

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

AD A 0 4 9 7 4 3

ASD-TR-77-76

12

✓

JDC FILE COPY

**INVESTIGATIONS TO SUPPORT PHASE I OF
THE USAF MIDAIR PREVENTION SYSTEMS
(MAPS) PROGRAM**

*ARINC RESEARCH CORPORATION
2551 RIVA ROAD
ANNAPOLIS, MARYLAND 21401*

DECEMBER 1977

DDC
RECEIVED
FEB 8 1978

F

TECHNICAL REPORT ASD-TR-77-76
Final Report for Period June 1977 – November 1977

Approved for public release; distribution unlimited.

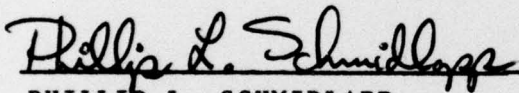
AVIONICS AND AIRCRAFT ACCESSORIES SPO
DEPUTY FOR AERONAUTICAL EQUIPMENT
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433

NOTICE

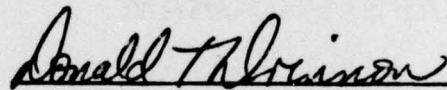
When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

This report has been reviewed by the Information Office (OI) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.



PHILLIP L. SCHMIDLAPP
Project Engineer
Directorate of Equipment Engineering



DONALD T. DRINNON, Major, USAF
Program Manager
Avionics & Acft Accessories SPO

FOR THE COMMANDER



EDGAR J. BARTHEL
Chief Engineer
Avionics & Acft Accessories SPO

"If your address has changed, if you wish to be removed from our mailing list, or if the addressee is no longer employed by your organization please notify ASD/AEAI, W-PAFB, OH 45433 to help us maintain a current mailing list".

Copies of this report should not be returned unless return is required by security considerations, contractual obligations, or notice on a specific document.

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER (18) ASD-TR-77-76	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER <i>rept.</i>
4. TITLE (and Subtitle) (6) INVESTIGATIONS TO SUPPORT PHASE I OF THE USAF MIDAIR PREVENTION SYSTEMS PROGRAM (MAPS)	5. TYPE OF REPORT & PERIOD COVERED (9) Final June 1977 - Oct 1977	6. PERFORMING ORG. REPORT NUMBER (14) 1924-01-1-1676
7. AUTHOR(s) (10) F. Crum, K. Haspert, S. Kowalski, N. Sullivan J. Underwood	8. CONTRACT OR GRANT NUMBER(s) (15) F 09603-77-A-3104 <i>new</i>	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
9. PERFORMING ORGANIZATION NAME AND ADDRESS ARINC Research Corporation 2551 Riva Road Annapolis, Maryland 21401	11. CONTROLLING OFFICE NAME AND ADDRESS Dept. of the Air Force Aeronautical Systems Division (AFSC) Wright-Patterson AFB, Ohio 45433	12. REPORT DATE (11) October 1977
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) ATTN: Code ASD/AEAI (12) <i>110p.</i>	13. NUMBER OF PAGES 110	15. SECURITY CLASS. (of this report) Unclassified
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) midair collision, near midair collision, midairs, airmiss, midair prevention system, MAPS, MAC, NMAC, hazardous air traffic reporting system, HATRS		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The objectives of the study presented in this report were to: (1) further define USAF requirements and objectives in reducing midair collisions; (2) establish organizational relationships and participation in midair pre- vention efforts; (3) investigate possible alternative methods to reduce USAF midair collisions; and (4) further define follow-on phases of the Midair Pre- vention Systems (MAPS) program that the USAF could undertake to reduce midair collision potential. <i>→ next page</i>		

DDC
RECEIVED
FEB 3 1978
RESOLVED
F

DD FORM 1 JAN 73 1473

EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)


400 247

JB

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

→ This report provides background information and analysis on the midair collision experiences of the USAF from 1968 through June 1977 and the near midair collision experiences from 1975 through June 1977. The midair and near midair collision information is analyzed from many different aspects such as altitude, type flight plan, category of aircraft, mission activity, commands, and phase of flight. Midair collision programs were identified and actions that could be taken by the USAF to reduce midair collision potential are specified.

This report also identifies various organizations that would be involved with the USAF midair problem and identifies their relationships in attempting to reduce the midair potential. The report also discusses the FAA and civilian viewpoints and activities as they relate to midair collision prevention.



Unclassified

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

PREFACE

This study initiates the USAF Midair Prevention Systems (MAPS) Program and is an outgrowth of the ASD Strobe Light Evaluation (ASD-TR-77-33). Three more major program phases are anticipated. The work and results of each phase will be reported in an ASD Technical Report at the end of each program phase. Technical Reports will also be published covering specific task areas in each phase and will be documented in the overall phase Technical Report.

Copyright © 1977

ARINC Research Corporation

Prepared under Contract F09603-77-A-3104, which grants to the U.S. Government a license to use any material in this publication for Government purposes.

