A possible development: Free flight

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"Some men see things as they are and ask, 'why?' I dream things that never were and ask, 'why not?'" Robert F. Kennedy

INTRODUCTION

Robert Kennedy's eloquent observation[1] is an appropriate way to begin this brief paper. Historically aviation has been a domain built by dreamers, such as, the Wright Brothers, Bleriot, Lindbergh, Vedrines, and Ader. The early excitement and adventure of aviation was described to an eager public by authors such as De Saint-Exupéry, Gann, Mermoz, and Bach. These pioneers and authors surely dreamt things that never were and asked, 'why not?' If they had not posed their "idiotic" questions, we would still all be stuck on the ground.

Kennedy's observation also describes much of the current thinking in aviation, where today many people continually ask "why are things are the way they are." Why are airports busy? Why can't we more more traffic? Why is flow control not working? A lot of people in today's relatively stable aviation environment seem to create lots of changes – e.g., change a procedure, add more computers, add more rules – but nothing is really different. Airports are still busy, flights are continually put on ground hold, and luggage is still lost. As the old french saying goes: *Plus ça change, plus c'est le même chose.*

Plus ça change

Aviation today is looking for ways to make the air traffic system both more effective and efficient. For decades people have asked the question, "How can we increase capacity, while maintaining safety?" However, the magnitude and quality of the dreams of the current crop of "aviation pioneers" seem to be held captive by those people who continue to "see things the way they are."

Plus c'est le même chose

Over the past three decades the aviation agencies of the world have developed and implemented

[1] This quote is a paraphrase from a similar quote by G. B. Shaw, who stated: "You see things as they are and ask, 'Why?' I dream things as they never were and ask, 'Why not?'"

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many types of technological tools, aids, and fixes with the goal of improving the air traffic flow and safety. These visionaries moved from fires on top of hills, to electric light beacons, to ADF and radio-range, to VORs, and most recently to satellite based navigation. The air traffic systems of the world continue to add higher technology radars, as well as, more and higher-end computing power. But airports today still have long queues of aircraft waiting to take-off and land. In reality, after all the money has been spent, we have "c'est le même chose."

Descriptions of the limitations of the "things as they are" weltanschauung have not been limited to Kennedy and Shaw. One can also find more theoretical descriptions in the writings of the mathematicians such as Évariste Galois, Alfred North Whitehead, Bernard Russell, and Ross Ashby. These writers, in their descriptions of Group Theory and the Theory of Logical Types, have provided the theoretical underpinnings for understanding of the "Plus ça change, plus c'est le même chose" syndrome.

Changing Perspectives

Group Theory provides a framework for understanding how a large number of changes can take place, while the system itself remains the constant[2]. The Theory of Logical Types, on the other hand, provides the framework for understanding the metamorphosis from one logical level to another[3]. Watzlawick, Weakland, and Fisch (1974) have used these two theoretical models[4] to demonstrate why it it often impossible to effect changes peoples behavior. They argue that all too often we try to change a person's specific undesirable behavior rather that changing their way of behaving.

Watzlawick et al. argue that the concepts found in the Theory of Logical Types provide a way to actually change a system. They argue that for a system to "change its way of behaving," its members must step outside the current system and redefine the complete process and invent a new system or group. It must change its way of behaving not just one or two of its behaviors.

This author has argued for several years (see Wise, 1991) that the real problem in air traffic control is that it has reached its asymtope in performance and cannot be improved substantially! He has argued that the real solution to our air traffic systems will ***not*** be found in 1) more or better trained controllers and pilots, or 2) in improved processing power of ATC computers, or in 3) increased number of navigation aids or sectors. The current air traffic system has bumped up against its own theoretical limits. It cannot get much better. *Small improvements* could be made but only at an *very large cost.* The only way that one could create significant increases in performance is to change the system itself.

[2] Group theory basically describes how a group or system operates given the group's basic operating rules. By definition, if one plays by those rules it is impossible to change the system.

