ADVANCING FREE FLIGHT THROUGH HUMAN FACTORS

WORKSHOP REPORT

AUGUST 1995

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We are pleased to present this report on the technical workshop, Advancing Free Flight Through Human Factors, jointly sponsored by the FAA's Air Traffic Plans and Requirements Service and the Office of the Chief Scientific and Technical Advisor for Human Factors. The results of the workshop represent an important first step in the consideration of human factors issues in the integration of free flight into the National Airspace System. While much of the critical work remains to be done, these results will assist human factors scientists, system designers, and operational experts in making free flight a reality. Our commitment is to develop the best possible system by applying the best possible research and human factors information. We appreciate the interest and efforts of all the workshop participants representing industry, academia, and the federal government. Without their help the progress made would have been impossible.

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EXECUTIVE SUMMARY

This report describes the results of the Advancing Free Flight Through Human Factors technical workshop held on June 20 and 21, 1995. The purpose of this technical workshop was to begin the process of identifying and solving human factors issues related to a new aviation concept called "free flight." The FAA sponsored an RTCA select committee to define the concept of free flight and to identify the issues and activities that must be undertaken to advance the concept. The select committee prescribed free flight as a concept encompassing a real time air traffic management triad: People, Procedures, and Technologies. The long range changes envisioned by the RTCA select committee to move the system toward free flight will involve the human as the most critical element in the use of new technologies, equipment, and procedures. There were four human factors related issues that were among the key issues identified in this select committee. These are:

- What modeling and analysis effort is necessary to ensure safety?
- How will the FAA and users coordinate development and accommodate evolving technologies and new requirements?
- What are the human factors considerations?
- Can the separation assurance function shift between the pilot [and] controller?

To meet these human factors related challenges, the FAA Chief Scientific and Technical Advisor for Human Factors (AAR-100) and the Director of Air Traffic Requirements (ATR-1) invited approximately 70 leading aviation human factors and operational experts to participate in a technical workshop. The workshop was envisioned as the first of a series of initiatives to help guide and manage human factors research and development (R&D) activities in support of free flight. The primary purpose of this workshop was to identify and define major human factors challenges associated with free flight and assess their relative importance for research and implementation.

The participants were divided into four work groups mirroring the four domains called out in the RTCA report: Oceanic and International; Domestic En Route and Cruise Transition; Terminal, Final Approach, and Airport Surface; and Traffic Flow Management. The four working groups generated a great deal of information and issues to consider in developing the free flight concept. The discussions and products of each working group indicated that many of the issue areas are applicable to multiple domains. The information can be categorized into 14 different issue areas. Of these 14 areas, 13 of them were addressed by multiple groups.

Several general conclusions have been drawn from the findings of the workshop. It was concluded that a central coordination point is needed for the important elements of free flight development represented by “people” (the third leg of the RTCA program). There are now and will be in the future many other requirements for the coordination and dissemination of human factors free flight efforts. A planned approach to this coordination and dissemination is necessary. Also, it was concluded that a follow-on activity that identifies, analyzes, filters, and prioritizes the human factors work to be done is needed. Finally, it was concluded that the workshop results must be transmitted to the RTCA task force and that joint ATR/AAR-100 participation in any agency response to the RTCA work is required.

The findings and conclusion of the workshop provide insight into the challenges associated with human factors and free flight. There were many specific recommendations made for research efforts, however, the major general recommendations are:

1. Designate ATR and AAR-100 as a joint FAA focal point for human performance considerations in Free Flight

2. Charter the FAA focal point with resources and responsibility to:

- further identify, prioritize, and develop essential human factors issues and requirements
- develop a program to systematically monitor critical human factors areas and ensure their resolution
- ensure that human factors efforts supporting free flight development (FAA and industry) are fully coordinated and integrated

3. Charge the focal point to conduct efforts in support of human factors in free flight that:

- expand the coordination effort initiated by this initial workshop
- disseminate findings, conclusions, results, and products related to future developments in free flight human factors

4. Establish formal joint ATR/AAR involvement in agency response and follow-up to RTCA Free Flight developments by:

- Formal transmission of this report to RTCA Free Flight Task Force 3
- Participating in any agency response to the RTCA recommendations
- Participating in future agency free flight developments

ADVANCING FREE FLIGHT THROUGH HUMAN FACTORS REPORT

PURPOSE

This report describes the results of the Advancing Free Flight Through Human Factors technical workshop held on June 20 and 21, 1995. The purpose of this technical workshop was to begin the process of identifying and solving human factors issues related to a new aviation concept called "free flight."

