U.S. Department of Transportation
Federal Aviation Administration

Aeromedical Research Resume
Research Project Description Subtask for FY00

1. Title: Free Flight: Studies for the Integration of General Aviation	***2. Sponsoring Organization/Focal Point (FP)*** AIR-3; Nancy Lane AAM-1; J. Jordan, M.D. AFS-400; R. Wright (FP) AND-710; P. Hwoschinsky AAR-100; R. Simmons	***3. Originator Name, Organization, Phone :AAM-510; 405-954-6826*** Kurt M. Joseph, M.S. AAM-510, (405) 954-9155
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8. Parent MNS: 187	***9. RPD Manager Name, Organization, Phone:*** David J. Schroeder, Ph.D. AAM-500, FAA Civil Aeromedical Institute (405) 954-6825	

10. Research Objective(s):

Identify and evaluate issues that concern the general aviation (GA) pilot and arise as a direct consequence of the change from the current NAS to the concepts associated with Free Flight (FF). In particular, identify those combinations of equipment, flight segment, traffic density and type of airspace that offer promising approaches to FF concept developments and those that do not. Specific circumstances and combinations of variables leading to success or failure of the criterion of maintaining separation assurance will be detailed and evaluated. Another objective of this research is to ensure that FF system concepts and variations tested are based on clearly defined NAS functional and performance requirements for a particular set of FF operations, rather than being influenced exclusively by technology that is available at a point in time, by air transport needs and preferences, or by political / organizational factors. A key issue in this research project is, “Can the separation assurance function (SAF) in a FF system be shared or shifted in real time between the pilot and controller, each supported by a particular level of automation within GA mission structures”.

11. Technical Summary:

The development of a functional architecture for traffic flow management (TFM) is an important step in the proposed technical approach. Here, human factors payoffs can be realized by identifying human performance measures (e.g., workload) and criteria for discriminating among candidate FF system concepts, and by evaluating those candidates through analytic and computer-based, flight-simulation research. Accordingly, a GA FF system and function analysis will be conducted to identify the specific tasks and conditions that are performed in the following FF mission segments: (a) low-level en route; (b) transition from en route to terminal airspace; and (c) transition from terminal airspace to the airport traffic area (i.e., tower). These analytical data will be used to identify and specify information and display requirements and to develop experimental protocols for use in real-time simulation provided by a GA aircraft cockpit integrated with an ATC workstation. Fundamental to the technical approach used here is the acknowledged need to perform a “front-end” analysis that ensures understanding of NAS system implications and protects against “sub-optimization” of FF system design.

12. Resource Requirements:

	FY 99	FY 00
FAA Staff Years	3.0	3.0

13. Description of Work:

(2) Brief Background

The National Airspace System (NAS) has been unable to keep pace with current demands and will continue to degrade as the level of air traffic increases over the next several years. According to the report of the RTCA Select Committee on Free Flight, the NAS is plagued with insufficient capacity, limited access, and excessive operating restrictions that have escalated operating costs, increased delays, and generally decreased efficiency. FF is briefly defined as "A safe and efficient flight operating capability under IFR in which operators have the freedom to select their paths and speeds in real time." The major functional requirement that must be filled irrespective of FF approach is the "Separation Assurance Function" (SAF), or the assurance that aircraft separation be maintained at all times. Three events requiring control during FF operations involve (1) tactical [short-term] conflict resolution, (2) traffic flow management (TFM), and (3) entry into special use airspace (SUA). The primary difference between the current system and the FF concept is that, under certain conditions, GA pilots will be able to operate their flights without specific route, speed, or altitude clearances.

FF concepts will require redefinition of the role, responsibility, and authority of pilots and controllers in maintaining aircraft separation under conditions of uncertainty. Roles and responsibilities are likely to be dynamic during flight, with shifts between primary system components. Successful operation of the FF system will depend upon the development of new rule-based procedures and guidelines that provide for smooth and timely transition depending upon existing operational conditions and circumstances. FF for GA crewmembers will lack the dispatcher or "company" component of the air transport system. This entity helps to perform flight planning and flight following functions. In the current system, flight service stations (FSS), transcribed weather, and pilot reports (PIREPS) help the GA pilot with those functions. Concepts for GA FF systems will need to recognize these functional requirements, particularly if the FSS are discontinued or become highly automated.

