INTERNATIONAL ADVISORY GROUP AIR NAVIGATION SERVICES

THE HUMAN IN THE LOOP ?

World Air Traffic Control Aspects

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by

Frank W Fischer

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ANSA
Legal Seat and Main Office
Bürenstraße 23, CH 3312 Fraubrunnen, Switzerland
Tel + 41 - 31 - 767 - 8235 / Fax + 41- 31 - 767 - 9285
President Frank W Fischer / Executive Secretary Bernhard Rüthy

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Air Traffic Control; Do We Really Need It ?

International air transport has become a reality to most people in the world. It is a matter of private or official profit business and consists of three quasi separate professional environments, the Airport World, the Airspace User World, and the Air Navigation Services World. All three are often referred to as Civil Aviation, and only little is known among the industrial public on the air navigation services world and on Air Traffic Control, which forms part of it.

Besides all three of these worlds belonging to the international air transportation system, they practically perform their business in isolation, with air traffic control affecting both the airspace users and the airports as an intervening factor.

Use of the various air traffic control services by international agreement has become mandatory, wherever being provided; but do we really need it ?

With air traffic control´s main objective of separating flights from each other in avoiding collisions between them, it is a fact that one flight at a time does not require collision avoidance service, as well as two flights at a time over two widely separated geographical locations. However, the situation changes with many aircraft planning for flight at the same time from one and the same location to another common destination. The above consideration, however, has its philosophical consequences. It leads tax money spenders to the consideration of "when and in which situations will it become unavoidable to provide a mandatory separation service to airspace users?" and not "when will it become desirable?".

The implications of this type of thinking are facing us everywhere in civil aviation today; i.e. no air traffic control service being provided at all or in such humble way that it becomes meaningless. This situation, unfortunately, still prevails in too many geographical areas of the world.

2
The Invention of ATC

So the question arises "who invented air traffic control after all and for which purpose?"

With the past dominance of the USA in aviation, the answer is ready. It was the United States who introduced such a service in the 1930´s in order to regulate the growing number of flights in bad weather from and to common locations, with airline and airport companies involved in the provision of this private service. Reports say that it was Mr. Glen Gilbert and Mr. Earl Ward, who on December 1, 1935 established an all-airline "air traffic control centre" as a private enterprise in the Newark airport terminal building. This centre, first of three like it, established a precedent that control of air traffic on the routes leading into congested terminal airspace best resided with an agency on the ground and not with competing pilots.

3
The Foundation of ICAO

At the Versailles peace conference in 1919, an International Commission for Air Navigation (ICAN) was set-up and out of the conference was created the following rule: "Every aircraft in cloud, fog, mist or other condition of bad visibility shall proceed with caution, having a careful regard for the existing circumstance". This rule says it all and nothing at the same time. And one must stand back in awe and marvel at such rule revelling in its glitter emptiness, because it ignored the realities of flying an airplane in cloud and relied on the fact that few airplanes were aloft at any given moment. But it does not read too different from a similar statement in the operations manual of a major airline of today, which reads "Flight crews are always expected to adhere to prescribed procedures, to act according to their best judgement, to apply good airmanship, and to give due consideration to all relevant factors. They shall aim for the highest personal skill, exercise great care and accuracy in all flying, and know their aircraft and procedures well". This says it all again and nothing can happen to us airline passengers anymore. It sounds fortunate that governments took over to provide air traffic control services to all flights, but unfortunately quite a number of aviation authorities still seem to apply the 1919 ICAN rule only.

Resulting from experience in the mass movement of aircraft during World War II, a large number of nations of the world in 1944 established the International Civil Aviation Organisation (ICAO) to serve as the medium through which the necessary international understanding and agreement can be reached. ICAO`s membership now comprises 185 sovereign states. In 1947 it became a specialised agency with the United Nations.

One of ICAO´s chief activities is the establishment of international standards, recommended practices and procedures covering the technical fields of aviation, such as rules of the air and air traffic services. Annex 11 to the Convention of ICAO contains the standards and recommended practices on the provision of the air traffic services, including the air traffic **control** service in ICAO Memberstates.

4
Air Traffic Control, A Service That One Cannot Reject

Present civil aviation opinion considers it generally the pilot´s right to accept or reject the use of a specific air traffic **service**, leaving the ultimate authority as to the disposition of an aircraft under his command. International standards to this extent are laid down in Annexes 2 (Rules of the Air) and 6 (Operation of Aircraft) of ICAO.

This opinion, however, is only partly true, since the pilot is forced to accept air traffic **control** ´service´ at all times under specific conditions, such as during instrument meteorological conditions or for the commercial transport of passengers and freight on scheduled flights and while operating in controlled airspace. This rule makes the acceptance of air traffic **control** service mandatory, and the pilot´s adherence to air traffic control clearances and instructions become a must in order not to endanger his and other flights. Corresponding international standards are contained in Annex 11 (Air Traffic Services) of ICAO. Apparently, the two standards are contradictory. The cause for this situation is the aviation law, which boroughed the corresponding rule from maritime regulations with the captain of a vessel having the same authority and rights. At the time of the adoption of the standards as contained in Annexes 2 and 6 it apparently was not realised that air traffic once would become so dense that no exception from control could be tolerated. Also, maritime regulations are based on the fact that a vessel traffic control system does not exist, in contrary to the air traffic environment. The consequences of this public consideration is that some governmental authorities therefore often consider the performance of air traffic control services by their personnel as less important or valuable as compared to pilot duties.

It must therefore be realised that except the pilot´s ultimate decision as to the disposition of his aircraft in an emergency situation, the right to reject an air traffic control service does not exist.

"Controllers provide a service only. They pass to pilots weather and traffic information only. They do not exercise control in the form of commands over pilots!" This opinion is often heard and often enough results in ridiculously low salaries to air traffic controllers, such as for instance 100 US $ monthly or for better comparison, in a twentieth of a pilot´s salary in the same country.
Definitions

The standards and recommended practices in Annex 11, together with the standards in Annex 2 (Rules of the Air) govern the application of the "Procedures for Air Navigation Services - Rules of the Air and Air Traffic Services" as contained in ICAO Document 4444, the ATC bible.

Annex 11 (Air Traffic Services) pertains to the establishment of airspace, units and services necessary to promote a safe, orderly and expeditious flow of air traffic. A clear distinction is made between air traffic control service, flight information service and alerting service. Its purpose, together with Annex 2, is to ensure that flying on international air routes is carried out under uniform conditions designed to improve the safety and efficiency of air operations.

These standards in Annex 11 apply in those parts of the airspace under the jurisdiction of a contracting state wherein air traffic services are provided and also wherever a contracting state accepts the responsibility of providing air traffic services over the High Seas or in airspace of undetermined sovereignty, such as for instance the Nauru flight information region in the South Pacific.

What is "Air Traffic **Control** Service?"
It is a service provided for the purpose of 1) preventing collisions a) between aircraft, and b) on the manouvring area of aerodromes between aircraft and obstructions, and 2) expediting and maintaining an orderly flow of air traffic. Air traffic service, incorporating air traffic control service, means variously flight information service, alerting service, air traffic advisory service, air traffic control service, area control service, approach control service or aerodrome control service.

Another basic rule to remember is that the issuance of ATC clearances to pilots constitutes authority for an aircraft to proceed only in so far as "known" air traffic is concerned. Also, clearances issued by controllers relate to traffic and aerodrome conditions only and do not relieve a pilot of any responsibility whatsoever in connection with a possible violation of applicable rules and regulations.

States determine, in accordance with the provisions of Annex 11 and for the territories over which they have jurisdiction, those portions of the airspace and those aerodromes where air traffic services will be provided. Thereafter, they establish and supervise such services.

The need for the provision of air traffic services is being determined by consideration of the types of air traffic involved, the density of air traffic, the meteorological conditions (see for instance Iceland) and other relevant factors.

The decision on the implementation of air traffic **control** service is governed by a number of different elements, such as the mixture of different types of air traffic with aircraft of varying speeds (propeller, jet, etc.) necessitating the provision of air traffic services whereas a relatively greater density of traffic where only one type of operation is involved, would not. On the other hand, open stretches of water, mountainous, uninhabited or desert areas might necessitate the provision of such services even though the amount or frequency of operations is extremely light.

ICAO standards foresee that air traffic control service be provided to all flights under instrument flight rules (all commercial scheduled transport of passenger and freight) in controlled airspace. There are many cases in which this standard is being violated.