BACKGROUND

After the U.S. airline industry was deregulated in 1978, air carriers began lobbying for more fuel efficient routing and fewer air traffic control imposed delays. International pressure crystallized in 1991 when the U.S. adopted the ICAO FANS concept. The pressure to reduce constraints in the National Airspace System reached a crescendo in 1993 with the Airline Commission Report. Several air carriers and aviation associations, particularly the Air Transport Association (ATA) called for a new approach and labeled it "free flight." The Federal Aviation Administration (FAA) joined with the aviation industry under the auspices of an RTCA select committee to define "free flight." The committee defined free flight as:

> A safe and efficient flight operating capability under instrument flight rules (IFR) in which operators have the freedom to select their path and speed in real time. Air traffic restrictions are only imposed to ensure separation, to preclude exceeding airport capacity, to prevent unauthorized flight through special use airspace, and to ensure safety of flight. Restrictions are limited in extent and duration to correct the identified problem. Any activity which removes restrictions represents a move toward free flight.

The select committee also prescribed free flight as a concept encompassing a real time air traffic management triad: People, Procedures, and Technologies. The long range changes envisioned by the RTCA select committee to move the system toward free flight will involve the human as the most critical element in the use of new technologies, equipment, and procedures. These changes will, in turn, necessitate a "new way of doing business" for both the FAA and the aviation industry with organizational, staffing, job design, training, communication, and other implications. In addition, the RTCA report identifies several issues which must be dealt with for free flight to be successful. Four of these issues were identified by the Director of Air Traffic Requirements (ATR-1) and the Chief Scientific and Technical Advisor for Human Factors (AAR-100) as critically related to human factors:

- What are the human factors considerations?
- What modeling and analysis effort is necessary to ensure safety?
- How will the FAA and users coordinate development and accommodate evolving technologies and new requirements?
- Can the separation assurance function shift between the pilot [and] controller?

To help answer these questions and meet the human factors challenge, the FAA recognized the importance of involving the nation's leading technical experts early-on in the development of this concept to ensure that human factors are usefully and systematically considered. To this end, ATR and AAR jointly sponsored the technical workshop on Advancing Free Flight Through Human Factors. The participants of this workshop were a select set of approximately 70 aviation human factors and operational experts from various government, industry, and academic organizations. (See Appendix A for complete list of attendees.)

The workshop was envisioned as the first of a series of initiatives to help guide and manage human factors research and development (R&D) activities in support of free flight. The primary purpose of this workshop was to identify major human factors challenges associated with free flight and assess their relative importance for research and implementation. In addition, it was the goal to provide input from the human factors community to the RTCA Task Force 3 effort regarding the human factors issues generated in the initial RTCA select committee report.

ORGANIZATION OF THE REPORT

The remainder of the report is organized into the following four sections: a description of the workshop, the findings of the working sessions, conclusions, and recommendations.

DESCRIPTION OF THE WORKSHOP

Prior to the workshop, the participants received a read-ahead package of materials pertaining to free flight. The documents in this package included the *Report of the RTCA Board of Directors' Select Committee on Free Flight*, the January-March 1995 edition of *The Journal of Air Traffic Control*, and a *Human Factors Issues in Free Flight* white paper by the Mitre Corporation. The purpose of the read-ahead package was to establish a common understanding of free flight for the workshop participants.

The workshop participants received presentations describing free flight concepts, complexities, and challenges from several senior executives from the FAA and NATCA. In addition, research findings, free flight functions demonstrations, and presentations of various free flight scenarios were provided. The participants were divided into four technical working groups based on the four operational domains described by the RTCA select committee: Oceanic and International; Domestic En Route and Cruise Transition; Terminal, Final Approach, and Airport Surface; and Traffic Flow Management. Each group was co-chaired by both a human factors and an operational representative. The groups were asked to define the human factors issues in each of three areas: current initiatives towards free flight, transition to free flight, and mature free flight.

The results of each technical working group were presented to the plenary session of the workshop. The co-chairs of each working group served as panel members for a discussion of conclusions and recommendations. This report constitutes the findings of the four work groups and their conclusions. (Appendix B is a table that presents the correspondence between working group issues.) The workshop concluded with closing remarks from senior FAA executives. (See Appendix C for the workshop agenda.)

WORKING GROUP FINDINGS

Traffic Flow Management

The free flight concept holds that the design of the present NAS overly constrains user access and operations. It sets out the fundamental directive to identify changes in the NAS that remove restrictions, allowing system users the flexibility to make choices based on business considerations subject to the constraints necessary to ensure safety. In TFM, this directive will have particular significance for developing a functional architecture which describes the roles, responsibilities, and authority for strategic and tactical decision making with respect to system restrictions. In turn, the functional architecture will be influenced by associated requirements for information gathering, use, sources, and distribution.

Human factors should play an integral part in supporting the integration of the automated TFM functional components with the humans that will operate them. The TFM working group defined nine major issues that should be addressed as part of free flight research and development.

Information Collection, Dissemination, Display and Use

Information collection, dissemination, display, and use in TFM was a key issue for discussion in the TFM working group. It was recognized that in order to support meaningful participation by users in TFM, more information sharing and exchange would have to occur at all stages of the decision making process. The types of information required include the following: information necessary to set constraints, information on the constraints, reasons for the constraints, allocation of capacity to users, choices available within the constraints, information necessary to evaluate the choices, intentions of users based on the choices, and feedback on the results of the choice.

