Human-Automation Interaction in Single Pilot Carrier Operation

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Of course techologically it <u>can</u> been done. <u>Should</u> it?

- Long history of GA single pilot operations, including some aircraft as large as 19 passengers (e.g BE 1900)

- Allegedly Sullenberger handled all tasks in the Hudson River ditching

- Embraer is designing aircraft for single pilot operations in the 2020-2025 timeframe

Arguments against Singe Pilot Operations

- Unacceptable to flying public?
- Too much faith in automation and communication reliability?
- Won’t save money; just moves people to the ground?

Different types of challenges

A1. Add routine tasks of pilot-not-flying to those of pilot-flying: increased workload

A2. Substitute ground-based human to be second pair of eyes and hands: attention and communication issues

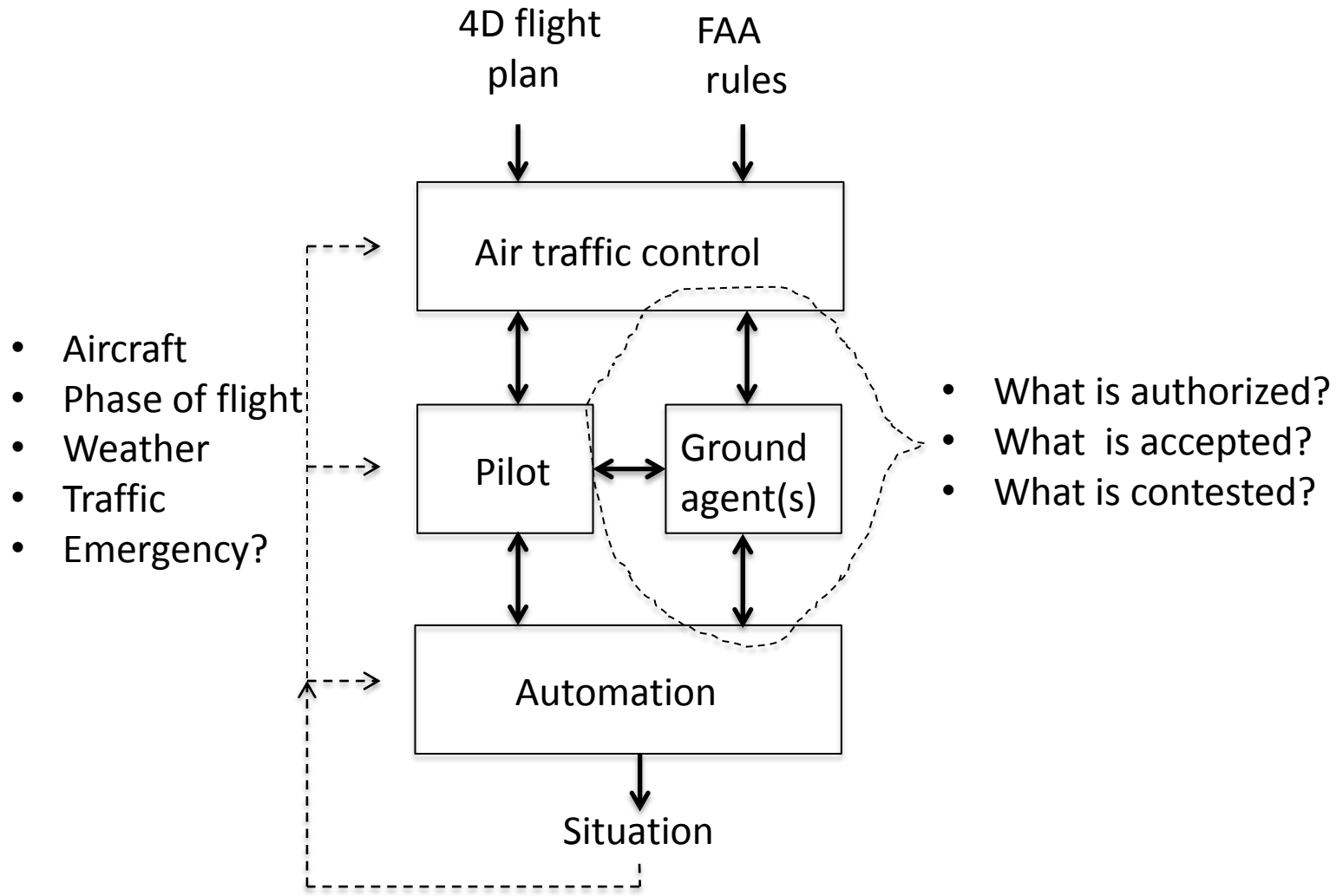
B1. Take over control in case of single plot incapacitation - **benign**