As regards the operation of the air traffic control service the international standard foresees that ATC units in providing this service shall be provided with information on the intended movement of each aircraft, or variations therefrom, and with current information on the actual progress of each flight. These units shall then determine, from the information received, the relative positions of "known" aircraft to each other, issue clearances, instructions and information for the purpose of preventing collision between aircraft under their control and of expediting and maintaining an orderly flow of traffic. They shall coordinate clearances as necessary with other neighbouring units, whenever a flight might otherwise conflict with traffic operated under the control of such other units, and before transferring control over a flight to such other units. Also, the responsibility for the control of an aircraft shall not be transferred from one ATC unit to another without the consent of the receiving unit. For a significant number of ATC units in the world this constitutes an ideal, which cannot be realised due to lack of ground/ground and air/ground communication aids.

The list of inefficiencies and shortcomings, especially as regards communication aids for large areas in South East Asia, the Pacific, Africa, South and Central America, in Asia Minor and the Mediterranean was long. It has lately been extended in also covering large areas of Eastern Europe and parts of the Former Soviet Union. For the status of present day state-of-the-art in radio communication technology, the list is too long. There are too many cases where ATC units cannot communicate with each other directly or only with great delay and where ATC units cannot communicate directly and instantaneously with aircraft in flight. The reasons are not technical, they are financial and infrastructural. It is for these reasons that in too many geographical areas States have not implemented air traffic control services for the control of flights under instrument flight rules in controlled airspace or have not established controlled airspace for the same reason. This situation, however, does not prevent the airlines from flying in these areas, day in, day out, without the protection of ATC´s separation assurance.

It therefore is a known fact that for these and additional reasons many flights do not become known to ATC units in either national or international airspace before and while entering their airspace of jurisdiction. And these flights most of the time are civilian airliners and not, as in the Namibia accident, two military airplanes. Mostly, these "uncoordinated entries" are caused by the lack of functioning communication equipment.

Consequently, conflicts between flights either do not become known or cannot be resolved, with so-called near or real mid-air collisions developing. The danger is imminent and great, despite the still low number of real mid-air collisions, which have happened due to this situation. Some major accidents have been caused b y this inefficiency in voice communications between controllers and between controllers and pilots in the past, or was a contributing factor to those accidents.

The number of incidents, i.e. near mid-air collisions resulting from conflicts based on operational errors or system shortcomings, which go unreported or unnoticed is much higher. The author of this paper estimates this number with civil and military flights under ATC world-wide to be in the order of 3000 annually. A totally different picture on the given safety record would evolve, if safety planners would count near collisions as real hits, because it was not them or their system, which avoided the real collisions.

As a consequence of this situation and being forced to do something despite its contradiction with Annex 11 standards, ICAO, IATA and some national aviation authorities have implemented TIBA, a "traffic information broadcast by aircraft" procedure for application in vast areas where lack of money, of communication equipment and of properly trained and proficient controllers prevent the provision of air traffic control service.

In such areas only flight information services (FIS) or air traffic advisory service (ATAS) are being provided or should be provided as an inefficient substitute to air traffic control service, with both these services constituting only very limited means of collision avoidance. Commercial scheduled flights by ICAO rules should be banned from such areas.

The application of the TIBA procedure is voluntary. In using it, pilots transmit into the blind their position, altitude, speed, course and intentions in hoping that other possibly conflicting aircraft listen to this blind transmission, plan, react and report accordingly. TIBA, FIS and ATAS must therefore be considered totally unacceptable in guaranteeing the desired level of flight safety as regards the possible encounter of aircraft in flight, taking present day speeds and conflicting air routes and flight altitudes into account.

As an escape out of this dilemma, which exists in too many parts of the world, the airspace users are seeking for other ground-service independent solutions, such as airborne collision avoidance systems or cockpit based traffic situation displays for the pilots to make their own avoidance decisions. Both possibilities lack sufficient safety potential, with the latter resulting in a snowball effect in high traffic density areas. The greatest collision risk, however, exists in high traffic areas.

5
Territorial Application of the Rules of the Air

The rules of the air apply to aircraft bearing the nationality and registration marks of an ICAO Contracting State, wherever they may be, to the extent that they do not conflict with the rules published by the State having jurisdiction over the territory overflown. Over the High Seas, therefore, these rules apply without exception. If, and so long as, a Contracting State has not notified ICAO to the contrary, it shall be deemed, as regards aircraft of its registration, to have agreed as follows: "For the purposes of flight over those parts of the High Seas, where a Contracting State has accepted, pursuant to a regional air navigation agreement, the responsibility of providing air traffic services, the appropriate ATS authority referred to is the relevant authority designated by the State responsible for providing those services".

But, what does it help that these rules apply, when the provisions for the air traffic services in many parts of Africa, over the Pacific and elsewhere are not or cannot be made. Rudimentary, part-piece and inefficient systems are not sufficient. If all international and national organisations would look after their ATC systems as they look after the airplane, its completeness, airworthiness, operational readiness, etc., then a new safety prone era in ATC and air transportation in general would begin.

The airplane is being looked after, because it normally is being operated by and in private or quasi-private business environments, whereas governmental authorities all too often insist on their right to either neglect their own good rules or not to apply them at all for various short-sighted reasons. Naturally, in this respect there is a lot of difference between governments the world over, some to the good, others to the bad.

Also, these rules say that before beginning a flight, the pilot in command of an aircraft shall familiarise himself with all available information appropriate to the intended operation. But all too often, all appropriate information is not even available. It was for this reason that years ago the Algerian State delegates lost their lives when they were shot down on their flight to Iran. The notice to airmen (NOTAM) on the prohibited area, which they entered, had not been available to them.

The rules for pilots also say that an aircraft shall not be operated in such proximity to other aircraft as to create a collision hazard. That sounds fine, but it is not the pilot´s fault that inefficient ATC systems bring them in such close proximity, often without the possibility of becoming aware of it due to flight in clouds or for other reasons.

The present set of rules for the operation of aircraft and the provision of air traffic control services do not leave much room for the escape of conflict situations. In order to change this situation, we either must fulfil all the rules in an utmost manner without exceptions with all of us fulfilling all the agreed standards and recommended practices, or stop flying.

Because it cannot be accepted by the flying public that for reasons of cost/benefit equations one shall accept a certain level of reasonable risk in air transportation as in all other transportation modes, if this risk is caused by known deficiencies of negligent character. As negligent character one must consider the lack of air/ground radios and ground/ground voice telephone switching systems, radio navigational aids, properly trained and treated proficient ATC staff, and so forth, because all of these can be bought off-the-shelf on the market, except for the controllers. But if somebody illegally fires 11.800 controllers over night and at once, like the former US president Reagan, then there must be many more available on his market to replace them. It seems unbelievable, but is true that in the provision of air traffic control services to airspace users, governmental authorities act in a way, which every sound judge would call negligent. This ignorant behaviour can be compared with driving a train without brakes, because the tracks are long enough for it to roll out. Should, however, another train appear opposite on the same tracks by human error, then this would constitute an acceptable risk.

6
Collision Risk

To realistically portray how serious the situation is, one must take into consideration the "near collision" statistics. When a "near collision" incident report is filed, it reflects a virtual collision and that the ATC system has failed in some way.

Taking the USA as an example of a highly developed aviation environment, the Federal Aviation Administration back in 1968 had received and analysed 2.230 near mid-air collision reports by pilots. 1.128 of these reports were classified as hazardous to flight, with 719 occurring in the terminal airspace around airports. 621 of these occurred within a 30 mile radius of airports with control towers and 98 occurred in the vicinity of airports without control towers. The situation in all of the western European countries was not very different, comparing the geographical sizes.

These figures prove that none of these nations´ ATC systems was prepared to cope with the real demand of air traffic at that time. Up to 1972, 19 nations have had at least one mid-air collision resulting in a total of 1.209 fatalities. The average predicted number of mid-air collisions is closely related to the average predicted amount of traffic at any one airport and in any one portion of the airspace. It is only a few aviation authorities, such as the US FAA, the UK NATS and formerly the German ATC organisation, who publish, respectively did publish the reported numbers of near-misses, which fortunately have decreased considerably in number over the recent years, especially in Western Europe.

West Germany for instance, with traffic densities higher than the Chicago control area, in 1985 reported "only" 48 such cases, compared to a record 483 15 years earlier. The numbers for the USA however were 311 in 1982, 475 in 1983, 589 in 1984 and 777 in 1985, and at least 812 in 1986. The increase in these numbers in the formerly "number one aviation country" are more than alarming. They give rise to the assumption that something basic is wrong with the ATC system in the USA. It can only be estimated how alarmingly high similar figures are for other countries in the underdeveloped aviation world, who are not used to publish such results.

Apart from technical deficiencies, collision risk is greatly influenced by pilot and controller alertness. In today´s advanced ATC systems, wherever they are available, most of the mistakes by pilots, which could result in mid-air collisions could be detected by controllers in their consequences, provided digital radar presentation with SSR modes A (identification) and C (altitude) information being available.