Measures and Metrics

The changing patterns of traffic in the system will necessitate new definitions of traffic flow problems and in turn, collection of new information on problem characteristics, locations, and probabilities. Measurement of system capacity, demand, and capacity utilization will undergo significant changes in a free flight environment. Metrics are needed for predictive decision making and TFM performance assessment. This requires development and display of new classes of metrics to provide feedback that can reduce uncertainties before decisions are made and help validate the effectiveness of TFM decisions after they are made.

Uncertainty and Predictability

In addition to determining what types of information and metrics would be needed in a free flight environment, the TFM working group also discussed issues of information quality and availability. Use of uncertain information in TFM decisions will require new ways to represent this uncertainty for display to users and operators. Improved dissemination of information will be accompanied by greater variability in accuracy of information. Display coding techniques will be required to clearly represent attributes such as the age and source of the data. Automated and manual procedures will be needed to reconcile inconsistencies in the data and guide users responses.

Selection, Training, and Education

In the TFM working group, selection, training and education programs were discussed as a vehicle for implementing new roles for traffic managers and promoting trust among all of the players involved in the TFM process. Additional knowledges and skills may be required, and therefore, the criterion for selecting traffic managers may change. Training will need to emphasize team work and cooperative decision making. All participants must be educated concerning their respective roles, the roles of the other participants, and how these individual roles fit together. Ensuring a common understanding and awareness of participants roles and their interrelationships was considered to be a prerequisite for developing greater consistency and commonality in the criteria that will be used at the local facility level to establish resource constraints and parameters.

Functional Architecture

A basic and overriding concern in the area of TFM and Free Flight was the development of a functional architecture for TFM which addresses preflight as well as airborne decisions. Determining an appropriate functional architecture will involve analyzing the information requirements dictated by alternative allocations of functions, including the requirements for distribution of information among the various players. Human factors can help determine and evaluate the number, roles, and interactions of TFM elements. Specific contributions focus on determining human performance metrics and criteria for discriminating among alternatives, and evaluations of alternatives via analytic studies, computer simulations, and human-in-the-loop studies. Human factors input can also help in prioritizing the alternatives according to their relative performance with respect to the criteria and presenting these results for discussion by the representatives of the TFM players. Participant comments and preferences can then be factored into the priorities to help arrive at a consensus.

Transition: Phases vs. Levels

Two classes of transition issues were noted in the TFM working group. One class of issues concerned the potential complexity introduced by multiple levels of free flight capability within the NAS. The TFM group discussed issues associated with human monitoring, awareness, and responses under multiple levels of free flight capability in the system. The second class of transition issues discussed by the group concerned the process of moving from the current system to a future system. In this area, the group discussed personnel and institutional issues related to government provision of TFM services. The group also identified the need for systematic testing and evaluation of transitional steps based on predefined performance parameters and criteria.

Roles, Responsibilities, and Authority

In the context of TFM, the discussions on roles, responsibilities, and authority centered on maintaining trust and honesty among decision makers in the face of uncertain information. The challenge in this area is to establish roles and responsibilities which will allow users and air traffic service providers to cooperate and employ "win-win" strategies rather than competing with "win-lose" strategies. To support a cooperative environment, the roles and responsibilities of each party must be defined explicitly and timely feedback must be provided to reinforce appropriate behaviors and discourage inappropriate behaviors.

Airspace Changes

The TFM working group discussed the potential impact of changes in airspace and traffic patterns on controllers. New TFM metrics that take into account human workload will be needed to predict manageability and prevent overload situations. Increased flexibility in routes, flight altitudes, and altitude transitions will affect the manageability of the airspace. New procedures with acceptable lead times must be devised for transitioning an airspace to increase traffic structure when necessary to maintain manageability.

Player Acceptance

The TFM working group concluded that effective and coordinated human performance will be required for the successful implementation of TFM role changes associated with free flight concepts. A key to effective performance is that the participants accept and endorse their new roles. To ensure participant acceptance, the design of the new functional architecture must consider issues associated with the separation of decision making authority from the execution of functions. Moreover, the plan for implementing Free Flight capabilities must consider user acceptance issues and develop plans to address those issues. Although the group recognized that substantial participant involvement must be inherent in the Free Flight design process, it was also acknowledged that it will be impossible for all potential participants to be involved. It is therefore necessary to develop a plan for assessing reactions and concerns of potential participants who have not been involved and for the use of orientation, training and participant feedback programs to address the concerns.