ACCESSION	on	<input checked="" type="checkbox"/>
NTIS		
DDC	Bill Section	<input type="checkbox"/>
MANAGING D		<input type="checkbox"/>
J S I		
BY		
DISTRIBUTION/AVAILABILITY CODES		
SPECIAL		
A		

TABLE OF CONTENTS

CHAPTER ONE: INTRODUCTION. 1

 1.1 Background 1

 1.2 Program Approach 2

 1.3 Report Content 3

CHAPTER TWO: ORGANIZATIONAL RELATIONSHIPS 5

 2.1 Introduction 5

 2.2 Internal Air Force Organizations 5

 2.2.1 Headquarters USAF 5

 2.2.2 Air Force Inspection and Safety Center . . . 7

 2.2.3 Air Force Systems Command 8

 2.2.4 Air Force Communications Service 8

 2.2.5 Air Force Logistics Command 9

 2.2.6 Air Force Test and Evaluation Center 9

 2.2.7 Major Commands 9

 2.3 Organizations External to the Air Force 9

 2.3.1 Federal Aviation Administration 9

 2.3.2 National Transportation Safety Board 10

 2.3.3 NASA Aviation Safety Reporting System 11

 2.3.4 National Associations 11

 2.3.5 DoD Advisory Committee on Federal
 Aviation 11

 2.3.6 Army Aviation Organization 12

 2.3.7 Naval Aviation Organization 12

 2.4 Summary 12

CHAPTER THREE: DATA ANALYSIS AND PROBLEM DEFINITION 15

 3.1 Introduction 15

 3.2 Data Collection 15

 3.2.1 Literature Search 15

 3.2.2 Air Force Inspection and Safety Center
 Data 16

 3.3 Analysis of Near Midair Collision Data 16

 3.3.1 NMACs by Geographical Area 17

 3.3.2 NMACs by Category of Aircraft Encountered . 18

 3.3.3 NMACs by Command 22

 3.3.4 NMACs on Low Altitude and Olive Branch
 Training Routes 26

PRECEDING PAGE BLANK-NOT FILLED

3.3.5	NMACs by Flight Activity	28
3.3.6	NMACs by Type of Flight Plan Filed	28
3.3.7	NMACs by Cause	31
3.3.8	Miscellaneous Data on NMACs	33
3.3.9	NMAC Situation in USAFE	33
3.4	Analysis of Actual Midair Collision Data	40
3.4.1	Introduction	40
3.4.2	Types of Midair Collisions	41
3.5	Comparison of Actual and Near Midair Collisions: Nonassociated Flying	43
3.5.1	Geographical Area	44
3.5.2	Category of Number Two Aircraft	45
3.5.3	Commands	46
3.5.4	Cause.	46
3.5.5	Flight Activity	48
3.5.6	Time of Occurrence	49
3.5.7	Type of Flight Plan	50
3.6	Data Summary	51
CHAPTER FOUR: CIVILIAN VIEWS AND ACTIVITIES		53
4.1	Civilian Assessments of the Collision Problem	53
4.2	Current FAA Activities	55
4.3	Research and Development Efforts	56
4.3.1	Historical Background	56
4.3.2	Current Programs	59
4.3.3	User Community Views	59
4.3.4	Technical Considerations	61
CHAPTER FIVE: BASIC CONCEPTS AND USAF ACTIONS		65
5.1	Introduction	65
5.2	Basic Problem	65
5.3	Equipment	67
5.3.1	Non-Cooperative Collision Avoidance System (NCAS)	67
5.3.2	Cooperative Collision Avoidance System (CAS)	68
5.3.3	Discrete Address Beacon System/Automatic Traffic Advisory and Resolution Service (DABS/ATARS)	68
5.3.4	Air Training Command Collision Avoidance System (ATC CAS)	68
5.3.5	Radars in Europe	69
5.3.6	Visual Enhancement	69
5.3.7	Simulators	69

5.4	Aircrew Procedures	70
5.4.1	Improve See-and-Avoid Capabilities	70
5.4.2	Determine Impact of Changing Tactical Call Signs	71
5.4.3	Evaluate Aircrew Workload	71
5.4.4	Increased Use of Airborne Radars for Midair Prevention	72
5.5	System Control Procedures	72
5.5.1	Determine Best Low Altitudes for USAF to Fly	72
5.5.2	Determine Best Airspeeds for USAF Aircraft Below 10,000 Feet	72
5.5.3	Investigate Trade-Offs Between Maximum Use of IFR Flight Plans and Using See- and-Avoid Techniques on VFR Flight Plans . .	73
5.5.4	Reduce Instrument Approach Plate Complexity.	73
5.5.5	Investigate the Use of Mandatory Avoidance Vectors Away from Unknown Traffic	73
5.6	Training	74
5.6.1	Develop Techniques and Methods to Better Teach See-and-Avoid	74
5.6.2	Teach Use of Outside Reference for Pitch, Bank, and Heading Control	75
5.6.3	Determine Impact of F-15 and F-16 Air-to- Air Roles on Midair Collision Potential . .	75
5.6.4	Examine Ways to Reduce the Potential for Midair Collisions on Low-Altitude Training and Olive Branch Routes	75
5.6.5	Review Formation and Air Refueling Requirements, Procedures, and Techniques . .	76
5.7	Other Activities	76
5.7.1	Investigate the Establishment of a Joint Midair Working Group	76
5.7.2	Improve the Information Exchange Between the USAF and the General Aviation Community	77
5.7.3	Drone Unique Requirements	77
5.7.4	MAPS Program Integration	77
CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS		79
6.1	Conclusions	79
6.1.1	Near and Actual Midair Collision Data	79
6.1.2	Air Force-Air Force NMACs and MACs	79
6.1.3	Air Force-Air Carrier NMACs and MACs	79
6.1.4	Air Force-General Aviation NMACs and MACs .	80

