Enhancing Air Safety for Pilots and ATC using TRIZ

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Abstract

Air Safety is a term embracing the concepts, theory, investigation and categorization of flight failures, and the prevention of such failures through regulation, education and training. The Pilots and Air Traffic Controllers (ATC) face a whole panoply of critical decisions during the flight, and most of them are taken within split second under stressful situations. The displays of cockpit and ATC and design of cockpit, are very crucial factors for successful flights. The pilot and ATC face lot of conflicts while performing their roles. The need to display more information conflicts with the focus needed for flying. The vital information needs to be segregated from the routine information. The need to have more switches to control the aircraft conflicts with the operational effectiveness. This article explores the use of TRIZ principles for resolution of some of these conflicts in order to enhance the Air Safety.

Keywords: Air Safety; Air Traffic Controller (ATC); TRIZ; Contradiction; Conflict; TRIZ Principles; Night Flying; Distance Illusions; Visual Autokinesis; False Horizon Illusions; Black Hole Effect; Vection Illusion.

1 ATC Task

The primary goal of an ATC is to provide for safe, orderly and expeditious movement of traffic. ATC displays are very critical for controllers to comprehend and interpret the displayed information and instruct accordingly the pilots about direction, separation and other conflict avoidance scenarios. The safe separation of aircraft involves all the three spatial dimensions and time, and this separation is assured through the enforcement of minimum vertical and horizontal separation standards. ATC rely on tools like radar display and flight progress strips (FPS).

1.1 ATC Display Contradictions

The need to display additional information intended to help the controller conflicts with the need to minimize information overload. He needs to focus and distinguish the critical information from the routine ones (Hipple, 2008). The display screens show locations, directions and altitude of all aircraft within a given radius of jurisdiction of a given controller. As aircraft travel to their destinations, **handoff** (Cummings and Tsonis, 2005)occur between various ATC centers in designated locations. Common language, symbols and acronyms are used in the aviation industry to ensure unambiguous communication and instruction. The graphical user interface (GUI), the environment in which this interaction occurs, noise level, time of the day, number of aircraft in the area and other conditions are important mediating and moderating variables for this communication. Optimizing the human factors aspects of ATC displays, can minimize the training costs, equipment charges and risk of precious lives.

The fundamental conflicts, in this context, arise between **display engineering** (data, formatting, coding and layout) and the **Human Computer Interface (HCI) engineering (interpretation and interaction)**. The TRIZ contradiction table can be set up as :

Desired Improving Parameter	Undesired Result	Suggested Principle
Difficulty of Detecting the event	Loss of Information	**Parameter Changes**, Homogeneity, Blessing in Disguise, Cheap Short Living Objects
Loss of Information	Safety	**Preliminary Action**, Mechanics Substitution, Intermediary, Nested Doll
Extent of Automation	Loss of Information	**Parameter Changes**, Homogeneity
Extent of Automation	Device Complexity	Dynamics, Intermediary, Preliminary Action
Measurement Accuracy	Device Complexity	Parameter Changes, Cheap short living objects, Preliminary Action, Discarding and Recovering
Appearance	Loss of Information	Local Quality, **Nested Doll**, color changes, Preliminary action, Asymmetry
Information on Display	Area of Display	**Color Change**, Taking Out, Local Quality, Another Dimension
Added Functionality	Simplicity	Color Change, Parameter Change, **Asymmetric Symbols**
Information on Display	Information Overload	**Color Change**, Nested Doll

Table 1: Contradiction Table and Suggested Principles for ATC display

Parameter changes like changing the shape and behavior of the symbol displayed can improve the detection without loss of any information. **Preliminary Action** can be used to increase or decrease the displayed information depending on the air traffic or weather conditions. **Nested Doll** suggests that displayed information can be nested so that a pick on the screen can display the additional information related to that aspect. **Color Change** can be used to signify critical events during the flight. **Asymmetric Symbols** can be used to embed additional information in the symbols for urgent intervention cases.

All the information need not be displayed at all the time on the screen.**Separation upon condition** can be used to selectively display certain conditions prominently in bright colors such as weather conditions, separation conflicts, trajectory conflicts, transitioning aircraft during handoff. Information overload can be reduced by temporary omission, reduced precision, Queuing, Filtering, reducing categories, Decentralization etc as the case may be.

1.2 Loss of Separation Conflicts

ATC rely on important cognitive resources to maintain separation between aircraft and manage traffic flow through (Galster et al., 2009; Nunes and Mogford, 2003; Loft et al., 2007) accurate mental models and up-to-date picture of ATC systems. **Mental models** are long term storage of rules, relationships, information, strategies, action sequences and procedures. **Picture** is temporary conscious storage of information, strategies, procedures etc. used to accomplish tasks. ATC updates and maintains the pictures after integrating various visual, auditory, tactile and other sensory information needed to maintain the picture. These Changes in Pictures are aligned with mental models and accordingly mental models keep altering.

Desired Improving Parameter	**Undesired Result**	**Suggested Principle**
Loss of Horizontal & Vertical Separation	Trajectory Conflict	Parameter Changes, Preliminary Action, Color Changes

Table 2: Contradiction Table and Suggested Principles for Loss of Separation Conflicts

Loss of separation Conflicts can be resolved by taking **preliminary action** like trajectory prediction, and **color changes** to represent the conflicting aircrafts, which need urgent attention.

2 Pilot Task

2.1 In Flight Conflicts

In case of emergency, if the ATC directives are at conflict with the navigational instruments, the pilot faces a dilemma, whether to follow ATC directives or decide himself on the basis of navigational instruments. His navigational instruments may be faulty or the ATC may be careless in giving the directions. In this case the contradiction table can be given as

Desired Improving Parameter	**Undesired Result**	**Suggested Principle**
ATC directives for Flight Contingency	Reliance on Navigational Instruments	Feedback

Table 3: Contradiction Table and Suggested Principles for In Flight Conflicts

Giving **Feedback** of navigational Instruments to ATC and then realigning with the ATC directives resolves this conflict.