In situations of instrument weather conditions, i.e. flight in clouds and under reduced visibility, pilots are helpless in any unknown conflict situation, because they can´t see. Even if they learn by radio from another pilot or controller that such conflict exists, they must rely on the controllers action, because they do not know of all the other traffic around them, which might also constitute a conflict, once they initiate avoiding action on their own.

This situation basically does not change even by the use of modern threat collision avoidance systems (TCAS) onboard of airliners, because not all aircraft are fitted with them, yet.

In situations of visual weather conditions pilots are by ICAO rule responsible to look out for any conflicting traffic for the avoidance of collision (see and avoid) even on instrument flight rules flight plans under the control of ATC. This "look out" apparently was not practised by both air crews involved in the "Zagreb" collision, where two airliners were on collision courses above clouds in clear air.

Due to the high closure rates involved with today´s speeds it cannot be a matter of philosophy in the future to consider the avoidance of collisions possible by pilot´s alertness. Only positive control of all aircraft in a given block of airspace with ATC ground stations separating all aircraft in that given block of airspace can be the solution; because conflicting aircraft can approach from behind and below, from behind and above, climbing from the left, descending from the right, faster than the own aircraft, and so on. It still remains to be explained, how one could ever expect an aircrew on a 10 hour flight to continuously look out for traffic. The grade of vigilance required to do so would cause a nervous breakdown after only a few hours during such a long flight. So pilots may look-out, but they don´t search.

The deletion of this rule for flight in controlled airspace is long overdue, as is the implementation of the rule to conduct flights for the commercial transport of passengers and freight in controlled airspace only.

If one takes a look onto the air navigation charts of Africa, one will find uncontrolled airspace almost exclusively, because all the basic technical tools to provide ATC service in the African countries are not available. And even if controlled airspace is shown, air traffic control service most of the time is not provided for a variety of reasons. The International Air Transport Association (IATA) has therefore suggested and ICAO has consequently accepted to recommend the application of a substitute collision avoidance risk reduction procedure, called TIBA. It cannot be difficult even for a layman to conclude what practical use this voluntary procedure can have.

7
What Can Go Wrong ?

Almost anything can go wrong in the ATC system, like in any other system. Unfortunately, it, however, will fail or go wrong at times, when we do not want it or are not prepared for it to go wrong. "Murphy´s Law", that everything, which could go wrong, will go wrong, but at one time, has been proven all too often in ATC.

Despite lack of technical equipment, such as radios and telephone systems, most discrepancies, irregularities and failures, which result in incidents and accidents, are to be found in the following areas:

- wrong items, in flight plans go unnoticed by aeronautical information service personnel and are transmitted to ATC personnel, who do not re-check or cannot re-check on such items, resulting in mistakes in radio call signs, times, speeds, route data, aerodrome location indicators, addresses and remarks
- notices to airman are not being forwarded or are not being read by controllers or pilots
- wrong SSR codes are being assigned to controlled flights by mistake
- flights are being assigned wrong altitudes, which go unnoticed during "omit position report" procedures
- wrong radio telephony frequencies are being assigned to pilots by mistake under stress conditions
- re-routings and diversions are forgotten in required coordination with adjacent control sectors and ATC units

- departure times are not being relayed or are forwarded too late
- aerodrome controllers do not visually check on the execution of their instructions and clearances by aircraft under their control
- controllers do not actively listen to the contents of pilot reports by radio, but believe, what they want (expect) to hear
- controllers do not actively check on what they transmit to pilots by radio with the contents of the message transmitted being contrary to their intention, e.g. "climb to flight level *two* nine zero" versus the transmission "climb to flight level *three* nine zero".
- hardware and software component restrictions are not being considered or observed in their full operational consequence
- coordination is performed in the mother language by telephone instead of in English as required or one of the other official international aviation languages (Spanish, French and Russian)
- co-ordination is not performed by intercom or telephone channels, precluding voice recording for legal purposes and later investigation
- more traffic is being accepted than the system is designed for, hoping that everything will operate normal, weather will be good, equipment will not fail,, enough personnel will be available and will be proficient enough to handle the traffic, and so on
- management does not stay abreast with required operational knowledge and makes wrong decisions, which go unnoticed because of lack of coordination with operations personnel

This list and the number of resulting reported accidents is long. The number of resulting incidents stemming from operational errors, however, is considerably higher, the world over. Remember that in the USA, for instance, back in 1969 there were 1.444 reported near mid-air collisions, 966 of which were classified as hazardous by the US National Transportation Safety Board (NTSB). In 1970 the number was 1.456 and then declined. Ten years ago the number reached almost 1000 annually again. Similar numbers existed and still exist for other high activity environments. Exact figures are not available, because everyone, civil or military, must have an interest to hide them and a great majority of incidents remain unreported by either controllers or pilots, because they either go unnoticed or are being kept secret to avoid disciplinary action by the employer. Incidents in fact are all infringements of standard separation between controlled flights.

What can be done about it ?
With the one or other exception like the USA or Canada, and generally speaking, an ATC incident reporting system is missing. If such an obligatory system would be introduced on an ICAO world-wide basis, holding the reporter harmless, a large number of cases could be investigated and their causes found. But, most of the aviation administrations and organisations seem to be not interested, because such causes would force changes to be made to present systems and governmental attitudes, resulting in more spending on personnel, hardware and software, as well as changes in rules, resulting in infringements of political, professional and operational interests of various groups of airspace users and others involved.

A solution to the problem could be to make it a contracting rule for ICAO Memberstates to only provide air traffic control services over their territory by ICAO personnel following the same set of rules, this personnel having UN status and being trained and paid by ICAO exclusively, with one operational language to be used, namely English.

General shortcomings and inadequacies in the air navigation systems relate to hardware, software and liveware. Most of the shortcomings again relate to operational matters, such as system rules and regulations, operations procedures and the like. Proper maintenance of equipment comes next, with many organisations not being able to train their technicians properly and to employ them permanently under required conditions, which allow proper remuneration and required refresher training. The same applies to the ATC personnel.

In this connection it is a sad fact that in some parts of the world some controllers earn as much money in a month than others get in a day, if not hour.

A good number of factors contributing to those incidents and accidents could be summarised under the following causes. These are

- speed as closure rate
- aircraft attitude
- limited visibility out of cockpits
- lack of proper look-out by pilots in VMC
- wrong instructions by controllers
- pilot non-adherence to ATC clearances and instructions
- wrong navigation
- lack of communication aids
- mis-understandings between pilots and controllers due to language problems
- lack of information as required by controllers
- lack of information as required by controllers
- lack of information as required by pilots
- traffic overload on controllers
- system breakdowns in the order of minutes and hours
- ATC equipment malfunctions
- inadequate rules, regulations and procedures
- improper training and proficiency of controllers

8
The Requirement To Communicate

Radiotelephony (voice) communication as a means to coordinate pilot intentions as to the planned progress of their flight including subsequent changes, caused by predicted or unpredicted influences, such as weather, technical malfunctions or other operational necessities, with the air traffic controller´s requirements and plans to disturb the planned progress of flights for the assurance of standard separation between them constitutes a basic requirement.

Since speeds and corresponding closure rates are so high that one can no longer rely on the pilot´s capability of visual collision avoidance, besides flight in clouds, there is a need for one central point of coordination of the above mentioned intentions. Since aircraft are made to move, this point must be on the ground. It is the ATC units with an individual controller per defined airspace sector as a focal point of coordination, which fulfil this function.

Communications between controllers and controllers and between controllers and pilots must be instantaneous, since flying speeds are high and the detection of conflict situations, conclusions for solution and avoidance commands and evasive action are often to be performed within seconds.

This clear requirement, however, is being impaired by the fact that not all controllers and not all pilots speak the same language. In order to minimise this problem, ICAO has decided on the four international aviation languages, English, French, Spanish and Russian. In most part of the world, English is being used as the primary language in radiotelephony communication between pilots and controllers. That not all problems are herewith solved, becomes clear from the following information circular issued by the Civil Aviation Directorate of Tanzania.

"The investigation of a recent aviation incident and tape transcripts of radiotelephony recordings have revealed a disturbing shortcoming on the part of both controllers and pilots in the use of radiotelephony phraseology and procedures. The objective of good RTF technique and discipline is to enhance the general level of operational safety in the air and on the ground. Therefore, constant attention needs to be paid to the correct and concise phraseologies and to the procedures concerning the use of RTF. Recently noted examples of poor RTF phraseology and discipline included clipped transmission, non-standard phrases, provocative statements and arguments, use of non-aviation language, etc. It should be realised that such laxity works against operational safety and clearly, it is in everyone´s interest that all user are aware of the need for the correct use of standard RTF phraseologies and procedures. The Directorate anticipates the cooperation of all users in this respect to enhance aviation safety in the Tanzania airspace". One can only hope that pilots and controllers in other parts of the aviation world also hear the message.

Why is instantaneous ground/ground communication by telephone between ATC units required?