6.1.5	NMACs and MACs by Flight Activity and Altitude	80
6.1.6	NMACs and MACs on Military Low-Level Training Routes and Olive Branch Routes	80
6.1.7	NMACs and MACs by Air Force Commands	80
6.1.8	NMACs and MACs by Cause	81
6.1.9	Formation and Associated Air Force Flying	81
6.2	Recommendations	81
6.2.1	Overall Recommendation	81
6.2.2	Specific Recommendations for Phase II Activities	81
6.2.3	Other Recommendations	83
REFERENCES	85
APPENDIX A: MISCELLANEOUS NMACs DATA	87

FIGURES

2-1 Air Force Organizations Cooperating with MAPS 6

2-2 Organizational Responsibilities/MAPS Coordination 13

3-1 NMACs by Category of Number 2 Aircraft (Jan 75-June 77) . . 19

3-2 NMACs by Flight Activity of Number 1 Aircraft 29

3-3 NMACs by Flight Plan 30

3-4 NMACs by Cause 32

3-5 USAFE NMACs by Flight Plan 35

3-6 Formation Midair Collisions 42

3-7 Total Nonassociated Midair Collisions by Flight Activity . 43

3-8 Nonassociated Midair Collisions with Civilian Aircraft by
Flight Activity of AF Aircraft 43

4-1 BCAS Program R&D Schedule 60

A-1 NMACs by Radar Stage Available 90

A-2 NMACs by Factor Sighted 91

TABLES

3-1	Number of NMACs by Geographical Area	18
3-2	Average Flying Hours per NMAC by Geographical Area	19
3-3	Altitude of NMACs with Air Carriers	21
3-4	Primary Cause of NMACs with Air Carriers	21
3-5	NMACs per Flying Hour by Command	23
3-6	Comparison of Critical Eleven Minutes and NMACs	31
3-7	USAFE NMACs by Phase of Flight	34
3-8	Comparison of USAFE and Total Air Force NMAC Causes	36
3-9	Controller and Pilot Error in USAFE NMACs	36
3-10	USAFE NMACs by Country	37
3-11	Total Midair Collisions	42
3-12	Air Refueling Midair Collisions by Aircraft Type	42
3-13	Number and Rate of Nonassociated Midair Collisions	44
3-14	MACs and NMACs by Geographical Area	44
3-15	Comparison of CONUS and USAFE Nonassociated MACs	45
3-16	Comparison of Category of Number 2 Aircraft NMACs and MACs	45
3-17	Comparison of Category of Civilian Aviation NMACs and MACs	46
3-18	Comparison of MACs and NMACs by Command	47
3-19	Comparison of MACs and NMACs by Cause	47
3-20	Comparison of MACs and NMACs by Flight Activity	48
3-21	Comparison of MACs and NMACs by Altitude	49
3-22	Comparison of MACs and CONUS NMACs by Time of Day	49
3-23	MACs by Time of Day and Category of Aircraft Encountered	50

TABLES (CONT.)

3-24	Comparison of Air Force Flight Plan and MACs and NMACs . . .	50
A-1	NMACs by Transponder Usage	89
A-2	NMACs by Radar Service Available	89

MANAGEMENT SUMMARY

1. INTRODUCTION

The purpose of the five-month (June-October 1977) project described in this report was to define the Air Force midair collision problem, formulate concepts to reduce midair collision potential, and prepare materials defining follow-on program phases, including drafts of Statements of Work and information for a Program Management Plan.

The work was performed by ARINC Research Corporation for the Avionics and Aircraft Accessories System Program Office, Aeronautical Systems Division (ASD), Air Force Systems Command, Wright-Patterson AFB, Ohio. That Program Office has management responsibility for the Midair Prevention Systems (MAPS) Program. The MAPS Program, which resulted from an ASD recommendation, is a systematic, thorough approach to considering all aspects of midair collision prevention. The program was divided into three phases. Phase I was a planning phase during which a management plan and tasking requirements for the long-term program were to be prepared. Initial problem definition and cost and schedule estimates were also to be developed. The work described herein is a part of the Phase I effort.

Previous Air Force midair prevention efforts were fragmented and addressed limited areas. As examples, one effort involved collision avoidance hardware; another, strobe lights; and a third, aircraft paint schemes. Therefore, we were also to consider efforts currently being conducted and the organizational relationships between the performing activities.

2. DATA COLLECTION AND ANALYSIS

The primary source of data on near and actual midair collisions was the files of the Air Force Inspection and Safety Center at Norton AFB, California. Data from that source were supplemented by information obtained during trips to the major Air Force flying commands and to HQ USAF and Navy offices concerned with midair prevention. Visits were also made to the offices of the Federal Aviation Administration. In addition, when it was determined that the U.S. Air Forces in Europe (USAFE) were experiencing unique midair collision potential problems, a trip was made to Germany to collect USAFE-peculiar information.

The collected data were analyzed from several different perspectives. These were, first, the characteristics of the near midair collisions; then the characteristics of the actual midair collisions; and finally, a comparison of the two. Our objective was to identify as many characteristics of near and actual midair collisions as possible; however, in some instances the data were inconclusive. In other instances, the information was of such significance that further study or recommended actions were in order.