B2. Take over control in case of single pilot incapacitation - **conflict** (e.g., Jet Blue 191 JFK to LAS A320 with no other on-board pilot)

C1. Cope with on-board automation failure

C2. Cope with communication or ground-based automation failure: need for redundant and non-overlapping channels

Agents and variables in single pilot operation



Task assignment to ground controller /automation

	TRADE CONTROL	SHARE CONTOL
COOPERATE	• All tasks reassigned • Pilot initiated	• Selected tasks reassigned • Pilot initiated
CONFRONT	• All tasks reassigned • Ground or automation initiated	• Selected tasks reassigned • Ground or automation initiated

Tasks of human agent on the ground

1. CONCERNED ONLY WITH tasks of PILOT-NOT-FLYING?
- Shared by ~5 other aircraft
- Capability to hand off to other ground agent if get too busy

or…

2. COMBINED WITH tasks of REGULAR CONTROLLER?

Also…

Any tasks for human staff agent on-board?

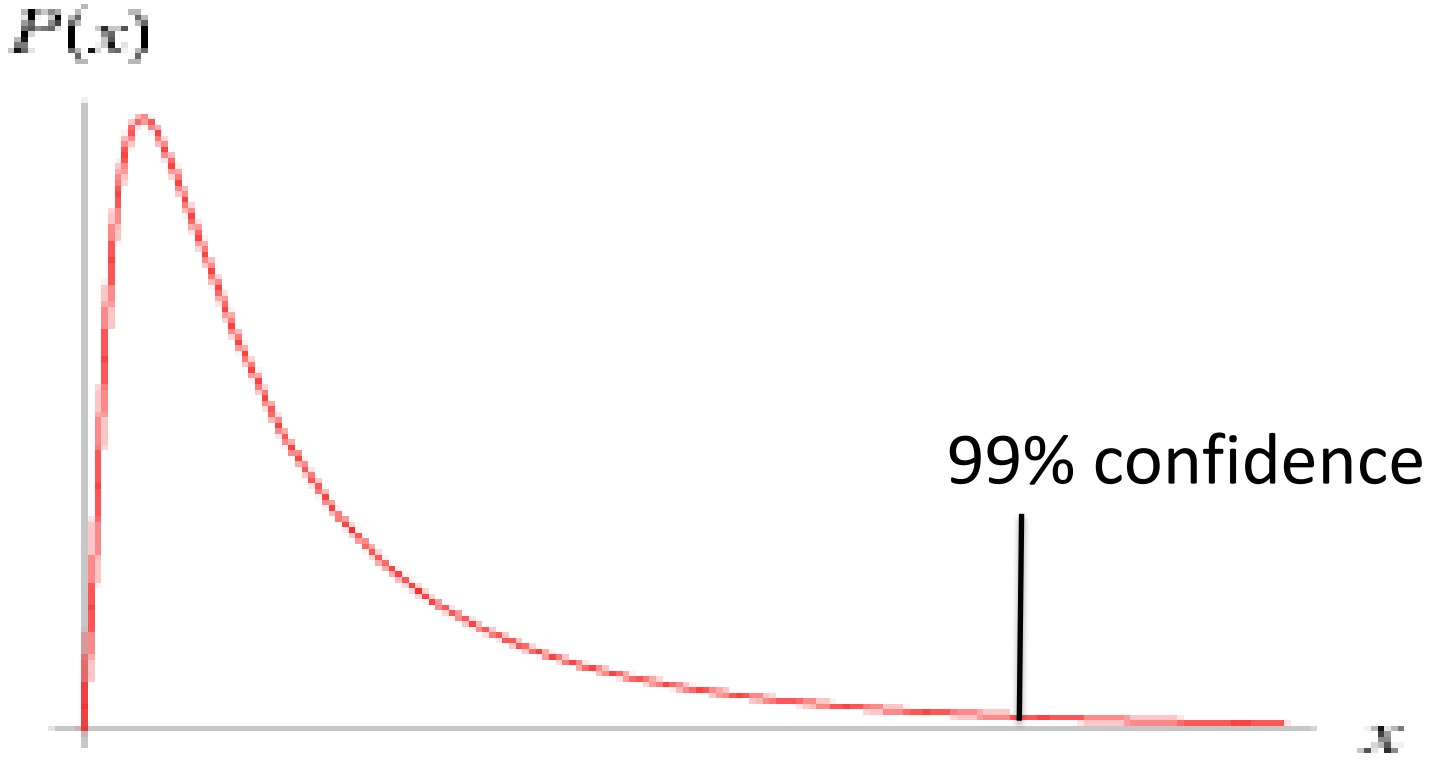
Teamwork: What does it take for humans and computers to "cooperate"?