In fulfilling their various tasks on coordinating the actual and intended movement of flights between them, ATC units are required to exchange the following messages relating to the control over these flights:

ATC clearance requests
ATC clearances and instructions
flight plans and changes thereto
time estimates for reporting point station passage and revisions thereto
changes in flight altitudes, speeds, times and courses
delays and holding manouvres enroute
diversions to alternate aerodromes
departure times and take-off delays
notices to airmen
significant weather information
arrival times and delays
releases (authorisation) for departures
expedite clearances
flight cancellations
traffic flow control measures
traffic information
position reports
alert, urgency and distress messages
hijack messages
changes in the operational modes of their systems and equipment
approach and landing sequences
expected approach times
pilot requests
take-off and departure sequences
and the like

It would help controllers a lot, if such messages, which have to be relayed from man to man, from sector to sector, from system to system, from country to country, could be entered only once with the ground/ground data communication system forwarding these messages to the individual concerned recipients automatically and only at the time when needed.

In the ICAO Europe region the member states of EUROCONTROL, the European Organisation for the Safety of Air Navigation, are fortunate of having taken the first and second steps towards this goal with the online data interchange (OLDI) and the ATC radar tracker and server (ARTAS) functions. In many other parts of the aviation world, revisions on current flight plans of aircraft in flight, flight progress data, such as estimates, altitudes, speeds, routes, etc. have still to be coordinated from person to person for most of their ATC systems. This process is very time consuming and error prone. It is the source of very many malfunctions of the ATC systems, because data are either incorrectly forwarded, received, understood or plainly forgotten.

As has been realised in North America and in Europe, this risk can be reduced and the speed of the system internal coordination loop be increased to match present day aircraft speeds. If the speed of voice and data communication subsystems is not drastically increased, active flow control will never become possible.

Against this problem background one must consider the speed of the world wide aeronautical fixed telecommunication network (AFTN), probably the largest telecommunication network in the world. Its speed is 50 bps only, where it exists and functions. Even this basic communication system does not exist everywhere and is far from functioning properly everywhere.

What is required ?
For ground/ground communication all ATC units will have to be equipped with voice telephone systems, allowing them to communicate instantaneously with all their adjacent ATC units, in using either discrete direct landline or public telephone systems, and where necessary, in making use of satellite voice communication systems. In most parts of the world we are still far away from reaching this goal.

For air/ground communication all ATC units will have to be equipped with voice radio systems, allowing them to communicate instantaneously with all aircraft within their assigned airspace of responsibility, in using direct line of sight and/or remote HF, VHF and UHF radios, or where necessary also satellite radio relay stations. This might sound self-explanatory, but go to Africa or Siberia and look at the situation there.

Another most serious deficiency is the lack of an aircraft radio override channel allowing ATC ground stations to reach all aircraft within radio coverage. Such a radiotelephony override capability is required to enable controllers to reach pilots in conflict situations, when these are momentarily or erroneously have switched to another frequency channel than that of the ATC unit having control over such flight.

9
Separation Assurance

All aircraft constitute objects, be they civil or military, light or heavy. All of them constitute a collision risk to one another, if their speed is high enough to cause damage upon impact. Collision risk calculations and past mid-air collisions have proven without doubt that the risk is high, provided aircraft are flown unregulated within small portions of the airspace, such as along one and the same enroute track or in final approach areas onto one and the same airport. Any other statistical calculation in trying to prove that there is reasonable chance not to be involved in one of these collisions must be insane, if performed solely for the purpose of not having to change the present situation.

The reasonable approach to the collision risk problem must be to eliminate inadequacies in the ATC systems, which are not only caused by the lack of money, but often by the unwillingness to change existing rules, procedures and personal attitudes. It cannot be stressed enough that all the necessary equipment for the efficient provision of ATC services is available on the international market. Should money not be available for the purchase of required equipment and for the recruitment and training of controllers, then existing flight rules should be made more restrictive, because it is better to be late than dead.

Air traffic control systems in providing air traffic control service without the use of radar are often classified as "conventional" or "procedural", since all control is based on available information as received by reports from pilots on the basis of the teletype flight plan and via radio.

Applying conventional control methods and corresponding procedures stands for the application of procedural separation minima, which differ according to the navigational aids and avionics systems available on the ground and in the aircraft, leaving navigational responsibility completely with the pilot.

However, exercising **radar control** stands for the application of radar separation minima, cutting distances between flights often by a factor of ten. Except for radar vectoring, navigational responsibility still rests with the pilot, but the progress of flights is continuously and actively being monitored by controllers in respect to vertical (SSR Mode C), longitudinal and lateral deviations from cleared tracks.

The implementation of radar control was a very effective tool in the determination of navigational deviations off cleared tracks and in assisting pilots in navigation, but it resulted in the controllers being tasked with monitoring and "steering" everybody under very reduced separation minima, increasing the collision risk and cutting their time budget to sometimes "nil" and making them the focal point of the whole ATC system with the pilots in a subordinate role.

Unfortunately, there is a good number of ATC facilities in the world, where controllers refuse to exercise active radar control, because of the workload and responsibility involved. Mostly, these facilities only passively monitor the progress of flights by radar, avoiding to apply the small radar separation minima between flights. The Former Soviet Union ATC facilities know this form of operation as the standard.

It is a controversial point for discussion, if radar really will remain to be the great help in enroute navigation for ATC. Undoubtedly, radar will remain to be the primary tool in ATC for departure and arrival control in terminal areas around airports, where vectoring is a necessity in order to be able to build up the queues for final approach and to check on distances to thresholds for departure sequencing.

From the safety point of view, it was and still is dangerous to vest all separation critical activities in one person, the controller, with distances between aircraft being critically small compared to their speeds and closure rates, and with the limited time budget available for counter-action by controllers in cases of conflict or unforseeable deviations from cleared tracks and altitudes. For it must be impossible for any human being to always maintain optimum vigilance and attention, also for radar controllers, who very often are pushed by their administrations to always aim at the minimum of prescribed separation and not at their optimum, unless the declared minimum constitutes already the optimum. For the same reason, some administrations are now applying only 2,5 nautical miles of separation between arrivals on final approach in order to increase the runway capacity.

Determination of radar separation minima is different from state to state and from system to system, based on the various equipment used, target symbol positioning accuracy, analogue or digital presentation methods applied, plot extraction or tracking application and general collision risk prediction calculations.

Most of these calculations, however, are based on ICAO recommended separation minima with analogue radar application, i.e. 3 nm within 30 nm of the antenna and 5 nm beyond 30 nm of the antenna, measured from centre to centre of targets for primary radar and measured from edge to edge for solo SSR targets.

Problems arise during situations of handover of flights from one system to another, while transfer of control takes place, with the aircraft leaving radar coverage of the one radar system and coming under the coverage of the next.

Among the countries, who not uniformly apply 3, respectively 5 nm separation are Australia with SSR separation minima of 6,5 nm up to 50 nm distance from the antenna, 7,5 nm up to 100 nm and 9,0 nm up to 300 nm; Canada, applying 10 nm for primary radar and SSR; Denmark, applying 7 nm up to 100 nm and 10 nm beyond 100 nm; and the former West Germany having applied 4, 6, 8 and 10 nm formerly, again depending on the distance of the aircraft from the antenna. The European ARTAS should soon have solved this situation for all of the Eurocontrol, if not also later on for the whole ECAC area.

There are many more different cases, but these examples already show that ATC to ATC system interfaces (host to host computer) are required in order to be able to eliminate such separation minima differences in the various geographical "transfer of control" areas.

What is required ?
Where the traffic volume demands, at least secondary surveillance radar (SSR) should be available to ATC units, because it fulfils the basic operational requirement and is cheaper than primary radar. In high traffic density areas conflict prediction functions based on automated data processing should be used in applying automatic flight plan track updating by radar track data, besides the presentation of radar conflict alerts on the controller´s radar display.

Such functions should be assisted by monopulse SSR Mode S (select) installations in order to make radar data more accurate and to allow the use of SSR supported collision avoidance systems (TCAS = threat alert and collision avoidance systems and AIRCAS = air derived SSR collision avoidance systems), which has meanwhile become mandatory in the USA and will be in the area of the European Civil Aviation Conference (ECAC) member states.

10
Navigational Accuracy

The need to navigate accurately is great and independence from ground source radio navigational aids during enroute phases of flights is desirable in order to be free from ground navaid services and possible outages.