3. BASIC CONCEPTS AND USAF ACTIONS

After the data-analysis phase was completed, basic concepts and actions that the USAF should explore to reduce the midair collision potential were developed. Because all aspects of the problem were considered, a very wide range of actions was formulated and divided into the following five categories:

- Equipments
- Aircraft Procedures
- System-Control Procedures
- Training
- Program Integration

4. PROPOSED STATEMENTS OF WORK AND PROGRAM MANAGEMENT PLAN

Tasks included in the above categories were then evaluated for their potential to reduce the midair collision threat. We examined alternative methods for technical development and acquisition with their cost impacts. The task list, including recommendations for organizational responsibility for task completion, estimated cost, and a time-phased development cycle, became the basis for the Program Management Plan (PMP). For the majority of tasks, for which information was available in sufficient detail, proposed statements of work were also prepared.

Information for the Program Management Plan and draft statements of work for the recommended tasks were provided to the Air Force in a separate report. The reasons for this are twofold. First, the Air Force wanted no restrictions on dissemination of this report. Including drafts of proposed statements of work and estimated costs and schedules for tasks which may be performed contractually under competitive procurement could understandably restrict dissemination. Secondly, the inputs to the Program Management Plan had not been coordinated within the Air Force. Therefore, additional internal Air Force review was required before they could be disseminated.

5. DEFINITIONS

Before presenting the conclusions resulting from the data analysis and the actions recommended for the Air Force to undertake, the following definitions are provided:

- Near Midair Collision (NMAC) - An unplanned event in which the aircrew of an aircraft took abrupt evasive action to avoid a midair collision, or would have taken evasive action if circumstances had permitted.
- Midair Collision - An accident or incident occurring between two or more aircraft during flight, where flight is defined as all operations between the beginning of the takeoff roll and the end of the landing roll.
- Associated Flying - Flight involving two or more aircraft operating in a limited airspace; each aircraft is aware of the presence of, but not necessarily the exact location, of the other.
- Nonassociated Flying - Flights where the aircraft involved are not both aware of each others' presence.

6. CONCLUSIONS

Air Force aircraft were involved in 301 midair collisions during the nine and one-half years from January 1968 through June 1977. In addition, during the two and one-half years from January 1975 through June 1977, Air Force aircraft were involved in 376 near midair collisions. On the basis of this experience and additional analysis contained in this report, it is concluded that the Air Force does have a midair collision prevention problem.

6.1 Near and Actual Midair Collision Data

The near midair collision (NMAC) data being collected and formulated by the Air Force Inspection and Safety Center are extremely valuable in identifying the characteristics of NMACs, and in many areas the data correlate closely with the data related to actual midair collisions. The NMAC and MAC data would be easier to use and more meaningful comparisons could be made if the two separate files were restructured to include command data elements and retrievability codes.

6.2 Air Force-Air Force NMACs and MACs

Air Force aircraft are experiencing a higher number of MACs with other Air Force aircraft than would be expected from the number of NMACs being reported. Approximately 75 percent of all Air Force MACs are with other Air

Force aircraft, while only 12 percent of the NMACs are with other USAF aircraft. The majority of the MACs occur during relatively high risk operations such as air refueling and formation flying. Since no NMACs were reported during these types of flight operations, it is concluded that the NMAC data parallels or models only the nonassociated data on MAC. Nonassociated MACs between two Air Force aircraft during the period January 1963 through June 1977 occurred at approximately the same rate as between Air Force aircraft and general aviation aircraft.

6.3 Air Force-Air Carrier NMACs and MACs

With the exception of one MAC with a foreign air carrier (DC-4) in Viet Nam, the Air Force did not experience any MACs with air carriers. However, during the period January 1975 through June 1977, the Air Force experienced 22 NMACs with air carriers, 10 of which were in the U.S. Because of these NMACs and the potential fatalities that would result from a MAC between an Air Force plane and a wide-body jet air carrier, it is concluded that the Air Force must devote efforts to preclude this possibility as a part of Phase II of the MAPS Program.

6.4 Air Force-General Aviation NMACs and MACs

Almost 70 percent of the NMACs reported involve general aviation aircraft. From January 1968 through June 1977, general aviation aircraft were involved in 54 percent of the Air Force nonassociated MACs, and during the more recent period January 1973 through June 1977, 83 percent of all Air Force nonassociated MACs were with general aviation aircraft. Based on the data from this more recent period, it is concluded that with the exception of Air Force high risk operations such as air refueling and formation flying, the Air Force's greatest midair collision problem is with general aviation aircraft.

6.5 NMACs and MACs by Time of Occurrence

The majority of the nonassociated MACs and CONUS MACs occurred during daylight hours. However, the percent of night MACs is higher than the percent of night NMACs. It is quite likely that there are more NMACs at night than are being reported because aircrews do not see the other aircraft in the darkness. Of course, all MACs are reported and 20 percent of the nonassociated MACs occurred at night. Just over half of these involved civilian aircraft.

6.6 NMACs and MACs by Flight Activity and Altitude

Almost 64 percent of the NMACs and 83 percent of the nonassociated MACs occurred during the takeoff-departure and arrival-landing phases of flight. On the basis of flight activity and related data, this analysis reconfirms earlier conclusions that the majority of both NMACs and MACs occur at relatively low altitudes (below 5,000 feet), and in the vicinity (within 10 nautical miles) of airports.

6.7 NMACs and MACs on Military Low-Level Training Routes and Olive Branch Routes

Less than 10 percent of the NMACs occurred on military low-level and Olive Branch routes. Only one MAC (in USAFE) of the 24 nonassociated MACs occurred on such routes. This, coupled with the conclusion presented in the paragraph above, leads to the additional conclusion that while TR and OB routes deserve attention in the MAPS Program, they have received publicity and emphasis disproportionate to the total Air Force midair collision potential problem.