- If their goals are different there will surely be conflict (as clearly demonstrated in control theory).
- They must also be continually giving feedback to one another to stay synchronized.
- A big challenge is how to measure and model the intentions and adaptive behavior of the human so that the computer can "understand."

How much information is too much information for a user to assimilate and utilize in the available time?

- There is a limit on how fast human can absorb information and decide what is relevant.

- Human response times follow a lognormal distribution, meaning some fraction of responses may take a very long time.



Lognormal distribution. Exact shape depends upon σ.
P(log x) would be normally distributed.

Flying alone can be boring, so

- Increase communication with human controller on ground beyond nominal tasks?

- Allow communication with a designated on-board staff person?

Human-centered automation: Should humans always be in charge?

- Not when the designated human is inattentive.
- Not when there is no time for a human to respond (even though attentive).
- And not when the human does not have the knowledge on how to manage responsibly.

- ABILITY > AUTHORITY > CONTROL > RESPONSIBILITY

How smart and how useful can we expect decision support tools and automation to be?

- Human may have unrealistic expectations of what given decision support tools know or what automation can do (experience, training, trust).

- Using decision support tools takes time, and if time is critical it may be best to act on experience and intuition.

DARPA PILOT'S ASSOCIATE, CIRCA 2004

- Infer from detected actions the intent of the pilot and communicate these intentions to the other subsystems,
- Model the current pilot workload in order to adapt the behavior of the information presentation and aiding subsystems,
- Configure cockpit displays and controls to present the most important information in the most effective manner,
- Assist the pilot by performing actions approved for the PA to implement,
- Identify and compensate for pilot actions that might result in errors with serious consequences, and
- Provide the interface between the pilot and planners by managing and presenting proposed plans, allowing the pilot to accept or reject proposals, proposing alternatives where appropriate, and removing proposals when the were no longer appropriate.

Who is in charge what when?

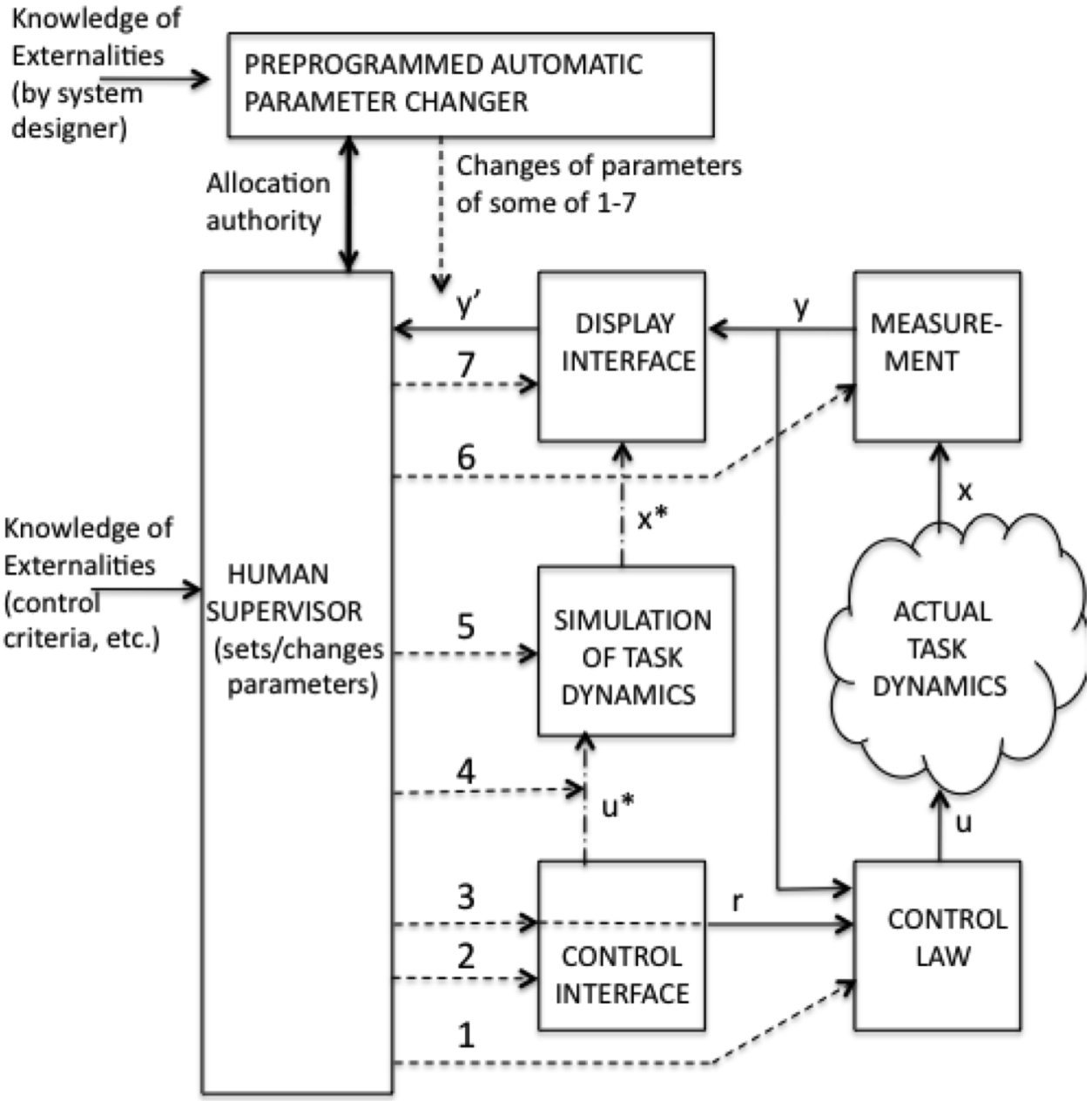
Should or can authority (how control is enabled) and responsibility (accountability in case of failure) always go together? Complicating factors are:

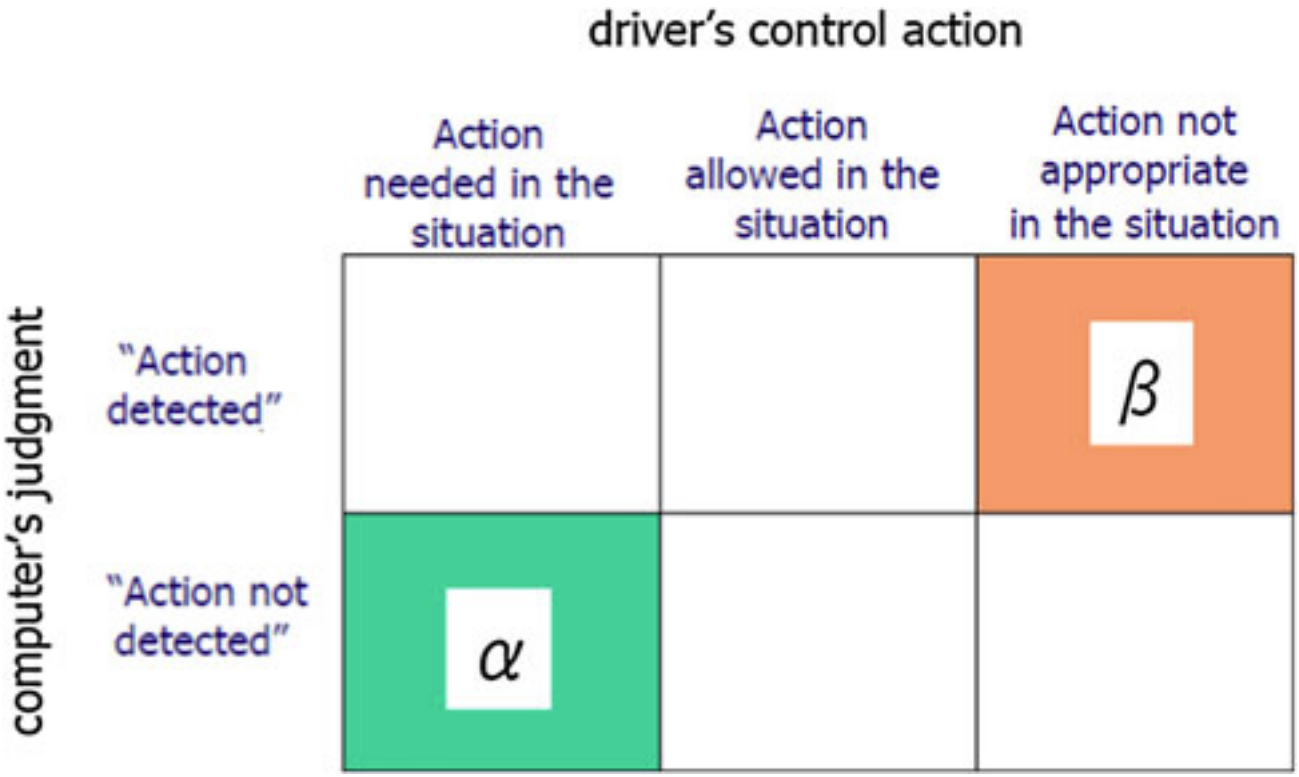
- In modern organizations both authority and responsibility tend to be shared vertically.
- Human users become dependent upon automation and decision support tools. Can automation be held responsible?
- Difficult to pinpoint a specific locus of human input (design, manufacture, installation, maintenance, training, operation).