The performance of ground navaid services is influenced by all kinds of problems, such as lack of money, spare parts, personnel, proficiency, etc. ATC today still relies mainly on non-directional radio beacons (NDB), VHF omni-directional radio ranges (VOR), distance measuring equipment (DME), instrument landing systems (ILS) and aircraft based self-contained inertial navigation systems (INS) for trans-oceanic navigation as far as navigational accuracy has an effect on separation minima. Other navigation systems, such as previously and widely used VLF, Omega, Loran, Doppler or airborne radar only complement an aircraft´s navigational capability as regards ATC. The almost endlessly debated use of the US Global Positioning System (GPS / Navstar) and the Russian counterpart GLONASS are supposed to become the primary source of instrument navigation in the future.

Airspace sector delineation, air route layout and lateral separation for parallel routes are however only based on the navigational inaccuracies of NDB and VOR, with NDB navigation calculated to be accurate within +- 8 degrees and VOR with +- 5 degrees. DME accuracy is calculated to within +-3 % or +- 0,5 nm and the ILS glide slope to 0,1 degree and its localiser to 0,5 degree. In following minimum operational performance and navigation specifications (MOPS and MNPS) of RTCA, ARINC and EUROCAE, aircraft based inertial navigation systems have achieved much better results for enroute navigation. Area Navigation (RNAV) field trials with INS, updated by VOR/DME signals have not revealed deviations of more than 1 nm over courses of 400 km. These systems in cooperation with flight management systems (FMS) achieve an accuracy in calculation of +- 0,2 % for route, +- 0,2 % for time, +- 0,5 knot or +- 0,001 Mach for speed. On this basis ICAO has established required navigational performance values (RNP) for application in ATC. Two classes have recently been implemented in the Eurocontrol area, Basic-RNAV, accurate to navigate within 5 nm and Precision-RNAV accurate to navigate within 1 nm.

This navigational accuracy is not only required in terminal area operations (P-RNAV), but also on long range flights over vast areas with only a few or no ground navigation aids available along the route (B-RNAV).

Still controversial, the satellite based US GPS offers a much better accuracy, down to 100 m for civilian users, than ground or aircraft based systems. It also supports the reduction of standard vertical separation of 200 feet above flight level 290 to 1000 feet (RVSM) and thereby making additional urgently needed flight levels available to IFR flights in the upper airspace.

INMARSAT´s aviation industry satellite system AvSat adds to this navigational accuracy potential the possibilities of relaying precise aircraft positions to ATC via data link under "automatic dependent surveillance". Such vastly improved surveillance would also allow to reduce present lateral separation between over-water tracks (e.g. North Atlantic Tracks), which presently is 65 nm.

But, besides better navigation the ATC systems require better communication. It is of utmost importance to stress this point that all pilot and controller intentions on the basis of readily available accurate position information must be coordinated instantaneously the closer airplanes navigate to each other.

11
Re-Assuring Statistics ?

In December 1986, ICAO reported the total scheduled traffic of the world´s airlines to be 5 % above the 1985 traffic figures with total international and domestic traffic performed by the airlines of its then 156 member states on scheduled services estimated at some 176 000 million tonne-kilometres. These airlines then carried 938 million passengers, also some 5 % more than in 1985, and performed 1 429 000 million passenger - kilometres. About ten years later these figures have significantly increased.

In calculating the meeting of the desired level of air safety, ICAO and other organisations compare these beloved passenger kilometres with the number of accidents having occurred within the same period of time. For 1986, the number of accidents in civil aviation was reported to be 38. The result might look good by the low figure of accidents against passenger kilometres performed, but it is misleading as far as the separation assurance by ATC systems is concerned.

This counting of the number of passengers against kilometres of distance flown might be a very useful tool for commercial calculations of airlines and insurance companies. It surely is not so for the calculation of set safety margins as the desired separation assurance by ATC. Since these factors, which negatively influence the reaching of the desired level of separation assurance by ATC are known and can be corrected by spending the necessary money, by changing existing rules or by imposing restrictions to airspace users, the number of "system failures" should be counted against the number of flights conducted under the control of ATC.

It is obvious from these figures that for such calculations not the overall civil aviation activity must be looked at, but the traffic control system only, especially when one accepts that the prevailing situation is caused by lack of managerial capabilities only, for it is a known fact that all required resources are available.

12
Civil versus Military Interests

The public´s opinion that civil aircraft are always controlled by civilian ATC units and that military flights are always controlled by military ATC units is widespread, but wrong. One should realise that there are actually only two different systems, one being the air defence systems in providing air surveillance services and the other being the air navigation services systems in providing air traffic services. As regards air traffic, the first normally brings airplanes together and the latter tries to keep them apart. Also, there are civil and military traffic control systems, but all handle military traffic.

The air defence systems are often referred to as command & control systems, whereas the ATC systems are considered to be information and advice systems. This is only partly true, because the ATC systems constitute more of a command & control than an information & advice system.

As regards the coordination of civil and military flights under their control within international airspace, the adherence to ICAO rules becomes more difficult, since military flights through such airspace over the High Seas too often do not submit flight plans to the responsible ATC units in order to make their conduct unknown. This results in conflict situations between known civil flights and unknown military flights. It remains questionable, if the intent of military organisations to fly "between the rules" is acceptable or not. It is a well-known fact that quite a number of military flights in the past have been conducted not along, but off published air routes in international airspace, along the delineation of flight information region (FIR) boundaries and over geographical FIR corner position coordinate points in avoiding to come under the responsibility of either one of the ATC units left and right of these boundary lines.

Such a procedure was applied when soviet military transport aircraft flew out of Yugoslav airspace into international airspace over the Adriatic and Mediterranean Seas to Egypt during the war between Israel and Egypt. A dissimilar, but equally dangerous situation existed during the war between Greece and Turkey in the international airspace of the Nicosia FIR. Civil airlines continued flying through the Nicosia FIR over the Eastern Mediterranean Sea without being ensured proper ATC from a kitchen desk in a private house. At the same time a significant number of military aircraft of the USAF operated out of Turkey within the same airspace at the same time, unknown to the civil flights and to the various civil ATC units claiming jurisdiction over this airspace at that time. The result was a high number of near mid-air collisions.

Such types of operations are however not limited to times of war. Also in peacetime military transport and reconnaissance missions of foreign nations are being conducted within national airspaces without the knowledge of the responsible ATC units having jurisdiction over this airspace. There seems to be no exception to this "rule". Fortunately, satellites however made flights of American U-2s over the former USSR and of Soviet Mig-21s over West Germany superfluous. Such operations were and are dangerous as the case of a near mid-air collision over Stuttgart between an SR-71 (under air defence control) and a Gulfstream-IV (under air traffic control), when these two airplanes came as close as 8 metres at flight level 600.

These rare examples make clear that it is often not only for technical reasons that certain portions of international and national airspace remain to be uncontrolled, such as in South and Central America, where significant numbers of reports are being received on near mid-air collisions between civil and military aircraft.

Time and again it is being mentioned as self-explanatory during conferences that national aviation authorities as well as pilots and controllers would not be willing to make more information known on this sensitive matter. One should not blame these people, because the involvement of politics in aviation always also results in the involvement of pressure upon individuals.

These and more possible examples of an improper provision of ATC service in providing an always safe flight to known aircraft under control prove that international airspace in reality can constitute a no-mans-land with everybody taking the liberty to by-pass an international rule, if deemed necessary in one´s own interest.

One, however, cannot expect ICAO to exercise the political power to change this situation, since ICAO is a non-political sub-organisation of the United Nations. It therefore can be the UN only to agree upon the application of and adherence to better rules in solving this problem. At the same time it must be considered unrealistic to consider this possible for the foreseeable future.

13
The Human Aspect

One of the major causes for the sometimes inefficient provision of ATC service, besides technical shortcomings, resulting in incidents and accidents, is the human´s unwillingness to always perform in an utmost manner in this profession in working by unwritten laws of behaviour, which call for the managers´ proper oversight and the controllers´ and his assistants´ permanent vigilance, alertness and never-ending willingness to check, re-check and check again on each and every possible source of error and to apply all standards and regulations on ATC at all times, during day and at night and often long overtime hours, all resulting in the real stress in this profession, with time budgets often limited to seconds only.

However, such an attitude, necessary in order to maintain the desired level of safety, can only be expected from people, who are being selected, trained, treated and paid properly. This, again, for many parts of the world is not the case. The air travelling public should realise that it does not help to solve these problems in shooting controllers to death like in Uganda or in presenting them to court in chains like in the USA following the well-known PATCO strike or putting them to jail for years, like in Yugoslavia.

The operational tasks of air traffic controllers, in brief, could be summarised as alert, inform,

advise, control = separate, as far as aircraft pilots are concerned, and as coordinate, assist, relay, simulate, train, supervise, monitor and broadcast as far as system internal operations are concerned.

The proper fulfilment of these tasks is dependent on the controller´s capacity, capability, training, proficiency, remuneration, stress load and motivation.

As regards job satisfaction and motivation, the proper fulfilment of his/her functions is influenced by achievement, work alignment, recognition, responsibility, control authority, utilisation of perceived skills, challenge, discretionary flexibility and interest. The man/machine interface is dependent on his/her vigilance, stress, intricacy, restrictiveness, rigidity and decision making.