6.8 NMACs and MACs by Air Force Commands

Certain commands were shown to have NMAC and MAC rates noticeably above the USAF average. This was particularly true for USAFE, which demonstrated a NMAC rate 5.8 times, and a MAC rate 5.2 times the Air Force average. Two other commands, TAC and ATC, were also shown to have rates higher than the Air Force average. It is therefore concluded that these three commands deserve special attention during Phase II of the MAPS Program.

6.9 NMACs and MACs by Cause

Almost two-thirds of the NMACs and over one-third of the MACs resulted from the system-environment in which the aircraft are operated. Pending implementation of additional control procedures or collision avoidance hardware, or both, see-and-avoid must continue to be a major midair collision avoidance technique.

6.10 Formation, Air Refueling, and Associated Air Force Flying

A large portion (80 percent) of the Air Force MACs occurred during formation, air refueling, or associated flight. Most Air Force personnel contacted during this study indicated: (1) the risk is acceptable and (2) there is no way to prevent these incidents anyway. However, because of the large number of MACs involved in these categories (29 percent formation, 45 percent air refueling, and 6 percent associated), some MAPS efforts should be directed toward finding ways to reduce the midair collision potential in formation, air refueling, and associated flying.

7. RECOMMENDATIONS

7.1 Overall Recommendation

Chapter Three of this report indicates that the Air Force does have a midair collision prevention problem, and Chapter Five discusses concepts that could reduce the Air Force's midair collision potential. It is therefore recommended that Phase II of the MAPS Program be undertaken and that these concepts be evaluated.

7.2 Specific Recommendations for Phase II Activities

It is recommended that the following actions be undertaken during Phase II of the MAPS Program.

- Equipment
 - Institute comprehensive basic research into technologies that could lead to an Air Force Non-Cooperative Collision Avoidance System.
 - Actively monitor FAA development of a Cooperative Collision Avoidance System and work to assure compatibility between FAA developments and USAF requirements.
 - Investigate the practicality of a small, low-cost airborne CAS for use by the air training command in the military operating areas.
 - Evaluate actions planned to upgrade radars in Europe to ensure that they will provide the added capability needed to assist in reducing the midair collision potential.
 - Determine the visual enhancement characteristics required to be effective in reducing midair collision potential under daylight conditions.
 - Examine the use of simulators and their potential for reducing the midair collision problem.
- Aircrew Procedures
 - Complete a review of aircrew procedures and related in-flight duties which contribute to "heads-in-cockpit." Included in the review should be checklists, radio transmissions and frequency changes, aircrew workload requirements, and displays.
 - Determine the feasibility of alternative procedures on the use of mandatory traffic advisories and vectors.
 - Determine the feasibility of changing the procedures for assigning tactical call signs.
 - Determine the feasibility of increasing the use of airborne radars to reduce midair collision potential.
- System-Control Procedures
 - Determine the best altitudes for conducting low altitude flights.
 - Determine the optimum airspeeds for USAF aircraft below 10,000 feet.
 - Investigate trade-offs between maximizing IFR flight plans and using "see-and-avoid" techniques on VFR flight plans.
 - Reduce instrument approach plate complexity.

- Training
 - Develop better techniques and methods to teach "see-and-avoid".
 - Refine and teach techniques for using outside references for pitch, bank, and heading control.
 - Determine the effect of F-15 and F-16 air-to-air training on the risk of midair collision and develop an optimum training syllabus.
 - Review actions already under way or planned relative to low-altitude Olive Branch routes and determine additional actions necessary to reduce midair collision potential.
 - Review formation and air refueling requirements, procedures, and techniques, and recommend improvements needed to reduce midair collision potential.

7.3 Other Recommendations

It is recommended that the following additional recommendations be considered:

- Examine the operations and benefits of the Joint Air Miss Working Group in England and the Air Miss Evaluation Group in Germany, and determine whether the establishment of a similar group in the USA would be productive in reducing the midair collision potential.
- Review current programs and procedures for the exchange of information between the USAF and the general aviation community and recommend ways to broaden and enhance this two-way information exchange.
- Investigate the unique requirements of drones relative to midair collision potential.
- Initiate a separate program management-integration task to ensure that the above actions are coordinated and integrated into an effective midair collision prevention program.

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

In October 1975, the Aeronautical Systems Division (ASD) of the Air Force Systems Command (AFSC) recommended a systematic approach to the Air Force midair collision problem. The recommendation resulted in establishment of the Midair Prevention Systems Program (MAPS). The objective of the MAPS Program is to reduce the midair collision potential associated with Air Force flying. Throughout this report we define a midair collision as one between two or more aircraft during flight, where flight is defined as including all operations between the beginning of the take-off roll and the end of the landing roll.

Previous Air Force midair collision prevention efforts were fragmented and addressed limited areas. For example, one effort involved collision avoidance hardware, another strobe lights, a third, aircraft paint schemes. The MAPS Program is designed to consider all aspects of midair collision prevention thoroughly and systematically. In addition to hardware, such other considerations as training and procedures are to be included. Preliminary AF planning documents (e.g., References 1 and 2) divided the MAPS Program into the following phases:

- Phase I - During this phase a management plan and tasking requirements for the long-term program were to be prepared. Initial problem definition and cost and schedule estimates were also to be developed.
- Phase II - This phase was to include a more detailed definition of the problem and establishment of system requirements that would be used to evaluate potential alternatives. In addition, the feasibility of potential collision prevention systems were to be assessed as to cost, capabilities, and timeliness. The goal of this phase was to produce a coordinated and complete set of requirements for potential systems.
- Phase III - Using system requirements developed during Phase II, this phase was to develop, test, and evaluate the candidates previously recommended to determine their potential for the reduction of midair collisions. At the completion of Phase III, a midair collision prevention system would have been recommended for Air Force implementation, according to the early plan.