[3] The Theory of Logical Types on-the-other-hand describes the relationship between different groups and/or systems and therefore allows one to move from one set of rules to another.

[4] For a more detailed description of types of changes see Wise (1977).

In recent years , some people have begun to step out-of-the-box and realize that the current ground-based air traffic system did not come down from the mountain with Moses, but rather was a political (in the US anyway) and technological fix to a perceived problem in the 1950's.

The problem they were trying to fix was the pilot's inability to see, and thus avoid other traffic, in certain operational environments . There were two aspects that influenced that inability. First, the windscreens kept getting smaller as more electro-mechanical switches and gauges were added to the cockpit. Second, in instrument meteorological conditions it was impossible to see other aircraft independent of windscreen size. Given the technology of the day (i.e., vacuum tube based radar systems), and the fact that most administrators of national aviation systems were former military officers from World war II, quite naturally led to the design of a ground-based military style command and control system.

Given that the current system is solution based on a 1950's operational theory and technology, an important question to ask is 'what would an air traffic system look like if it were to be designed from scratch today?' This is a difficult question to answer unless you are a good science fiction writer, but given the tendency today toward distributed systems and empowerment, this author seriously doubts that a centralized ground-based system would have evolved.

Over the past six or seven years, there has been considerable discussion in the aviation community regarding dramatically changing the nature of air traffic systems. The leading Theory of Logical Types level of proposal would change the nature of air traffic systems from one where the basic control function is performed by a centralized ground-based "controller;" to a distributed and primarily airborne or cockpit centered system. Benel (1995) has noted that in such a system:

- Air traffic service does not intervene with the flight path except to:
    - Resolve a tactical conflict unresolved by the aircraft
    - Manage the traffic flow when demand exceeds capacity
    - Prevent entry into special use airspace
- Pilots will not be obligated to receive clearances prior to each action
- Pilot/controller responsibility for traffic separation may be shared
- Technology will allow a much smaller separation "bubble."

A cockpit centered air traffic system could have dramatic impacts on: 1) the costs and technologies associated with air traffic systems and; 2) aviation safety. Thus the successful implementation of this system will need significant forethought and careful design.

The reasons we can make such a dramatic change are many. First and foremost, (as mentioned earlier) the technology has evolved to the point where such a system is possible and practical.

These technologies include satellite based navigation systems that allows extremely accurate direct point-to-point navigation; cockpit displays of traffic information (like a miniature air traffic radar display) that provides pilots a display of the traffic around him; and the modern computer based flight management systems that allow precise time based navigation (e.g., arrive at the destination within a 15 second window). Likewise, the traditional system with a ground based controller violates any number of basic human factors principles, including having the controller working in a high control order environment using low resolution data that are several seconds old.

BASIC ISSUES

The development of such a highly complex system – using new technology that must work correctly (i.e., safely) the first time – will require the understanding and application of basic information system related behavioral science theory and design principles. Critical areas will involve human information processing, time constrained decision making, real-time problem solving, vigilance, basic perceptual issues, and information presentation principles.

For an cockpit centered system to be effective a significant amount of the decision making will need to take place at the location where it can most efficiently be implemented, i.e., in each cockpit. In the case of traffic avoidance, the display of local traffic information to the pilot may not be sufficient. Many theorists (e.g., Geddes, Brown, Beamon, & Wise, 1996) believe that the intentions of the other aircraft are also necessary, e.g., Where is the other traffic going?; Will it turn?; etc. The answer to the above question must consider at least the following issues: what data will be useful; what is the best way to present the data; what type of time penalty does joint decision making require; etc.

The introduction of a cockpit centered system concept to only part of the world wide aviation system could have dramatic influences at the boundaries of operation. For example, how would traveling from a aircraft-centric system to a tradition ground-based system effect the decision behaviors of of flight crews: would they be more aggressive; would they need different information; would they need different or additional training; etc.? Related questions can be asked about how crews who normally fly in a traditional system would adapt to a new environment.