What is required ?
It is urgently required almost all over the under-developed aviation world to upgrade the air traffic controller from being second class within the air transportation system, because their function is equally important for air/flight safety than that of the pilot. One could only hope that national governments will follow corresponding recommendations of the International Labour Office (ILO).

What will happen, if controller selection, training and treatment are not performed properly? A few cases might illustrate the consequences. There has been

- the controller, who ate the evidence of a conflict between two conflicting flights under his control by swallowing the flight progress strips

- the controller, who didn´t dare to inform two known flights in IMC on their dangerously conflicting flight paths, because they were flying in uncontrolled airspace

- the controller, who had two aircraft fly on exactly opposite courses at one and the same altitude on IFR flight plans within controlled airspace with a closure rate of almost 1000 knots, refusing to inform them or asking for evasive action

- the civil aviation director, who ordered controllers not to report on separation infringements in order to reduce the real number of near mid-air collision reports for better looking safety records

- the senior controller, who refused to afford priority to a medical evacuation aircraft carrying heavily injured victims from an earthquake, because "nothing was wrong with the aircraft"

- the radar controller, who continued to apply radar separation between flights without any radar picture available to him in "imagining where his flights were"

- another controller, who just left his working position during high traffic, when his radar display failed, because he was not trained and licensed for procedural control

- and the controller, who erased parts of a magnetic voice recording on a mid-air collision in order to save another controller, who contributed to the cause of the collision in ordering the trainee controller not to issue traffic information to both aircraft involved. As a result of this action the wrong civilian had to stand the wrong military investigation hearing, because three of the four pilots had died

This list could be written much longer. However, one should not forget that we are all human beings with all our weaknesses and that the list on ATC and airline managers and pilot´s behaviour could be as long.

What we therefore need is rule enforcement in ATC world-wide, allowing nobody involved in the ATC system to act against the rules in introducing procedures, which make any action known to other people involved by mandatory regulation. This procedure should not allow anybody involved in the system to act against the rules in isolation in implementing an obligatory "coordination before action" procedure. This must especially include supervisors and directors as managers in the ATC system. It must also include the mandatory manning of ATC centre sector working positions by at least two controllers at all times and the recording of radar display traffic situation presentations.

14
The Realisation of a Necessity

National aviation authorities due to the type of their organisation sometimes cannot or do not realise the real nature of the air traffic control services provided. With governmental civil service organisations employing civil servants or government officials and employees in ATC in a subordinate role within their hierarchical structures, they cannot appreciate the fact that these people come under no other command than their own during the exercise of their tasks and duties, whereas this rule of being free from superior interfering orders while on duty at an ATC working position is a necessity and must be maintained under all circumstances.

Since air traffic controllers in government service are therefore different in status from all other government personnel, their profession is often misjudged or underestimated with imminent consequences in the selection, training, treatment and remuneration.

Recognition and acceptance of necessities and requirements in and on ATC therefore often lack with ATC managers and directors, who have no practical experience in this profession.

15

ATC System Philosophy

ATC systems provide separation services under the following assumptions:

- the system consists of hardware, software and liveware
- the system provides services
- air traffic controllers are being responsible for the performance of operational functions relating to the provision of the various air traffic services to airspace users
- the system is a service system in providing information, advice, clearances and instructions
- safe and efficient operation of the system depends on the availability of equipment and information
- the system´s operation is based on the assumption that all information available is correct, and when detected to be incorrect, will be corrected immediately
- such information, required for the provision of air traffic services to flights in the three dimensional airspace environment will mainly constitute position, time, speed, altitude, intention, weather, topography, operational and technical status of available equipment, availability of portions of the airspace and of airports
- pilots remain responsible for the pilotage and disposition of their aircraft
- the need for the provision of air traffic control service is determined by consideration of the types of traffic involved, the density and mixture of this traffic, the weather conditions and other factors, such as political constraints
- the system will "control" only those, who seek control, i.e. service
- application of the principle "control by exception" is neither possible, nor feasible
- a controlled flight will be under the control of only one ATC unit at any given time
- responsibility for the control of all aircraft operating within a given block of airspace will be vested in a single ATC unit
- the control of flights may be delegated to other ATC units provided that co-ordination between all ATC units concerned is assured
- the ATC system is premised on navigational responsibility being vested within the aircraft, i.e. pilots are responsible for navigation and terrain clearance
- during radar control "vectoring" the navigational responsibility for the aircraft rests with the air traffic controller
- the prime responsibility of controllers is the prevention of collisions between aircraft

- the provision of separation is based on the quality of known positional information available to the controller

- such information constitutes past history on each flight

- assurance of separation between flights depends on the availability of information on the intentions of pilots as to the flight´s progress

- an aircraft will not be operated in such proximity to other aircraft as to create a collision hazard

- advance coordination on pilots intentions (flight plans and changes thereto) will normally be early and fast enough as to stay ahead of the real flight´s progress

- pilots do not lie to controllers and try their best in obeying good operating procedures

- controllers do not lie to pilots and try their best in obeying good operating procedures

16

ATC Management

What has ATC to do with management, besides organisational management of its administration, the management of airspace and of traffic flows?

In ATC systems, managing can be put as controlling, commanding and coordinating. It is the air traffic controller, who performs these tasks. In controlling he assesses all information on the position, progress and intent of flights under his control for conflicts and initiates the issuance of clearances to ensure a conflict free further progress of flight. In commanding he issues instructions for and to pilots on manouvres to be performed immediately in solving imminent collision risks. In coordinating he manages time, the activity of himself and other people in the system, material, the data available to him, and people, the supporting personnel around himself. In order to do so, the controller needs flight plan, radar and other aeronautical information in a reliable, fast and conclusive way.

Since an individual controller in performing his duties is solely responsible for all flights under his control, it becomes clear that it is left up to him to manage all available resources, such as equipment, time, data and persons.

Each of his managing tasks differ depending on the specific function to be performed, such as traffic flow control, planning or executive control, radar control, aerodrome, approach and area control.

Since machine liability does not exist, liability of natural persons is required to maintain personal incentive in avoiding negligent, inefficient and reluctant performance of work. It is therefore that one should not seek a replacement of the controller as the heart of present ATC systems by automated data processing machine functions.

In conclusion one could summarise as follows:

- the controller is the heart of the system
- the controller is no typist
- the controller is no computer operator
- the controller´s primary task is to separate aircraft
- the controller must be motivated
- the controller´s interest must be maintained
- underutilisation of controller skills causes non-recovery from system failures

- controller responsibility must be equal to authority
- on must help the controller to enable him to help the system

17

Must Traffic be Regulated ?

There is commercial regulation and technical regulation. Technical regulation as a consequence of commercial de-regulation is an effect, which was discussed for a long time and is now reality in most countries of Europe, following earlier similar developments in the USA. Technical regulation is better known as air traffic flow management.

The liberalization of commercial regulation does however not include air traffic flow management. Whereas regulation stands for commercial restriction or refusal, the restrictions imposed by air traffic flow (control) management constitute a distribution of anticipated delays at airports and along air routes.

Unregulated traffic loads will not mean unrestricted traffic flows, and commercial traffic deregula-tion will probably bring about a greater demand for traffic flow management.

Air traffic flow management developed on the grounds of formerly uncontrolled build-ups of too much traffic at certain times, airports and points in the airspace. This traffic is generated by the many travellers to and from the major international hubs and by passengers frequenting tourist destinations. Both often have to use the same airports and air routes. New destinations will only shift the problem onto new locations, but will not change it.

IATA just recently reported on world-wide air traffic congestion reaching "almost crisis proportions" during a meeting on ways to solve the problem. In some areas it was said that congestion could be helped with existing physical facilities and traffic flow could be eased by updating ATC systems, hiring more fully qualified air traffic controllers and improving management of airport resources.

Unregulated traffic flows create insurmountable congestions at certain neuralgic crossing points along air routes with a resulting disruption of the traffic flows, which must therefore be regulated.

The required ATC system capacities to handle present day traffic loads are always a combination of individual factors, which either isolated or in combination have a great influence on the overall traffic capacity. To these factors belong the available number of and individual controller capability, the number, structure and dimension of airspace control sectors, the structure of air routes and their proximity, the application of radar versus non-radar separation minima and the type of technical ATC equipment as regards systems capabilities, functions, layout, capacity and data throughput times.

The future procedure chosen should be to commercially deregulate in every way feasible, but to technically regulate, i.e. manage the traffic flow on a better than "first come, first served" basis.