The work being reported on herein was in support of the Phase I effort described above. The tasks of ARINC Research Corporation were to:

- Define the organizational relationships of the activities cooperating in various aspects of midair collision avoidance efforts. It was necessary to identify the various participating organizations; to understand their roles, responsibilities, and possible contributions; and to define how they will interact in the MAPS Program.
- Define requirements by identifying the characteristics of near and actual midair collisions. User requirements were to be examined so that any unique user problems could be addressed.
- Identify early initiatives that should be undertaken in the near term and formulate concepts to be examined in Phase II.
- Develop inputs for the Air Force Program Management Plan (PMP), based on the results of the previous tasks, as well as proposed Statement(s) of Work for tasks to be undertaken in Phase II.

1.2 PROGRAM APPROACH

The first step in completing the work was to visit as many of the organizations interacting with MAPS as possible. Visits were made to the major Air Force flying commands, the Air Force Inspection and Safety Center (AFISC), HQ USAF offices concerned with MAPS, and offices of the Chief of Naval Operations and the Federal Aviation Administration (FAA). Information was also received from such organizations as the Aircraft Owners and Pilots Association (AOPA). In addition, when it was determined that the Air Force midair collision problem in Europe was unique in terms of the number of midair collisions experienced, a trip was made to that theater of operation.

Data collected during visits to the interacting organizations served several purposes. First, the roles and potential contributions of these organizations to the MAPS Program were defined. Second, the data collected, particularly from the AFISC, helped to define the characteristics of both near and actual midair collisions. Finally, efforts being undertaken by the organizations to reduce the midair collision potential were evaluated for application in the MAPS Program, either as initiatives that the Air Force should undertake early, or as concepts that could be evaluated for inclusion in follow-on efforts.

Following the data collection phase, the data were analyzed from several different perspectives. The characteristics of the near midair collisions were determined, then those of the actual midair collisions. Finally, a comparison was made of the two. Initiatives already under way, such as hardware and increased traffic control procedures, were evaluated in relation to near and actual midair collision data. If increased traffic control procedures appeared to be a possible alternative, it was necessary to recognize that the Air Force really had little control over the implementation of new control procedures applicable to segments of U.S. aviation

outside the Air Force itself. The implications of this aspect made a special analysis of the civil aviation view and activities necessary.

Following the data analysis, a list of tasks recommended for inclusion in follow-on phases of MAPS was developed. The tasks were divided into five different categories and evaluated for their potential impact. We examined alternative methods for technical development and acquisition with their cost impact. The task list, including recommendations for organizational responsibility for task completion, estimated cost, and a time-phased development cycle, became the basis for input to the Program Management Plan (PMP). For the majority of tasks, where information was available in sufficient detail, proposed statements of work were also prepared.

1.3 REPORT CONTENT

Inputs to the Program Management Plan and draft statements of work for the recommended tasks were provided to the Air Force in a separate report. The reasons for this are two-fold. First, the Air Force wanted no restrictions on dissemination of this report. Including drafts of proposed statements of work and estimated costs and schedules for tasks which may be performed contractually under competitive procurement would understandably restrict dissemination until they had been coordinated and approved by proper Air Force authority. Secondly, the inputs to the Program Management Plan had not been coordinated within the Air Force. Additional internal Air Force review was required before they could be disseminated.

This chapter has provided background on the establishment of the MAPS Program and described the four proposed program phases.

Chapter Two defines the organizational relationships of the various activities interacting with the MAPS Program in terms not only of their existing responsibilities, but also their contributions to future phases.

Chapter Three presents the results of the ARINC Research analysis of the characteristics of the near and actual midair collisions, and compares the two. Unique aspects of the different major flying commands are also considered in relation to these characteristics. The chapter concludes with our assessment of the Air Force midair collision problem.

Chapter Four addresses the views of both the FAA and the various civilian users of the airspace shared with the Air Force. As shown in this chapter, the views and activities of these organizations impact on possible courses of action that the Air Force might take to reduce midair collision potential.

Chapter Five describes the effort to identify early initiatives that the Air Force could undertake. Concepts and alternatives that the Air Force could pursue in follow-on phases of the MAPS Program are presented.

Additional conclusions and recommendations resulting from the project are provided in Chapter Six.

During the research for this study, we gathered data relating MACs and NMACs to radar service, transponders, and to the aspect of the other aircraft first sighted that led the pilot to initiate evasive action. Unfortunately, the data included so many unknowns that they were of little value to this study. The information has been included as Appendix A to this report, however, with the expectation that it may be of use in later studies with different objectives.

Appendix B lists related references.

CHAPTER TWO

ORGANIZATIONAL RELATIONSHIPS

2.1 INTRODUCTION

A number of organizations, both internal and external to the Air Force, are working on various aspects of avoiding midair collisions. These organizations represent a wide range of activities. This chapter identifies the various participating organizations and their roles and responsibilities. Their potential contributions and relationship to the MAPS Program are also discussed.