Domestic En Route and Cruise Transition

The En Route work group focused on the six salient issues of information requirements and display; communication and decision making; coordination and delineation of responsibility; measuring and managing workloads; alternative strategies for separation; and human factors expertise in free flight concept development, requirements determination, and operational implementation:

Information and Display

Determination of En Route informational requirements imposes an evolutionary challenge in the free flight operational concept. With the removal of standard routes as well as unrestricted horizontal and vertical limitations, technology and procedures must find appropriate substitutes for stable flight paths. These informational requirements will place additional demands upon the aviation community to devise innovative approaches to display the required information. As new display technologies and techniques are developed, human performance considerations must be anticipated and analyzed. Because the En Route will provide an increasingly dynamic environment as free flight proliferates, the communication and display of information must be sensitive to the current and future operational context of the aircraft and controller workstation situation. This contextual sensitivity of information and display may provide opportunities for increased efficiency in pilot and controller tasks, but also poses the potential for increased complexity in hardware/software/liveware configurations, decreased situational awareness, and unanticipated human responses. Resolving the potential complications of the dynamic En Route environment will necessarily entail significant analysis of information and display alternatives and human performance simulation. The human factors work currently underway related to the demonstration and validation of information requirements (such as that related to data link, CTAS, CHI alternatives, and cognitive engineering) applies.

Cognitive Workload Allocation

The evolution of procedures and the new technologies introduced under free flight operations reflect only the tip of the iceberg of mental task load changes for pilots, controllers, and operations personnel. While there are needs to analyze and accommodate changes in the physical aspects of the new functions and methods (e.g., work station design, work space environmental parameters, equipment configurations, supervisory controls, staffing schedules), the most challenging and complex change will occur in the cognitive demands imposed by new procedures, tightly coupled supporting systems, increasingly complex software configurations, active user collaboration, dynamic air traffic situations, mixed equipage, increased variety of traffic patterns, and non-standard scenarios. Both new means to measure and revise threshold criteria (e.g., sector complexity and workload factors) are required to assess these impacts on operator workloads. Implementing free flight may result in revised human cognitive tasks associated with such considerations as changing memory demands, attention, situational awareness, fail soft and recovery, and transitions in phases of flight. New automation tools will impose a variety of sub-cognitive models for the controller and pilot. To assess how well these tasks and models are (and need to be) defined, structured, trained, maintained, and fully understood in routine and emergency conditions will place heavy demands on the resources of activities and facilities supporting free flight development and implementation. The most promising solution to this complex and challenging requirement is a comprehensive plan of distributed simulation modeling that becomes fully integrated into the FAA engineering and acquisition community.

Communication and Decision Making

Free flight in the En Route environment solves many questions and concerns of the current system architecture and operation, but it imposes many new ones. One of the areas likely to be significantly altered by changes in technology, procedures, and training is the area of air/air and air/ground communications. En Route operations are not expected to necessitate a unique treatment of this area, but all free flight communications are likely to see considerable change. Major emphasis must be placed on identifying the requirements for and providing the solution to information consistency, information sharing, information sufficiency, communication dynamics of shifting responsibility for separation, decision conflicts, decision voids, team coordination, cooperative team training, and the like. To address this area requires an effort to define the communication requirements under alternative En Route scenarios, and the use of exploratory simulation to communicate allocation schemes. A key part of this effort will involve evaluating integrated air/air and air/ground datalink with voice communication and automation.

Allocation of Responsibility

The unambiguous delineation of responsibility is one of the most fundamental principles of safe air travel under any set of procedures and technology. Under free flight, the allocation of responsibility must be no less clear. Achieving this clarity will entail a well orchestrated development process in which procedural and technological improvements and training for those modifications are well coordinated system-wide. To ensure uniformity in human and system performance parameters and common understanding by pilots and controllers will require increased attention to factors affecting awareness, decision making, and automation development trade-offs, especially as they affect failure recovery, active-passive interface with automation, redundancy, and structured versus non-structured environments. As with some other modifications to the pilot-controller-operations interactions, extensive analysis and simulation are necessary to provide data for trade-off decisions.

Separation Strategies

As the new technology of free flight provides greater opportunities for alternative concepts in maintaining separation, new challenges in designing the human interfaces (air/air and air/ground and ground/ground) must be addressed. For the future En Route environment to take full advantage of the opportunities presented by the new technologies entails exploring innovative methods for performing the traditional tasks of aircraft separation (for both pilots and controllers). In addition to capitalizing on improved equipment (e.g., faster response times, higher resolution of display, improved location correction algorithms), new approaches to pilot and controller actions must be assessed. Developing these new strategies for the controller and pilot interactions necessitates exploring areas where free flight procedures can complement the introduction of free flight technology. This exploratory work includes evaluation of single pilot operations, self separation alternatives and requirements, mixed equipage and non-participating complexities, assessments of variations in risk taking, standardization of pilot and controller response actions, proficiency evaluations, alternative alert and protection zone standards, managing different levels of conflict probe, determining acceptable false alarm rates, flight path and traffic flow predictability, accuracy of intent information, and many other factors involving human performance. In future En Route traffic management, an evaluation of these factors are likely to lead to changes in areas such as flight planning requirements, aircraft-to-aircraft and aircraft-controller teaming arrangements, new situational awareness methods (alerts and displays), and methods for communicating intent. There is little doubt that initiatives in these areas will play a critical role in the feasibility and sufficiency of alternative separation strategies.