What is required?
Since today´s air traffic flow control is of a passive nature, technical means must be found to allow for "active" traffic flow control. This requires that flight plan data flows within ATC systems become faster, that flight progress data become more accurate and that flow controllers on this basis become involved in the control loop. This will have to result in local ATC unit flow control cells to coordinate with central flow control facilities. Otherwise, it does not seem possible to also cope with additional future demand. There are too many areas where predicted traffic growth has been exceeded by a factor of 4, 5, 6 or 7.

18

Differences in the Various Types of ATC Organizations

Most states have charged their ministries for transport, communications, public works, etc. with subordinate civil aviation departments, authorities or administrations to act as their aviation authorities. These governmental institutions are also responsible for the provision of the air navigation services.

In some areas of the world, however, supra-regional organizations have been formed for the provision of these services. Among these organizations are ASECNA in Africa, COCESNA and CENAMER in Central America and EUROCONTROL in Western Europe.

Almost all states also maintain military air navigation services organizations for the control of military (mainly tactical) flights in parallel to civil authorities.

Other countries employ or plan to employ private organizations such as Switzerland with swisscontrol, Canada with NavCanada and Germany with DFS or the US Federal Aviation Administration in discussing such possibility also for the USA. Which considerations often play a significant role in such discussions is illustrated by a report on an executive debate over new structures for the US FAA. Mr. Helms, a former FAA administrator, foresaw the potential of security problems if a federal corporation were placed in charge of the ATC system in the USA. He cited the quick action of the ATC system in response to US Defense Department deployment of aircraft at the time of the 1984 Grenada invasion as an example of the close relationship between the FAA and the armed forces.

If national ATC systems for their organization are being judged by such national requirements, then there is no hope for a solution in situations of similar nature also in other parts of the world. This, possibly, is the reason why nowhere in the world is an international ATC unit for the control of international flights in international airspace by international personnel (UN status) to be found yet. This situation could be changed in making ICAO not only a technical regulating body, but also an international ATC service organization.

19
ATC System Planning, Operation and Maintenance

The planning and design of new and the upgrading of present ATC systems is a continuous, never ending process, the necessity to design and specify in an efficient and economic way is evident.

Most of the time ATC systems are planned, owned and operated by national aviation authorities. International uniformity in the availability of ATC system functions, however, is a necessity, since flights cross many system (State) borders.

If neighbouring states wish to employ the same separation minima in the control of flights and have system capacities and capabilities match, it is unavoidable that techniques have to be applied, which are similar to each other, if not identical.

As far as the provision of ATC services to international flights in international airspace (over the oceans) is concerned, one would expect to find functional system capabilities of similar kind, but not even this stage has been reached yet, because for the majority of systems to provide such services it is still the individual national authorities to plan, design, purchase, operate and maintain them. The role of ICAO in supporting these authorities in this process is not a dominating one. It is more or less of an advisory nature, because it is not ICAO, which purchases the systems, despite financial assistance through UNDP or other funds.

What is required?
Besides basics it is required to accelerate the coordination process between units, to increase the accuracy of flight progress data, to introduce a more flexible route system, to implement

active air traffic flow control, to allow the obeyance of the unity of control principle, to introduce automatic (non-radar) conflict prediction and to have automated data processing machinery take over routine functions in ATC.

System Configuration
Many times, the number, type and configuration of air navigation services subsystems are being considered separately, not realizing that their components, operational functions, capacity and capability as well as their interfaces are being part of an entity, the air navigation (services) system. They should, however, always be considered as a whole, if the system shall be safe and efficient, and function economically.

The system with its prime role of providing separation assurance between flights can be defined as a composite of equipment, skills and techniques capable of performing or supporting an operational role or both. A complete system includes all equipment, related facilities, material, software, services and personnel required for its operation and support to the degree that it can be considered a self-sufficient unit in its intended operational environment.

Air navigation (services) subsystems constitute a combination of sets, groups, etc., which perform an operational function within the overall system and are a major subdivision of the overall system.

In designing and constructing air navigation (services) systems it is important to know, which standards and recommended practices of ICAO exist on the operational functions to be performed by a specific system in a specific environment (country). ICAO has covered almost completely the field of operational requirements, but unfortunately not so the one of technical requirements as far as the design and construction of technical systems in ATC are concerned.

The design and configuration of air navigation (traffic control) systems depends on traffic demand, available technology, available money, geography, weather conditions, topography, service and safety philosophy, the possible capacity of men and machines, the services to be provided and the standards to be applied.

Often enough guidelines available from ICAO and consulting companies are being ignored in the realization of ATC (sub-) system projects, leading to a patchwork, because such guidelines are either being ignored or regulations for their observance are not considered necessary or cannot be paid for.

The capacity of an ATC system depends on the capacity, capability and proficiency of the air traffic controllers, coordinators and assistants running the system, and on the capacity and capability of the radio telephony system, the telephone system, the data communication system, the radar system, the flight plan processing system, the aeronautical information system, the involved airport/s, the number and proximity of air routes to be controlled, the corresponding number of conflict points, the separation minima to be applied, the type and mixture of traffic to be controlled, aircraft performances, the system´s fail-safe and fail-soft philosophy, its overall configuration, the type of system monitoring and control to be used, the logistics system, the type, number and accuracy of radio navigation aids available, the geographical size of the airspace to be served with the various air route distances to be covered and the like.

It seems evident that not every aviation authority responsible for an overall or part-project will take into account or will be able to take into account all of these and more aspects in properly planning their system. It also does not help the airspace users to say "let us not worry, we are not going to fly to this country, i.e. to land there", because they often will have to overfly such a country, i.e. "have to fly through such system´s airspace".

When considering operational safety as provided by an ATC system in trying to achieve a safe, orderly and efficient conduct of flights, one should recognize that ATC units do not know that a particular aircraft is performing the flight. There are no means of determination between particular airborne airframes, unless an aircraft operates in visual sight of an aerodrome control tower. Only Russian built airplanes make an exception to this rule due to their secondary radar transponder codes referring to the airframe number. For all other ATC units only the information as contained in the filed flight plan constitutes the flights, as wrong as it might be.

Whenever changes to this flight plan have occurred, of which the pilot believes that they had been forwarded to ATC units concerned, but have not been effected or received by these units, such units will have to believe in the old information as being reality and will act upon accordingly.

The cases are still too many, in which original or updated information on a flight is either not being transmitted in time or is not being received at all. Some time ago Australian controllers reported on an international Garuda flight, which was first heard of, when it finally managed to radio its position report to the Australian ATC unit, when it passed over Alice Springs in the middle of the Australian continent. Such incidents are neither the pilot´s nor the controller´s fault. They are the fault of the system provider / operator.

With the control of flights constituting an abstract process with hopefully true information on the real object and its intentions it cannot be repeated often enough that in this object sit real passengers. Often enough this aspect is not given sufficient importance in the selection and training of personnel entering the profession.

Therefore, applied standards and recommended practices are necessary on an international basis. ICAO defines these as follows.

Standard
is any specification for physical characteristics, configuration, material, performance, personnel or procedure, the uniform application of which is recognized as necessary for the safety or regularity of international air navigation and to which contracting states will conform in accordance with the convention.

Recommended Practices
reads the same, however with contracting states only endeavouring to conform in accordance with the convention.

20
The Impact of Automated Data Processing on ATC

The major areas in which automated data processing was introduced in ATC are flight plan data processing with associated flight progress strip printing and the calculation of estimated reporting point station passage times as well as radar data processing and presentation.

Flight plan processing was introduced to improve the error prone function of manual flight progress data calculation and control strip production. The shortcomings were of differing nature, and not sufficiently legible handwritings coupled with mistakes and omissions of characters on the paper strips under time pressure (e.g. calculate and prepare 100 strips on 15 different flight plans in ten minutes).

Radar data processing was introduced to improve the inaccuracy in position information presentation coupled with the limited capability of man to memorize large amounts of target data in a short time period (e.g. a few seconds to a few minutes).

These two ADP applications constitute the backbone of ATC in the provision of information to controllers for the performance of their separation tasks. Other additional operational ADP functions in ATC merely constitute refinements of these two general application areas.

To these additional applications belong the automated processing of aeronautical information required to support primary ATC system functions, radar tracking, conflict alert and conflict prediction functions, flight plan updating by radar track data and the pending electronic presentation of flight progress data in replacing flight progress paper strips.

The separation assurance functions of ATC involve a lot of thinking in commanding and controlling, i.e. decision making while performing these functions in predicting, detecting and solving conflicts between flights. A computer, however, cannot think. It can only be given recurring routine functions, which do not involve thinking. Thinking, however, involves responsibility, and in order to accept responsibility, one must be given authority.

All routine functions are performed by computers, whenever being activated by a stimulus. The operator is now dependent, because he can no longer decide for himself, when to activate such automated functions. Also, the machine is performing such functions much faster than man could ever do. He, however, still bears the responsibility for the end result of his/her and the machine´s performance.