2.2 INTERNAL AIR FORCE ORGANIZATIONS

2.2.1 Headquarters USAF

The internal Air Force organizations associated with the MAPS Program are shown in Figure 2-1. The figure reveals that practically all major Air Force elements are involved to some degree with MAPS Program efforts. At the HQ USAF level the two organizations primarily involved are the Airspace Management Branch in the DCS/Plans and Operations, Director of Operations, (AFXOO); and the Avionics Division in the DCS/Research and Development, Directorate of Acquisition and Development (AFRDP).

The Airspace Management Branch is responsible for Air Force airspace management policies. It coordinates its work with:

- Federal Aviation Administration (FAA)
- Air Force Representatives to the FAA
- Other HQ USAF Offices
- Major Air Commands
- Counterparts of the U.S. Army and Chief of Naval Operations
- DoD Advisory Committee on Federal Aviation

Assisting the Airspace Management Branch are the Air Force representatives to the FAA regions. These representatives are authorized by the

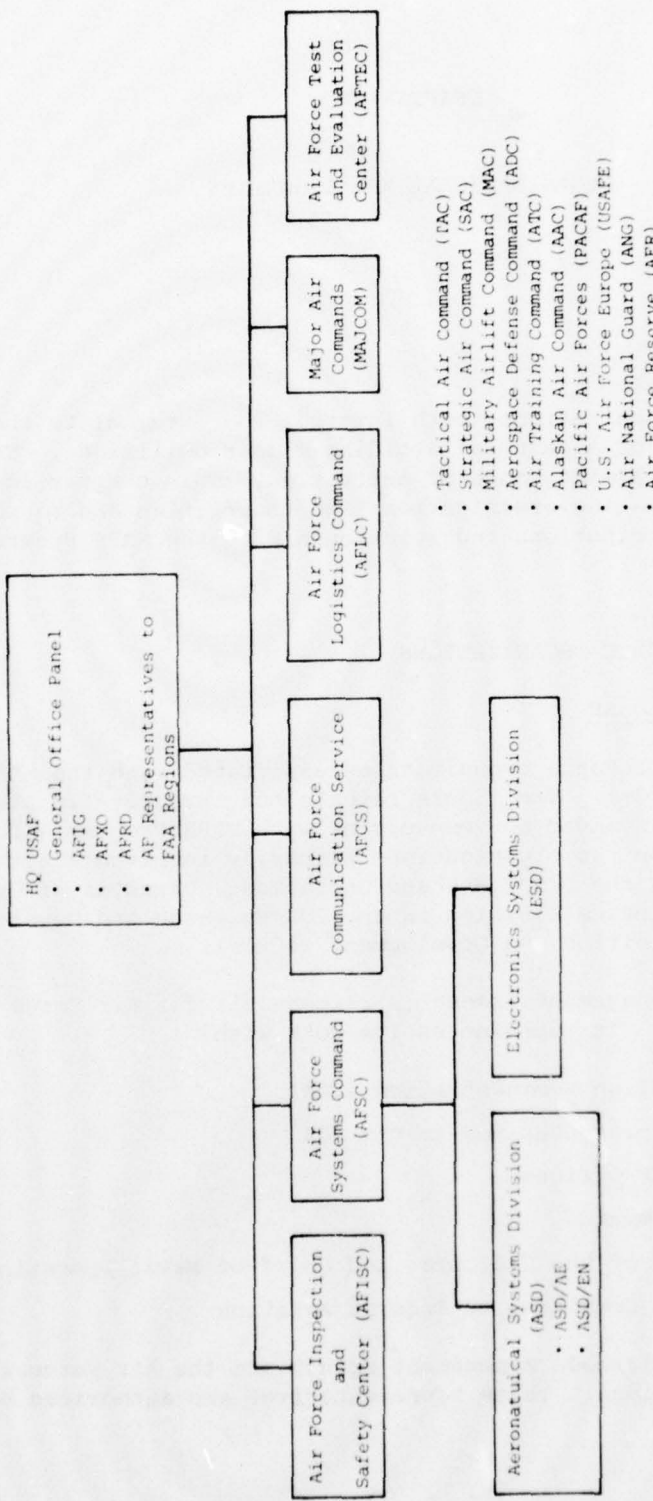


Figure J-1. AIR FORCE ORGANIZATIONS COOPERATING WITH MAPS

Secretary of the Air Force to coordinate and negotiate on airspace matters for the Air Force. In addition, these representatives:

- Act as liaison officers for the Airspace Management Branch on matters pertaining to the regional FAA air traffic services
- Maintain liaison with state and local governments regarding civil and general aviation interests
- Serve as Air Force spokesmen at informal airspace meetings held at FAA facilities or regional offices

Because of their close relationship with both the FAA and general aviation activities throughout the FAA regions, the Air Force representatives are in a unique position to assist the MAPS Program in areas requiring cooperation between the Air Force and general civil aviation.

The Avionics Division in the DCS/Research and Development, Directorate of Acquisition and Development, is the other major HQ USAF organization concerned with the MAPS Program. Any new equipment development or acquisition on the MAPS Program will be directed by the Avionics Division. Program Management Directive (PMD) R-P2021(6)/64212F/2713 was issued by this Division. Any changes to the MAPS Program, or approval to proceed with follow-on phases, will be directed by the Avionics Division via an updated PMD.

In addition to the two HQ USAF organizations involved with the MAPS Program, there is a USAF General Officer Panel for Safety Matters, which is chaired by the Air Force Inspector General's Office (AFIGI). This panel was formed in November 1975; it was known then as the General Officer Panel on Midair Collision Potential. The panel met frequently during 1975 and 1976 and initiated several actions that are now closely related to the MAPS Program (for example, strobe light evaluation). The panel's chairman calls sessions to monitor the progress of assigned tasks and to continue the panel's function as the Air Staff focus for action to reduce the potential for midair collision.