Integrated Structured Human Factors Support

During discussions of the technical issues and challenges, implicit and explicit references to management related obstacles periodically surfaced. Considerable concern was expressed about the need for a systematic and structured approach to integrating human performance considerations in the extra-agency developments related to free flight as well as the internal technical implementation of free flight operational concepts. While the visibility of human factors in the recent developments of free flight is an encouraging sign, there was some agreement that the discipline is inadequately represented in the organizations supporting free flight developments and in the processes by which the implementation is being conducted. There was general agreement that expert human factors involvement at every stage of free flight development was needed in order to identify and resolve the human interface requirements that will enable a smooth transition. The very core of this requirement are human-centered, performance-based analyses (especially in establishing system baselines and trade-off decision criteria) and human-in-the-loop engineering and simulation. To strengthen the current approaches in addressing this issue will involve priority, policy and organizational changes that will affect near, mid, and long term developments. It was recommended in the session that internal and external resources be devoted to monitor and manage human factors efforts as the free flight program evolves, and that increased human factors and subject matter expertise be employed in the related FAA Integrated Product Team (IPT) and system architecture development activities supporting the definition and development of free flight.

Oceanic and International

The Oceanic group began their session by discussing several typical oceanic scenarios under the current environment, highlighting the human component. They then defined the problems and issues with current oceanic operations that might be improved by free flight. Finally they described a free flight oceanic environment. The group considered the oceanic environment to be the most likely place to begin free flight operations because, given the area and traffic volume, separation problems are simpler and less frequent. Also the implementation of satellite communication and navigation for oceanic operations will yield large payoffs. The group agreed that the transition phase (between en route and terminal operations or across international boundaries) poses the greatest number of issues for implementing free flight in the oceanic environment. The Oceanic group identified 14 issue areas for human factors in free flight in the oceanic environment organized around either ground or airborne considerations. These have been collapsed into 11 issue areas.

Degradation/Failure of Automation

The Oceanic group discussed the need and the process for the automation to degrade in a manner that allows the controller and pilot to safely transition back to a system similar to today. Individual automation components should be able to fail independently of the complete system, and if this is available, loss of service can be limited. There is also a concern over skill degradation (for current manual skills) once the oceanic controllers begin depending on the automated system. Reverting to a manual system may not be a feasible backup if the controllers no longer are proficient in these skills.

Surveillance Requirements

Given that there is no passive surveillance available in the Oceanic realm today, any change will be a major improvement. How this information will be provided by the cockpit and displayed to the controllers, must be explored. The expected decrease in separation minima could lead to increased congestion in today's sectorization plan. It may become necessary to resectorize the oceanic airspace into smaller more manageable sectors. This scenario needs to be modeled to determine the impacts on controllers and automation.

Identification of Potential Conflict/Cockpit Conflict Probe

A conflict probe / conflict resolution system is envisioned as necessary for all environments under free flight. The Oceanic group predicted that this will affect the ocean in the same manner as the other domains for both controllers and in the cockpit. The matter of display to both sets of operators must be answered in the beginning of development through the use of rapid prototyping and simulation. The size and shape of the protected and alert zones and the distance/time for resolution may require some adjustment for the oceanic environment. Also, some standardization of the information and conflict probe/resolution capabilities and tools in the cockpit is necessary for free flight to be effective.

Controller Conceptualization of Flight Paths

The present oceanic airspace and route structure is simple and static. In free flight the possible route choices may be more variable and complex. Prototyping and modeling of these possibilities and how controllers will understand these more complex flight paths is required. Some study of tools and training is necessary to ensure that the controllers will still "have the picture" so that any intervention will be well informed and result in the optimization of conflict resolutions.

Transition from Free Flight Airspace to Structured or Sovereign ATC Environment

The most unique facet of the ocean operation is envisioned to be the transition from free flight to structured airspace (i.e. busy terminal airspace along the domestic coast), or the transition to and from free flight and international airspace (i.e. between U.S. free flight and another sovereign country's ATC system). This issue expands to standardization among airlines from all countries in terms of their ability to operate within the free flight system. These transitions may involve advance planning to sequence and separate the aircraft prior to the structured environment. Therefore the transitions may constrain free flight in the unstructured airspace. These issues must be resolved (particularly who is responsible for making the transition occur, the controller or the pilot). Additionally, the rules for the transition to international airspace must be negotiated within international groups (e.g., ICAO).

Display

As in the other environments, human factors engineering must be an integral part of the design phase of the oceanic display systems. If the oceanic systems are different from the domestic systems, this will require prototyping and modeling beyond that for the domestic systems. Commonality of user interface between oceanic and domestic systems would be highly desirable from training and work force utilization perspectives.