2.2 Night Flight Conflicts

For some pilots, night time is the best time to be airborne, because of less air traffic, the concealing cover of darkness, effective inertial navigation system and quiet radios etc. However, it's also the perfect time to experience **spatial disorientation**. The following visual illusions (Farrar, 2005) mar the otherwise enjoyable night flying.

2.2.1 Vection Illusion

Vection illusion is the sensation of self-motion induced by relative movement of other viewed objects. A vection illusion becomes more pronounced during night flying, when a well-lighted aircraft penetrates a cloud, haze, or precipitation. After penetrating into the visible moisture, the pilot's visual cues signal a speed increase, and the natural tendency is to slow down the aircraft. However, this unwarranted power decrease could cause a dangerous sink rate thereby stalling the aircraft.

Desired Improving Parameter	Undesired Result	Suggested Principle
Vection Illusion	Disorientation	Continuity of Useful Action, Feedback

Table 4: Contradiction Table and Suggested Principles for Vection Illusion

Continuity of Useful Action and Feedback suggest reliance upon performance instruments (particularly the airspeed indicator) for throttle adjustment decisions. The pilot must predict the possibility of a vection illusion in the described environment and depend upon navigation instruments for pitch-change decisions.

2.2.2 Visual Autokinesis

Autokinesis is perceived movement exhibited by a static dim light when it is stared at in the dark. It appears to move in several directions after around 10 seconds of visually fixation. The larger and brighter the object is , the less is the autokinetic effect. Autokinesis is most commonly found in dark conditions with only one or two lights present and becomes rarer with more and more lights present.

Desired Improving Parameter	Undesired Result	Suggested Principle
Vision of static dim Light	Perception of movement of light	Dynamics, Another Dimension, Merging, Feedback

Table 5: Contradiction Table and Suggested Principles for Visual Autokinesis

Dynamics may suggest that a pilot should shift his gaze frequently to avoid prolonged fixation on the light; make eye, head, and body movements to destroy the illusion. **Feedback** may mean monitoring flight instruments to prevent or resolve any perceptual conflict. **Merging** may suggest to view the source beside or in reference to a relatively stationary structure such as a canopy frame.

2.2.3 Distance Illusions

It becomes very difficult to estimate the distance of the other aircraft, just by seeing its beacon lights, as there isn't enough visual information available. During the daytime, reflected light provides the other necessary visual clues for the human brain to assess distance. During night flying, most of the light received by the human eye comes directly from illumination sources . The aircraft giving bright lighting (thereby perceived to be nearer) may actually be farther than the one giving low-illumination lighting. The contradiction matrix in this case can be set up as

Desired Improving Parameter	Undesired Result	Suggested Principle
Illumination Intensity	Difficulty of Detecting	**Color Changes**, Dynamics
Difficulty of Detecting	Safety	**Preliminary Action**, Mechanics Substitution, Intermediary, Nested Doll
Appearance	Loss of Information	Local Quality, **Nested Doll**, color changes, Preliminary action, Asymmetry

Table 6: Contradiction Table and Suggested Principles for Distance Illusions

Color Changes can be made contingent on actual altitude and distance by using navigation. **Dynamics** may mean stacking high on the lead aircraft, **Nested Doll** suggests that displayed information can be nested so that a pick on the aircraft can cross-check actual altitude, and ensure a stable distance between aircraft by using radar or air-to-air tactical air navigation.

2.2.4 Black Hole Effect

Night flight into an area lacking in ambient cues produces the black hole effect. During day time, our ambient visual system supports correct spatial orientation by enabling the brain to correctly assess the relative position of objects that reflect or illuminate light. At night, these cues are often missing over water or near sparsely populated areas. This produces spatial disorientation. The black hole effect become pronounced during landing, when few surface lights exist between a landing aircraft and the runway and pilots tend to fly too low and thereby crash.

Desired Improving Parameter	Undesired Result	Suggested Principle
Flying in Black Hole Condition	Disorientation	Continuity of Useful Action, Feedback

Table 7: Contradiction Table and Suggested Principles for Black Hole Effect

Continuity of Useful Action suggests disciplined reliance upon flight instruments. For a visual cross-check outside the cockpit, pilots must rely upon accurate **Feedback** from glideslope indicators.

2.2.5 False Horizon Illusions

In order to maintain horizontal and vertical orientation, the human brain sub-consciously uses the visual cues to monitor the Earth's horizon. These cues are compared to those encountered by the vestibular and somatosensory systems in order to provide positional orientation. In the absence of any discernible horizon, starlight can look like ground lighting and after reflecting off the water surface can confound the visual cues.In northern regions, the **aurora borealis** causes similar disorientation.

Desired Improving Parameter	Undesired Result	Suggested Principle
Maintaining Orientation	Mis-perception of Horizon	Preliminary Action, Beforehand cushioning, Continuity of Useful Action

Table 8: Contradiction Table and Suggested Principles for False Horizon Illusions

Preliminary Action and Beforehand cushioning suggest a good calibration check of navigational instruments, specifically for altitude, during ground operations prior to takeoff and **Continuity of Useful Action** suggests a continuous cross-check in flight to confirm correct operations.

Conclusion

The job of an ATC and a pilot involve lot of conflicts. The contradictions matrix and the TRIZ universal principles can be used for resolution of these conflicts. The contradiction matrix can be extended to include the kind of conflicts faced by the pilot and the ATC and the universal principles can be applied to the extended contradiction matrix. The ideas presented here are conceptual ones and they need to be substantiated by the experimental data.

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