It is for this reason that most of the automation processes stop right here, where the controller normally makes his individual decisions on what to do when, and data are at this point normally presented to him in static form to allow him to make such decision. The more data and routines are taken over by the machine at this point, the greater his problems will be to maintain control over these processes, depending on his personal proficiency, capability and capacity. Machine performances however can only be set according to average human performance. But, what is average?

The answer to this question has its effects on the possible extent of automation in ATC, i.e. on the ability of controllers to take over, on the roles of pilots and controllers and on redundancy requirements.

Since automation reduced routine manual tasks and increases data handling capacity, it should be employed wherever it helps the controller to perform his tasks by assisting in the compilation and presentation of information and in supporting decision making functions.

A problem to face in the future will be the accident which occurs due to a malfunctioning machine surpassing the controller´s capability to detect such malfunction. In trying to avoid such a situation, we must make sure that controllers and their assistants fully understand the functioning of their machines, components and data processing programmes. This knowledge, for many ATC systems employing ADP machinery, does not seem to be ensured.

Present and future possible use of automation in ATC will have its effect on the controllers practical ways of performing their task to provide a safe, orderly and expeditious flow of air traffic.

Areas of influence will be the maintenance of accurate flight data displays, the discrimination of relevant features of traffic situations, flight progress data validation, the decision of priorities of action, the determination of suitable solutions to traffic situations and the determination whether solutions are valid.

Since safe average performance of controllers is low, flexibility in employing machines in ATC is being lost with system capacity increasing. The tendency should therefore be to automate secondary functions first. As a consequence, the limit in ATC automation should be set at the point of detected conflict presentation in leaving the responsibility with the controllers, to automate around them, accelerate coordination between them, in making planning data more accurate, in shifting non-decision routine tasks to the ADP machinery, in limiting the number of data presentation sources and in providing warning and alert messages to the controller.

In trying to do so, one must decide on the required involvement of the controller, i.e. control versus monitor and manager versus operator. Navigational accuracies of present day navigation systems must be re-assessed for possible reductions in separation minima in comparison with the controller´s ability to handle a specific number of flights simultaneously.

Future separation minima must therefore take into account these factors, as well as future closure rates and aircraft manoeuvrability and the pilot´s capability of perception and reaction. At the same time we must newly define what constitutes a "conflict" between two flights.

Other, new ADP functions, among modern tools in ATC are the electronic presentation of flight progress data in replacing the flight progress paper strip, the full use of SSR Mode S potential in conflict threat prediction, detection, alert and recommended solution.

System designers will have to be aware of not going beyond the limits in giving machines authority, respectively responsibility. It will be a difficult time for system, designers to determine, who in the system shall have responsibility without authority.

Another area requiring clarification for the future will be to determine, if more responsibility to maintain separation can be shifted to pilots to permit the automation of some decision making functions on the ground. The question will evolve, if pilots will be able to cope with the additional presentation of information (a start has been made with the pending implementation of collision avoidance systems) and if the pilots will be willing to have their ultimate responsibility extended in becoming more responsible in the prevention of collisions as regards other flights around their aircraft.

On the ground it will have to be assured that controllers can take over functions, when system components fail and it will be required to train them to maintain skill in exercising conflict prediction and solution in such cases.

21
What Happens to Airspace User Charges

Besides landing fees for the use of airports, aircraft operators in many parts of the world additionally have to pay airspace user or navigation charges for the provision of air traffic services and radio navigation ground aids.

As a regional example, Eurocontrol, the European Organization for the Safety of Air Navigation, collects such charges from airspace users in its member states, as does IATA for some of the airlines.

As another example, Germany since 1981 covers 100 % of their air navigation costs. Charges collected for 1985 amounted to 277 491 891 DEM. This means that considerable amounts of money are becoming available to the various national aviation authorities.

These monies are being used for the current provision of services and also for the procurement of new systems and equipment. Unfortunately, however, airspace users through their organizations do not exercise enough control on their spending in participating in detailed planning and purchase of new equipment, systems and procedures, upsurging these monies in often odd proportions against governmental estimates.

A special case of airport user charges "non-spending" was the US aviation trust fund, in which over five billion USD had accumulated on the 1980íes. The interest earned on this money by the US Government was used to reduce federal budget deficit. It is now being used in the US FAA ATC modernization project, which already lasts over ten years and is still to be completed.

22
Who Causes Change ?

In all businesses it normally is the customer, who causes change. This is not so in civil aviation. Civil aviation´s customer actually is not the navigation charge paying airline, but the fare paying passenger. But his power to impose change, even in matters relating to his own personal safety, is nil. It may very well be that the ATC environment is one of the few areas remaining, in which the paying customer cannot cause change, because politics through governmental service provision become involved.

It must be for this reason of separation of ATC service provision from private profit business of airlines in the overall air transportation system, which puts the real customer in the back seat, i.e. the position of having no power at all.

This separation however is not sound, because it leads to developments, in which matters of secondary importance are being pursued before matters of primary importance, such as the assurance of separation between aircraft.

This, for instance, is the case with the planned introduction of private voice telephone services for passengers between airplanes and ground stations. Instead, the airlines should show much greater interest in ATC units being equipped with functioning voice radio and telephone systems for communication in the control of their flights and in the solution of the many other deficiencies in ATC systems world-wide.

On the one hand, it is the aerospace industry that suggests change in offering the application of newly developed techniques for the reason of making a profit and in using good arguments on the required improvement of the ATC environment.

On the other hand, it is the ATC services´ organizations with their controllers and engineers, who demand change in suffering from the existing, often deficient, status of their systems and equipment and in being held liable, if something goes wrong.

It must therefore be considered a typical consequence that some air navigation services authorities now ask for consequential liability by system manufacturers or corresponding insurance cover from insurance companies, for ATC system owners, especially those in smaller countries, who cannot afford to pay for the loss of two aircraft and their passengers in a collision caused by their system or their controllers in using machines.

Another question remaining is how responsible managers in civil aviation, in government and in the airline business can be held and be moved to force upon the various ATC systems in the world the required changes, with the USA topping the discussion list a few years ago.

My conclusion?
Since air traffic control cannot be a religion, one must be prepared to pay for it!
And remember!
It´s not the speed that kills you, it´s the sudden stop.

Abbreviations

ADP	Automated Data Processing
AFTN	Aeronautical Fixed Telecommunication Network
ANSA	International Advisory Group Air Navigation Services
ARCAS	Airborne Collision Avoidance System
ARINC	Aeronautical Radio Incorporated (USA)
ARTAS	ATC Radar Tracker and Server
ASECNA	Agency for the Security of Air Navigation in Africa and Madagascar
ATAS	Air Traffic Advisory Service
ATC	Air Traffic Control
ATS	Air Traffic Services
AVSAT	Aviation Satellite
BPS	Bits Per Second
CENAMER	Central American Air Navigation Organization
COCESNA	Corporación Centra Americana de Serviciós de Navegación Aérea
DEM	Deutsche Mark
DFS	Deutsche Flugsicherung (Germany)
DME	Distance Measuring Equipment
ECAC	European Civil Aviation Conference
EUROCAE	European Organization for Civil Aviation Electronics
EUROCONTROL	European Organization for the Safety of air Navigation
FAA	Federal Aviation Administration (USA)
FIR	Flight Information Region
FIS	Flight Information Service
FMS	Flight Management System
GLONASS	Global NavigationSystem (USSR)
GPS	Global Positioning System (USA)
HF	High Frequency
IATA	International Air Transport Association
ICAN	International Commission for Air Navigation
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
ILO	International Labour Office
ILS	Instrument Landing System
INMARSAT	International Maritime Satellite Organization
INS	Inertial Navigation System
MNPS	Minimum Navigation Performance Specification
MOPS	Minimum Operational Performance Specification
NATS	National Air Traffic Services (UK)
NDB	Non Directional Radio Beacon
NM	Nautical Mile
NOTAM	Notice to Airmen
NTSB	National Transportation Safety Board (USA)
OLDI	On-Line Data Interchange
PATCO	Professional Air Traffic Control Organization (USA)
RNAV	Area Navigation
RNP	Required Navigation Performance
RTCA	Radio Technical Commission of America (USA)
RTF	Radio Telephony
RVSM	Reduced Vertical Separation Minima
SSR	Secondary Surveillance Radar
TCAS	Threat Collision Avoidance System
TIBA	Traffic Information Broadcast by Aircraft
UHF	Ultra High Frequency

UK	United Kingdom
UN	United Nations
UNDP	United Nations Development Programme
US	United States
USA	United States of America
USAF	United States Air Force
USD	US Dollar
USSR	Union of Socialist Soviet Republics
VHF	Very High Frequency
VLF	Very Low Frequency
VMC	Visual Meteorological Conditions
VOR	VHF Omni-Directional Radio Range