Identification of Training Requirements

Given the radical paradigm shift required to move to free flight, considerable changes will be necessary in the training provided to both controllers and flight crews (perhaps in the AOC also). Prototypes and models must be examined for changes in the training objectives and perhaps training systems. Team based training which includes flight crew, AOC, and controller roles is necessary.

Roles and Responsibilities of Controller and Pilot in Maintaining Separation

Free flight posits a change in the roles and responsibilities of pilots and controllers. These roles may be dynamic, changing during a flight with separation responsibility transferring between the two parties. Based on the early modeling and prototypes, and continuing throughout implementation, new procedures need to be developed.

With conflict resolution tools available on the ground (and possibly in the cockpit) more than one conflict resolution solution is highly probable. The aircraft operator should be afforded the opportunity to choose the solution optimal for him/her. This could be accomplished by turning separation responsibility to the cockpit or, workload permitting, by negotiation between the controller and operator. Automation and procedures need to be designed and implemented to enable this process.

Mixed Equipage

Different levels of aircraft equipage pose human factors problems in free flight. Much of free flight presupposes automation and technology upgrades that allow for the transmission of digital information and the use of new navigation and communication systems. However, if aircraft without the latest technology continue to populate the system, controllers may be required to adjust their procedures and guidance to the equipage level of the user. This poses cognitive workload and training issues on the controller side which must be investigated before free flight is initiated.

Communication and Intent

Since significant communication improvements are envisioned for the ocean, the procedures and the means of displaying information must be determined. These issues need to be modeled and prototyped.

Intent is one of the central issues in free flight. Intent information is critical for everyone involved in separation. The nature of the intent information and how it is to be communicated/broadcast must be modeled as part of the basic human factors design. This information may include everything from velocity vector to flight plan.

International Standardization

There are tremendous advantages to having standard flight deck procedures throughout the world. This commonality should cross oceanic, domestic cruise, and terminal environments. There are human factors issues for training, cognitive load, and communication if these procedures are not standardized. There may be significant time and effort required for the U.S. to coordinate and negotiate with the rest of the world to adopt free flight procedures, particularly in the oceanic environment which is controlled by different countries in different areas. If the U.S. unilaterally changes oceanic procedures in the Pacific, there may be an outcry from other nations. If the U.S. unilaterally implements free flight domestically, the procedures may be out of sync with those in other parts of the world. Lack of standardization may lead to duplicative equipment and to human factors incidents and errors as a result of flight crews confusing procedures based on geography.

Terminal, Final Approach, and Airport Surface

The terminal group generated 17 issues related to free flight in the terminal environment. Three activities preceded the generation of these issues, which, in turn, helped to constrain and guide issue definition. These activities were:

- Defining the terminal environment under the free flight concept
- Establishing a set of assumptions
- Drawing from the RTCA Free Flight Report to use the "operational need of free flight" concept.

The terminal environment under the free flight concept was defined functionally as well as geographically. The functional terminal environment is made up of the pilot, controller, airline dispatcher, and automation which work together to varying degrees to perform the following functions: sequence aircraft, assign runways, separate aircraft, maximize airspace and airport capacity, and to merge traffic flows. The geographic terminal environment includes sector boundaries and restrictions (e.g., airspeed, altitude, separation). Both the functional and geographic terminal environments will vary dynamically depending on aircraft capabilities, traffic complexity, and traffic density. The group also argued that the definition of the free flight terminal environment will evolve from a current terminal environment with a free flight en route environment to a free flight terminal environment.

The terminal group also established a set of assumptions that serve as constraints for guiding issue generation:

- mixed capability aircraft must be accommodated
- traffic densities, airspace complexity, runway occupancy time, wake avoidance, and lateral separation will constrain the feasibility of free flight in the terminal environment
- runway preference will be an option for the pilot
- a conflict detection and avoidance automation capability will be available on the ground and in the flight deck
- aircraft separation assurance rests with the ground unless it is advantageous to shift responsibility to the air
- information available to the pilot allows traffic separation to the same degree as VFR operations

The RTCA Free Flight Report indicates that the operational need of free flight is keep protected zones from touching. According to this concept, alert zones can touch but with some level of intervention by the controller. The terminal group used this concept as key assumption in their discussions about free flight in the terminal environment.

Given the definition of the terminal environment under free flight, a set of assumptions, and the RTCA's operational need of free flight concept, the terminal group defined 17 human factors issues associated with free flight in the terminal environment. These have been consolidated into the 15 areas discussed briefly below.

Resistance to Free Flight in Terminal Area

User acceptance emerged as a concern for free flight implementation. There may be resistance to the free flight concept from the aviation participants and/or the flying public. There may also be restrictions placed on free flight in the terminal environment due to environmental issues such as noise abatement.