(*2) Statement of Work*

The proposed technical approach is guided by the systems engineering principle of establishing functional requirements and operating conditions as a prerequisite to developing and evaluating candidate system designs. This "front-end" analysis will produce various FF system concepts that can be simulated in conjunction with varying levels of automation, in the cockpit and/or on the ground, and evaluated against criterion levels of performance. Other criteria will need to be addressed that involve the performance of airborne (e.g., pilot) and ground-based functions (e.g., ATC and TFM). For example, optimizing the surveillance function to meet a particular SAF requirement cannot result in degraded performance of tasks related to other functions (e.g., navigation and communication). A general hypothesis is that procedures and equipment can be developed to allow GA aircraft to operate safely and effectively in a FF environment.

Task 1: Perform Human Factors Analysis of FF Operational Concepts.

Use information from the Safe Flight 21 to identify and specify proposed technological devices, and the associated enhancements in functional capability that these devices will afford GA pilots. Emphasis should be placed on the enhanced functional capability provided by use of digital data-link communication (e.g., FIS), augmented satellite navigation (e.g., GPS), and airborne surveillance technology (e.g., ADS-B). Technical information may need to be gathered from various sources, including avionics manufacturers, and survey data may need to be gathered to determine the extent of GA pilot familiarity with technological concepts (e.g., using GPS as a primary means of navigation). AOPA (1999) estimates indicate that about half of the GA aircraft fleet is equipped with some type of Global Positioning System (GPS) device.

Enhanced functional capabilities should be described in a common framework that reveals their impact on GA pilot functions and tasks. The framework should be designed such that it yields several important questions that can serve as input for Task 2. For example, how would GA pilots use the greater navigation precision afforded by GPS to achieve the prescribed limits that would be imposed by concepts such as Required Navigation Performance (RNP)? How would GA pilots use surveillance information that is derived from ADS-B to perform tasks such as station keeping? How would GA pilots use data-link flight information services to avoid risky flight conditions (e.g., weather, etc.)? This task was completed FY97Q2. The primary outcomes were a functional analysis, which was based on a GA, IFR mission, and three GA free flight system concepts whose underpinnings evolved from variations in assignment of functions to pilot/ATC/automation.

Task 2: Analyze FF Pilot-System Functional Relationships.

Use the output from Task 1, along with bottom-up analytical techniques, to illustrate functional relationships between proposed technological devices and GA pilot mission goals. Several functional relationships may exist for each of the questions posed in Task 1. For example, GA pilots may use several different equipage configurations to achieve similar navigation performance requirements for a particular environment. When this is the case, assessing the costs and benefits to performance of each configuration should identify the best functional relationship. Identification and specification of these relationships should be based on information provided by GA pilots, and will require appropriate use of methods (e.g., structured interviews, cognitive walkthroughs) for eliciting information. The survey data from Task 1 may be useful for establishing the breadth and depth of questions that should be asked during the information elicitation process.

A suitable framework should be utilized to map and illustrate functional relationships. Several frameworks exist, including Rasmussen's “means-end hierarchy”, which is consistent with a bottom-up analysis of functional relationships. Selection or development of a specific framework for illustrating functional relationships must be amenable to Task 3 protocol development. Formatting consideration also should be given to use of this information for the design of functional interface concepts. This task was completed FY98Q3 and included an analysis of the functional relationships between technological devices and GA pilot mission goals for Scenario 4 in the Flight 2000 initial program plan. GA free flight system concepts that vary assignment of command and control related functions (i.e., communication, navigation, surveillance) to pilot/ATC/automation were developed.

Task 3: Create Protocols for GA FF Simulation Study.

