. (Active versus passive learning).

Therefore we have poor understanding of the state, and state changes of a system under higher degrees of automation

Stage:	1	2	3	4
High Level			Automation does, unless human vetoes	
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WHAT CAN GO WRONG?

FAILURE OF: SITUATION AWARENESS

Failure of ACTION

1 NOTICING

2 UNDERSTANDING

3 PREDICTION

CHANGE BLINDNESS

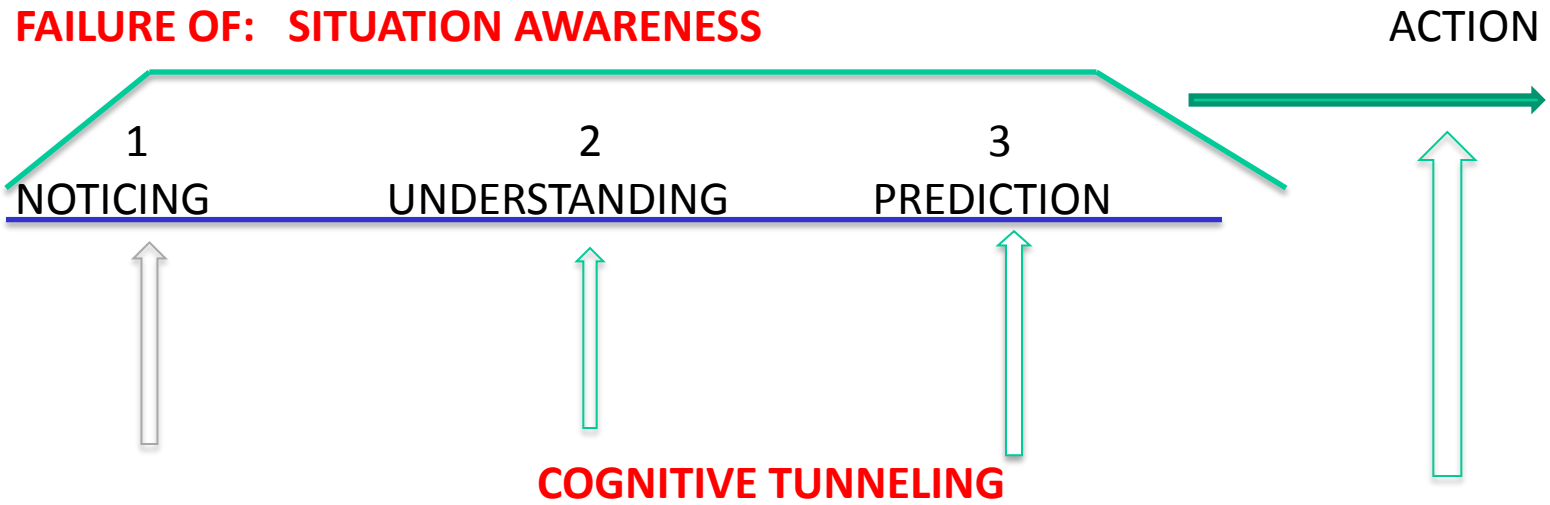
COMPLACENCY

4. THE AUTOMATION BIAS

We follow (trust) decision aiding automation more than we should (Mosier Skitka et al., 1998).
We don't "check the raw data" or "look over automation's shoulder" when things go wrong (Parasuraman & Manzey, 2010).

Shut down the wrong engine when automation tells you to do this.

WHAT CAN GO WRONG?



THE PERFECT STORM

- ANCHORING, OVERCONFIDENCE AND THE CONFIRMATION BIAS
- We **anchor** on our initial belief or hypothesis (and don't change it much in light of new data)
- We are more **confident** than we should be in the truthfulness of that belief (or in our forecast ability to do something correctly).
  70% believe we are better than average drivers.
- We seek, interpret and remember evidence to **confirm** we are right. We do not seek, we ignore, and we forget evidence that we might be wrong. (confirmation bias).
- THREE MILE ISLAND NUCLEAR POWER DISASTER

WHAT IS TO BE DONE?: Paths to Resilience.

DISPLAY

- Salient Alerts of Automation Failures (supports level 1 SA)
- Intuitive Process Displays. Graphically, what is automation **doing**?
  Makes it easier to understand: Ecological Interface Displays. (Supports level 2 SA).

DESIGN

Avoid highest degrees of automation if there is possible risk, in safety critical systems.

PROCEDURES

* Impose periodic times of removing automation. Force the human to “enter the loop”. Restore the **Generation Effect.** (Supports Level 2 SA)

TRAINING

- Impose automation failures during training. Create expectancy of failures:
  Change black swans to gray swans.

THANKS FOR YOUR ATTENTION

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