Requirements for Different Aircraft Capabilities

Mixed equipage in the free flight environment poses a complex challenge for the free flight concept. Specifically, the different requirements for general aviation, military, commercial, and rotocraft aircraft must be fully addressed. Some aircraft may be participating in free flight while others may not. Also, there will be various levels of aircraft equipage in the system. Some operators may have no alert or detection systems. Accordingly, the way in which responsibility is distributed and separation ensured must be examined. Research on a mixed equipage environment must be conducted and requirements for the different aircraft must be established.

Distribution of Responsibility/Mixed Responsibility

In terms of responsibility distribution, the terminal group discussed the responsibility of decision making and information sharing and how that responsibility should be distributed. The discussion was focused primarily on the separation assurance function (SAF) and whose responsibility it is to ensure aircraft separation. The SAF concept is based on the underlying assumption that aircraft separation assurance rests with the ground unless it is advantageous to shift that responsibility to the air. Given this assumption, the distribution of responsibility will by dynamic in nature or event driven. Additionally, in transitioning to the free flight environment, the issue of SAF responsibility, and procedures for establishing responsibility must be investigated.

With regard to shifting roles and responsibilities in a dynamic environment, the issue of pilots and controllers being aware of where responsibility resides is of concern. When the responsibility shifts from one party to another, how will all of the appropriate parties know when that responsibility has been shifted? It is critical that all participants in the aviation system understand their roles and other’s roles at all times. How this understanding of shared responsibility is ensured must be fully resolved.

The group also discussed the issue of authority. Authority becomes an issue when the pilots and controllers have conflicting goals or intentions. Therefore, who has the final decision making authority must be determined.

Another element regarding roles and responsibilities in the terminal environment concerns the requirements for training, technology, and procedures in the free flight environment. The training needs for pilots and controllers in the free flight environment must be addressed. New or different technologies and procedures may be required for this training. Additionally, the impact on selection and performance evaluation procedures for the free flight environment was questioned. The various participants in the free flight system may require different skills than those in the current environment. Therefore, the aviation community may be required to modify the selection criteria currently used.

Given the dynamic roles and responsibilities of pilots and controllers, mixed equipage, and the various levels of free flight in different areas, the issue of how to handle mixed responsibility is of concern. Specifically, the issue is whether the pilot is able to decline or request responsibility for providing his/her own separation. From the pilot’s perspective, there may be times when he/she does not want the added responsibility and resultant workload. This may be particularly true in the terminal environment where the aircraft are closer together and the pilot may be too busy handling the aircraft to assume separation responsibility as well. This raises another issue of how the controller will effectively separate aircraft under his/her control from other aircraft providing their own separation. The confined airspace of the terminal area make this a particularly difficult and important issue.

Arrival Flow

A unique issue regarding the dynamic terminal environment pertains to the arrival flow of aircraft and who is responsible for mediating or arbitrating the arrivals. Specifically the issue of mediating responsibility is of concern when there are two or more aircraft arriving at the same point or when there are “no-fix” arrivals. The workload associated with nonlinear arrivals (and departures) complicates this issue. Given the less predictable and structured traffic flows, the workload of both the pilot and controller may change significantly.

Phraseology/Terminology

The phraseology used by the various parties in the aviation system must be standardized. With the new free flight environment, it is necessary to ensure that effective and standardized phraseology by developed and used consistently. Both pilots and controllers must understand, accept, and consistently use this terminology.

Standardized phraseology applies to automated data exchange as well. There is concern that there will be vast amounts of “intention” data flowing back and forth that will need to be analyzed and reduced for relevant presentation both in the cockpit and the ATC site.

Separation Minima /Display Geometry for Alert Zones

The terminal group discussed the necessity for determining the requirements for airborne separation. In determining the separation minima, controller and pilot workload implications must be considered. Separation minima should be set at a level that limits the time for conflict resolution, but does not reduce safety.

Another human factors issue in the terminal environment concerns the display geometry for the alert zones in the different phases of terminal flight. While in the en route environment, the zones are often referred to as bubble or hockey puck-like in shape. In the terminal environment, a headlight-like shape may be more appropriate. The alert zones must be of sufficient size and shape that controllers and pilots will receive alert information in sufficient time for them to take appropriate action to avoid conflicts. Therefore, in determining these shapes and sizes, reaction times must be considered. The ability to identify conflicts will depend on the display geometry used, the automation developed, alerts and alarms of the future system, and must clearly be based on human capabilities to understand, retain, and act on information.

Training and Equipment Requirements

The terminal group discussed what training and equipment would be needed for pilots and controllers to keep protection zones separated. Analyses using models and prototypes need to be conducted to determine changes in the training requirements.

Transition from Controlled to Free Flight Environment and Vice Versa

In the terminal environment, there is an issue of transitioning from a free flight en route environment to a potentially more controlled terminal environment and vice versa. The description of concerns for shifting responsibilities and information requirements are related. Automation would most likely be employed to assist in this transition.