A Scale of Levels of Automation

1. Computer offers no assistance; human must do it all.
2. Computer suggests many alternative ways to do the task.
3. Computer narrows set of alternatives to just a few.
3. Computer recommends one way to do the task.
4. Computer executes that recommendation when and if human approves.
5. Computer allows human a restricted time to veto before automatic execution.
6. Computer chooses a method, executes, and necessarily informs human.
7. Computer chooses a method, executes, and informs human only if requested.
8. Computer chooses a method, executes, and ignores the human.

Modes of supervisory control/adaptive automation





α = automatic braking in response to lead vehicle deceleration

β = automatic lane change prevention when vehicle coming in new lane

"Authority and responsibility in human–machine systems: probability theoretic validation of machine-initiated trading of authority"
Toshiyuki Inagaki and Thomas B. Sheridan
Cognition, Technology and Work, Vol. 14, No.1, March 2012

DERIVED CONTINGENT PROBABILITY EQUATIONS where
U=unsafe, S=safe PARTICULAR SITUATION,
NA=no action, A=action BY PILOT
w=warning, a=computer intervention; "…" means "computer said"

$$P_{\mathrm{w}}(\text{accident prevention}|U,\mathrm{NA}) = P(\text{“}U\text{”}|U)\,P(\text{“NA”}|\mathrm{NA})\;P(\mathrm{IA}|\text{warning})$$

$$P_{\mathrm{w}}(\text{unnecessary warning}|U,A) = \mathrm{P}(\text{“}U\text{”}|U)\,P(\text{“NA”}|A)\,.$$

$$P_{\mathrm{w}}(\text{inappropriate warning}|S,\mathrm{NA}) = P(\text{“}U\text{”}|S)\,P(\text{“NA”}|\mathrm{NA})\,.$$

$$P_{\mathrm{a}}(\text{accident prevention}|U,\mathrm{NA}) = P(\text{“}U\text{”}|U)\,P(\text{“NA”}|\mathrm{NA})$$

$$P_{\mathrm{a}}(\text{unnecessary automatic braking}|U,A) = P(\text{“}U\text{”}|U)\,P(\text{“NA”}|A)\,.$$

$$P_{\mathrm{a}}(\text{inappropriate automatic braking}|S,\mathrm{NA}) = P(\text{“}U\text{”}|S)\;P(\text{“NA”}|\mathrm{NA})\,.$$

Designing for surprise: What are the tradeoffs?

- Preparation for any contingency is good, but how much to spend on preparation?

- A most conservative criterion, to be prepared for the worst case, is too conservative. But an expected value criterion (probability times cost) is too liberal.

History of Pilot Models

Pilot as servomechanism: analytic models using differential equations of control theory

- Simple crossover model (McRuer, Krendel, Jex)
- Optimal control, internal model (Baron, Kleinman, Levison)

Pilot as cognitive agent (supervisor of automation, flight manager) using rule-based computer simulation

- ACT-R (Johnson-Laird et al)
- Air Midas (Corker et al)
- D-OMAR (Deutsch and Pew)

Foyle and Hooey: challenge of model credibility with increasing complexity and pace of change

Experiment with successively more challenging platforms

- Fast-time models
- Human-in-the loop simulations
- Flight trials with SPO-certified GA passenger jets
- Trials by express mail carriers
- Trials by short haul passenger carriers

Development of "automation policy" to guide design, operation and management of highly automated systems

Specify:

- Specific responsibilities of humans in specific situations.

- Who or what will be held responsible for which kinds of failures.

- What kinds of evidence are admissible in making such judgments.

Single Pilot Operation: Which will it be?