Develop experimental protocols to test and evaluate, via real-time simulation, the various candidate approaches for fulfilling GA pilot functional and task requirements. Protocols will focus on defining the bounds of those independent variables that are highly deterministic of FF system outputs; that is, levels of traffic, weather, pilot proficiency, and so forth, which may combine to cause degradation in performance and loss of SAF. An important test of the variable allocation of SAF would be embedded within a research protocol that includes a shift in responsibility for the SAF to the aircraft and a return shift to ATC due to increased traffic density. Experimental protocols will assume some means for displaying traffic information (e.g., CDTI) that is sensed by ground- and satellite-based surveillance radar and transmitted via data link. This task was completed FY98Q4. Products included several empirical questions that can be resolved using cost effective, AGARS-based simulations of a Flight 2000 GA mission scenario.

Task 4: Identify Common Information Requirements of GA Pilots and Air Traffic Service Personnel for Use in Decision Support System Development.

Interdependencies (via communication links) in flight planning and mission execution between pilots and air traffic service providers (i.e., ATC, FSS) will be described and analyzed with respect to common information access and decision-making requirements. This functional description will be contextually anchored to a typical GA IMC flight scenario. Candidate scenarios are available for AAL, ASW, and ANM Regions. The framework for functional descriptors will be such that the impact of emerging technological resources for Decision Support Systems (DSS) and Collaborative Decision Making (CDM) can be defined.
Because the goal is to provide pilots and air traffic service providers with access to the same flight planning information for decision making and mission execution, task-analytic techniques will be used to determine interdependencies and achieve a description that is suitable for developing team-centered procedures.

Methods described in Sage and those in Wickens will be relied upon extensively for completion of this task. While Wickens et al. (1998) is generally "ATC-centered," this task will produce several team-centered concepts for a DSS, all of which foster collaboration between pilots and controllers relative to potential role and responsibility changes associated with evolving technology-driven Free Flight concepts. The DSS concepts will be compared to those of avionics vendors to the extent that the software contained in the latter can be modified to achieve team-centered DSS criteria. These concepts will be provided in the form of display/control specifications for an interface that could be evaluated using AGARS flight simulations.

Task 5: Identify Information Requirements for Traffic Awareness in the Free Flight Environment.

Comprehensively examine, review, and critique the extant SA literature, with emphasis on research that specifically addresses pilot surveillance functions for the air carrier cockpit. The review must be balanced in that particular theories, research methods, and data should not be excluded at the expense of others. Research reports that contain terms such as "terrain awareness", "spatial awareness", "weather awareness", etc. should be included in the literature review. Research that doesn't mention SA per se, but does focus on topics associated with pilot surveillance functions (e.g., collision avoidance, graphical display of weather) should be examined for relevance. The review should clearly illustrate specific issues that have been of significant concern in past research and those that are important yet have received little, if any, consideration.

Identify and classify information requirements for all pilot surveillance functions in FF. The Function Allocation Issues and Tradeoffs (FAIT) method, which was developed and used by Riley (1989; 1997), should be used to complete this task. Several questions should be considered during completion of this task. 1) What information is required for pilots to perform surveillance functions? If it exists, a distinction should be made between information that is necessary and that which is currently available in most air carrier cockpits. For example, although weather information is currently available in many cockpits, refresh rates, information formats, and accuracy of data may greatly constrain a pilot's ability to remain safely separated from dangerous weather. Identification of constraints and how they affect performance would be useful in identifying research that targets specific limitations. 2) How do pilots currently perform surveillance functions? The answer to this question will require an examination of how functions are performed across a continuum of modes, ranging from manual (e.g., see-and-avoid) to automated [e.g., Traffic Alert Collision Avoidance System (TCAS)]. Differences resulting as a function of performance mode must be elaborated as these can be used to target limitations associated with specific performance modes. 3) How could technology be improved to benefit pilot performance of surveillance functions? Gaps in the extant literature, omission of critical information requirements in existing displays, and limitations associated with specific performance modes should be classified using a scheme that is both comprehensive and comprehensible. Assumptions about technology should be based on functional requirements associated with FF conceptual proposals related to NAS Modernization. Established and acceptable scientific methods for structuring and analyzing data should be applied as necessary.

Task 6: Conduct Initial GA FF Simulation Study.