Failure Modes

For the implementation of free flight concepts, detailed procedures must be found to address automation failure and how to handle such failure in the free flight environment. In the free flight environment, automation will be relied upon heavily. The terminal group specifically considered how to handle a frequency outage under free flight operations (e.g., a stuck microphone switch). Procedures for these rare but realistic problems must be addressed. Therefore, automation failure issues must be addressed with further research.

Allocation of Functions between Pilots, Controllers, and Automation

The allocation of functions was discussed in the terminal group in terms of the possibilities and likelihood of overloading/underloading the various aviation parties. The controller's and pilot's ability to maintain situational awareness requires that the task sharing between controllers, pilots, and automation be clearly understood at all times. All parties must be aware at all times what the other parties are doing.

Increased Terminal Workload

Allowing more aircraft into the en route free flight environment may put more pressure on and increase the workload in the terminal environment. How will free flight flow into the terminal be controlled?

Pilot, Controller, Dispatch, and Automation Coordination

Use of the "team concept" implies additional issues of coordination, integration, and cooperation. It is indicated in the RTCA select committee on free flight report the controller is responsible for keeping the aircraft separated. If the controller has the overlying responsibility of separation, the integration of team cooperation may be complicated. The allocation of functions between pilots, controllers, and the automation, and clarity of these functions (given different situations and dynamic densities) may require special training and/or practice to establish "team" performance. It was suggested that a Crew Resource Management (CRM)-like approach be used for achieving "team" performance.

Information Requirements

With the inevitable changes in the current aviation system, information requirements must be carefully addressed. What information must be available, to whom, and when? Changing information requirements will most likely require a re-distribution of workload. The group suggested that a functional analysis be conducted for the free flight environment that recognizes the system (e.g., pilots, controllers, dispatchers, and automation) and identifies the implications of the re-distributed workload. In terms of automation and information display, in an ideal situation, there would be “seamless” automation meaning that all parties concerned receive the necessary information in the exact same way using the same technology.

Human Factors Certification of the System

The terminal group recognized the need for comprehensive human factors involvement in the design, development, and certification of the free flight system. Further integration of human factors into IPTs is required.

Interoperability of Air/Ground

In order to ensure interoperability of air/ground, the terminal group suggested the use of a human factors checklist and the consideration of system integration during design and evaluation phases.

CONCLUSIONS

This workshop provided a survey of the technical and managerial actions necessary to implement the human portions of free flight requirements. The four working groups generated a great deal of information and issues to consider in developing the free flight concept. The discussions and products of each working group indicated that many of the issue areas are applicable to multiple domains. For example, all four working groups discussed roles and responsibilities in the free flight environment. The information can be categorized into 14 different issue areas (see Appendix B). Of these 14 areas, 13 were addressed by multiple groups.

The working groups came together for a final plenary session and discussed the working groups' findings. Several general conclusions were discussed. These conclusions are summarized below.

Free flight development must entail full consideration of the “people” portion to succeed. Free Flight development and implementation depends upon the full integration of human performance considerations. Efficiency in addressing the various human factors efforts requires extensive collaboration and coordination. Therefore, a central coordination point is needed for the important elements of free flight development represented by “people” (the third leg of the RTCA program).

The designation of a central point of contact and coordination for human factors in free flight should be viewed as the initial step in a process that provides information on the human factors issues to the development work including what is known about the issue, what is not known, how to resolve the unknowns, and where to do the work. Thus, a follow-on activity that identifies, analyzes, filters, and prioritizes the human factors work to be done is needed.

The workshop provided only limited, albeit significant, representation of the larger human factors aviation community. Intentionally, the workshop was conducted as an initial step in the development and integration of human factors in free flight. There are now and will be in the future many other requirements for the coordination and dissemination of human factors free flight efforts. A planned approach to this coordination and dissemination requirement is necessary.

In order to satisfy these actions, formal consideration of the human factors component must be undertaken. The first step in the formal process should include transmittal of the workshop results to the RTCA task force and joint ATR/AAR-100 participation in any agency response to the RTCA work. Other follow-on actions will entail additional coordination.

RECOMMENDATIONS

The findings and conclusion of the workshop provide insight into the challenges associated with human factors and free flight. There were many specific recommendations made for research efforts, however, the major general recommendations are:

1. Designate ATR and AAR-100 as a joint FAA focal point for human performance considerations in Free Flight

2. Charter the FAA focal point with resources and responsibility to:
- further identify, prioritize, and develop essential human factors issues and requirements
- develop a program to systematically monitor critical human factors areas and ensure their resolution
- ensure that human factors efforts supporting free flight development (FAA and industry) are fully coordinated and integrated

3. Charge the focal point to conduct efforts in support of human factors in free flight that:
- expand the coordination effort initiated by this initial workshop
- disseminate findings, conclusions, results, and products related to future developments in free flight human factors

4. Establish formal joint ATR/AAR involvement in agency response and follow-up to RTCA Free Flight developments by:
- Formal transmission of this report to RTCA Free Flight Task Force 3
- Participating in any agency response to the RTCA recommendations
- Participating in future agency free flight developments