Pilot vigilance will be critical. The current ATC tends to lull pilots into a sense of security, but an aircraft-centric system will demand a more active search strategy from the pilots. New and more effective ways of stimulating active search in an environment that has very few real targets. What would be the impact of using current equipment as a means of maintaining separation? What would need to be modified to make that technology work effectively? What are the basic information needs of a pilot using such a system?

Dynamic in-route flight planning (i.e., problem solving, decision making) will become more critical. For the most part current airline flights are fairly canned, but for free flight to be effective, the flights will need to continually change based on weather, winds, and traffic. Status displays and planning tools will be needed. Since most visions of free flight have time as a critical dimension (e.g., you can go anyway you like, but you must arrive at an exact time) ways of presenting time based navigation information in a effective manner will be needed. There will also be a requirement to inform pilots and adapt traffic to many kinds of event, such as severe weather, emergencies, runway or airport closures, and the like. To do so on an individual basis in a free-routing environment would seem to be impractical as a human function and so some form of computer assistance would have to be devised and applied.

Distributed Decision Making

While traffic flow management will remain an important part of air traffic service organizations it too will need to change to be effective. It will need to be much more amenable to shared decision making. For example, when a piece of air begins to have too many aircraft the air traffic service providers will need to work with the users rather than making command decisions. If there are ten too many aircraft planning to arrive at an airport in a given time-window, the user's (not air traffic flow management) will decide which aircraft will speed-up , divert, or slow down, etc. Or aircraft at or near a given location would assist in determining whether the actual weather (rather than the forecast) would necessitate flow restrictions. Training, information, and decision aids will be needed for all participants for this to work effectively.

Air Traffic Systems

Air traffic systems will face numerous human factors problems with a transition to a cockpit centered system. These will include the human-machine interface design, the provision and portrayal of information, the communication of data, the designs of tasks and workstations, and the allocation of responsibility. Air traffic specialists need to learn to become less interventionist and more of a team player. For example, they probably to *request* minor changes so that traffic would flow safely and efficiently.

Garland and Hopkin (1995) do not feel it will be possible to require the controller to treat free flights as individual elements of a strategic system. Thus safety implications at that level would probably have to use some form of automated checks both when the flight entered the system and during its subsequent path through it. They also note that some human factors problems seem particularly acute in any transitional environment with a mix of free flights and "traditional" traffic, since the simplest ways of reconciling them seem to imply unacceptable priority of one type of flight over the other.

Flight Crews

For the flight crew especially, a higher demand of real-time monitoring and modifying current flights will evolve. Weather, traffic, crew duty time, and business decisions will become more important and dynamic aspects free flight operations. In addition, the weather and traffic information will need to be provided in four-dimensions. To meet these needs new types of information displays and decision support tools will be needed.

Approximately 95% of aircraft, 60% of the aircraft operation hours in the United States fall in the "general aviation" category. Abbott (1995) notes that general aviation operations frequently have only one pilot, even on IFR operations, compared to the air carrier crews of two or more. Air carrier operations have extensive training budgets and conduct extensive training , while general aviation operations are frequently individual citizens with no such financial resources. Abbott also notes that under current air traffic system general aviation pilots are able to conduct safe flight in either IMC or VMC with knowledge that they "in the loop" of awareness and control as their air carrier counterpart. However, in a free-flight system they may suffer from lower levels of technology, i.e., they may not be able to afford it and consequently may feel and behave like second class citizens.

SUMMARY

For air traffic systems to meet future demands of the public dramatic changes will be needed. I have attempted to argue that the current system has met its operational limits and that a dramatic change is needed in the way air traffic systems operate if we are to meet that need. That change will involve a system where more decisions are made in the cockpit and fewer are made on the ground. Such system will require us to think carefully and design effectively. We will need to look outside of the current traditions of aviation to find the appropriate models on which to build our future.

If we are too conservative in our vision and our thinking, we will continue with, plus ça change, plus c’est le même chose. And perhaps worst of all, all those pioneers that we all grew up want to be like, will be sitting up in heaven looking down on us and wondering where their dream went wrong!

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