Use AGARS simulations to compare pilot performance in current NAS and the proposed FF environment. The products of this study would involve preliminary data on pilot ability to perform the primary functions of navigation, communication, and surveillance under a limited set of flight and traffic density conditions. Primary dependent variables (as noted above) would be degradation in the SAF function as measured by the number of interventions required by ATC due to conflict alerts, and changes in workload attributable to operation in the FF environment. Also of interest would be the number of information-transfer events between aircraft and ATC. Although there might be fewer control communications, there may be more advisory communications. This could be a bilateral issue in which both the pilot and ATC necessarily engaged in the "Be Advised" communication form.

Task 7: Conduct Follow-on Studies.

Design of follow-on studies will be responsive to needs for testing additional concepts, configurations, alternatives and variations in surrounding operational environments. The resulting data will provide a basis for development of FF design guidelines for hardware, software, and procedures for promising cockpit systems. Although the focus of this project is on the cockpit interface, useful data on ATC functions will be obtained under the conditions simulated. The degree to which ATC issues are considered will depend upon the extent to which high fidelity, ATC simulation can be conducted jointly and in real time with cockpit simulation.

Task 8: Report Findings and Recommendations.

This task involves the periodic and continuing effort of organizing findings to address priority questions and issues, and providing recommendations as to design approaches, conditions, configurations, and policies that tend to optimize the human role in FF systems, both in the air and on the ground.

14. Intended End Products/Deliverables:

End products will include (1) information and task requirements data for various mission profiles; (2) software developments and protocols for real-time simulation of alternative FF system concepts; (3) objective performance data reflecting pilot (and controller) performance as a function of a specified scenario; (4) various recommendations concerning pilot proficiency and training, cockpit design and layout, and operating procedures with respect to specific FF system alternatives; and (5) recommendations for future directions in FF system design including perceived requirements for future technological advancements in air and ground capability, pilot training, and system design, as well as for further simulation research.

15. Schedule/Milestones:

Task 1: Perform Human Factors Analysis of FF Operational Concepts	Completed 97Q2
Task 2: Analyze FF Pilot-System Functional Relationships	Completed 98Q3
Task 3: Create Protocols for GA FF Simulation Study	Completed 98Q4
Task 4: Identify Common Information Requirements of GA Pilots and Air Traffic Service Personnel for Use in Decision Support System Development	99Q4
Task 5: Information Requirements for Traffic Awareness in the Free Flight Environment	99Q4
Task 6: Conduct Initial GA FF Simulation Study	00Q1
Task 7: Conduct Follow-On Studies	00Q3
Task 8: Report Findings and Recommendations	00Q4

16. Procurement Strategy/Acquisition Approach/Technology Transfer

This project will be supported by a contractual effort, particularly in the performance of Task 4 to obtain information requirements data. Other contracts may be awarded during FY00 to deal with specialized issues or questions such as the development of decision aiding tools, design and/or procurement of specific displays, identification of training requirements, software development, etc. Guidance has been obtained from meetings and documentation produced by the FAA Safe Flight 21 program, FAA Free Flight Phase 1program, SAE G-10W Subcommittee on Free Flight, and RTCA, Inc. Technology transfer will likely occur through such avenues as Integrated Product Teams (IPTs), joint FAA/industry working groups, specialized issue groups, and through the preparation and promulgation of requirements and guideline documents providing human factors specifications, standards, and procedures for the various FF conceptual developments tested. Procurements will support the acquisition of $30K in avionics devices and software necessary to simulate the FF concept.

17. Justification/History:

The notion of FF within the NAS presents a number of critical human factors issues and problems, as have been noted and discussed in previous sections of this ARR. These issues are consistent with those identified in the publications of other FF working groups, including the SAE G10W FF Subcommittee's Aerospace Resource Document *Human Factors Issues in Free Flight*, the *Human Factors Action Plan for Free Flight Phase 1*, the Safe Flight *21 Test and Evaluation Master Plan* for the CAA ADS-B Operational Evaluation, the FAA's *Concept of Operations for the NAS in 2005,* and the RTCA Modernization Task Force. If GA is to make use of the savings and improvements that are promised by FF, the integration of GA missions and circumstances into the FF environment must be considered in a timely fashion, along with issues relevant to the air transport community. For example, within proposed FF environments there is a critical need to identify information requirements, the manner in which information is presented to pilots, and how pilots use this information in aviating, communicating, navigating, and surveillance. This research project recognizes the need to include GA requirements in FF system design. Furthermore, it presents a systematic plan for considering such requirements in real-time simulation research intended to support ongoing projects in the FAA's Safe Flight 21 and Free Flight Phase 1 programs.

18. Issues:

The salient questions associated with the concept of FF are where and under what conditions should the responsibility for separation assurance be assigned? Should it be ground based, aircraft based, or a joint responsibility shared by ATC and the pilot? This research proposal assumes that the SAF will not be assigned as the sole responsibility of any one entity. Rather the SAF is likely to be shared between ground and air, depending upon circumstances and/or limitations of GA missions, which are the subject of this research project. A further issue in the development of a FF capability is the degree to which there is an integrated human factors structure. A systematic and structured approach to integrating human factors considerations in extra-agency developments related to FF is imperative, as is the internal technical implementation of FF operational concepts. Expert human factors involvement at every stage of FF development is needed to identify and resolve the basic human-machine interface requirements that attach to any one conceptual approach, and to transitions among concepts during FF operations. Support for human-centered, performance-based analyses and human in-the-loop engineering and simulation must be forthcoming.

Because this research involves the use of human participants serving as pilots and ATCS's in the CAMI flight simulation facility, research protocols will be submitted for review and approval by the FAA Institutional Review Board (IRB) to ensure that proper consideration and protection is afforded the human participants.

19. Transition Strategy:

A joint industry/FAA steering group will undoubtedly develop and cautiously guide an evolutionary strategy for the transition from the current NAS to a FF environment. The ongoing Advanced General Aviation Transport Experiments (AGATE) program and associated FF objectives will provide a highly lucrative transition customer. FF concept test areas are likely to be established in low-density traffic areas, which may include representations of enroute, terminal, and tower control entities. These may not be actual facilities but simulated ones located at specified geographical points for purposes of system and operational testing of various FF system concepts. Regulatory action also will be required, at least on a temporary basis, to facilitate efforts to transition FF concepts to the operational domain.

20. Impact of Funding Deferral:

The human factors implications and potential impact of the various FF concepts on the GA pilot and the air traffic controller are critical to the test and evaluation of such concepts, and to the process of implementing them operationally. Continued development of FF without commensurate investments in closely coordinated human factors engineering (HFE) design, development, and test efforts related to GA circumstances and requirements will result in sub-optimized FF system performance at the very best. A lack of investment in HFE is more likely to result in major performance decrements in the NAS, including impaired system effectiveness, increased risk and compromised safety. Deferred funding of carefully conceived, planned, and executed HFE support could easily result in the complete failure of the FF system concept.

21. R&D Teaming Arrangements:

Coordination will be maintained with other agencies and activities currently involved in conducting FF human factors research such as the SAE G-10W Subcommittee on Free Flight, FAA William J. Hughes Technical Center, NASA, MITRE, and the National Research Laboratory in the Netherlands. The possibility of teaming with another agency, industry, or university group has been pursued, and will be used to align current efforts with the Concept of Operations for the NAS in 2005. The AGATE program also presents several opportunities for coordinating or teaming with industry partners in the development of flight systems and pilot training requirements that would facilitate the development and test of innovative GA aircraft systems.

22. Special Facility Requirements:

CAMI's GA Flight Simulation Facility will be required for this study. Depending upon the level of technology to be represented in the cockpit, either the BGARS or AGARS flight simulator will be available. AGARS provides for rapid prototyping of cockpit displays to represent highly innovative multi-function displays. Furthermore, AGARS incorporates an on-line ATC workstation that will be employed.

***23. Approvals (Signature Authority)*:**	***Project Revalidation***	***Performing Organization***
Nancy Lane Special Assistant to the Director Aircraft Certification Service (AIR-3)	Date	William E. Collins, Ph.D. Director, FAA Civil Aeromedical Institute, AAM-3
Jon L. Jordan, M.D. Federal Air Surgeon, AAM-1	Date	Date