2.2.2 Air Force Inspection and Safety Center

The Air Force Inspection and Safety Center (AFISC) at Norton AFB, California, directs the Air Force inspection and safety programs, and evaluates operational readiness, accident prevention, and management systems. All aircraft accidents, including midair collisions, are investigated by the AFISC. Data and statistical analyses regarding these accidents form the basis for many internal Air Force recommendations on midair collision prevention.

The AFISC also operates the Hazardous Air Traffic Report (HATR) Program (Reference 3). This program includes reports on near midair collisions involving Air Force aircraft. Although the program was not formally begun until 1976, the AFISC collected data on near midair collisions through part of 1975 and entered these reports into an automated data file. The file is still being established, but initial output from it used during this effort

indicates that it will be extremely valuable as a source of data on Air Force near midair collisions. The AFISC also publishes a monthly magazine, *Aerospace Safety*, which is a valuable source of information on all aspects of safety including near midair collisions. Articles published in the magazine such as "Heads Up" (May 1977), "Contradictions in Midair Collision" (November 1975) and "The Critical 11 Minutes" (September 1976) play an important role in informally educating Air Force crew members.

The AFISC has a significant function in the MAPS Program. AFISC efforts include:

- Collecting data on AF midair and near midair collisions
- Analyzing the data and providing the results to other concerned organizations
- Making crew members aware of midair collision potential and ways to reduce that potential
- Appraising the effectiveness of proposed programs to reduce midair collision potential

2.2.3 Air Force Systems Command

The Air Force Systems Command (AFSC) is the implementing command for the MAPS Program and is also responsible for the overall management of the development program. This responsibility includes coordination of the MAPS Program with related developments in AFSC and in the major systems program offices within the Aeronautical Systems Division (ASD) and the Electronics Systems Division (ESD).

Within ASD, program management is the responsibility of the Avionics and Aircraft Accessories System Program Office (SPO) (ASD/AEA). Technical support is provided by the Deputy for Engineering (ASD/EN). AFSC coordinates efforts of the ASD with the Traffic Control and Landing Systems (TRACALS) SPO in ESD.

2.2.4 Air Force Communications Service

The Air Force Communications Service (AFCS) manages Air Force air traffic control. This responsibility includes site engineering, installing, operating, and maintaining ground TRACALS facilities and equipment. In coordination with the FAA and the USAF flying commands, AFCS establishes TRACALS objectives and plans for submission to HQ USAF for approval. In addition, as the operational managers, AFCS prepares and periodically updates the USAF TRACALS Plan.

The AFCS will coordinate efforts with the MAPS Program in two primary areas: TRACALS ground elements and operation of USAF air traffic control services. Any recommendations for changes or additions to ground-based equipment to reduce the midair collision potential must be compatible with existing/planned equipment in the USAF TRACALS plan. In addition, any systems or procedural changes that impact on air traffic control operations must be coordinated with the AFCS.

2.2.5 Air Force Logistics Command

The Air Force Logistics Command (AFLC) has Air Force engineering responsibility and configuration control for existing TRACALS equipment and program management responsibility for TRACALS equipment modification programs. The AFLC is also required to assist AFSC on the MAPS Program in logistics planning and support, retrofit, and life-cycle cost studies.

2.2.6 Air Force Test and Evaluation Center

The Air Force Test and Evaluation Center (AFTEC) will be responsible for monitoring any Initial Operational Tests and Evaluation required by the MAPS Program. (Developmental Test and Evaluation will be an AFSC responsibility.)

2.2.7 Major Commands

The other USAF Major Commands (MAJCOM) also participate to varying degrees in the MAPS Program. For example, all MAJCOMs are required to establish and maintain a Hazardous Air Traffic Report (HATR) Program. Several of the commands have, on occasion, conducted special tests (e.g., strobe light and painting scheme tests) related to midair collision prevention. Probably the greatest contribution that MAJCOMs can make to the follow-on phases of the MAPS Program is further evaluation and validation of requirements to reduce midair collision potential unique to their operational missions and environment. For example, the Major Commands would aid in further evaluations of the unique operational requirements in Europe or in Alaska as opposed to those in the Continental U.S. (CONUS). Other examples include further validation of the unique operational requirements of the Air Training Command (ATC) and the Tactical Air Command (TAC). Special situations such as increased traffic mix with Civil Aviation, as experienced by the Air National Guard and Air Force Reserve (AFRES), must also be considered. The MAJCOMs are the operators of aircraft involved in the midair or near midair collisions. Any systems resulting from the MAPS Program must therefore meet the specific requirements of the MAJCOMs.

2.3 ORGANIZATIONS EXTERNAL TO THE AIR FORCE

2.3.1 Federal Aviation Administration

The Federal Aviation Administration (FAA) of the Department of Transportation (DOT) develops and operates a common system of air traffic control and air navigation for both civilian and military aircraft. The FAA also regulates air traffic to foster aviation safety. However, the USAF retains responsibility for planning and managing Air Force programs uniquely concerned with military air traffic control facilities. In general, en route services are provided by the FAA (or foreign host governments); in terminal areas at USAF fixed bases, services are provided by the USAF.

Several mechanisms exist to ensure that coordination required between FAA and the Air Force is achieved. As indicated in Section 2.2.1, the Air Force provides representatives to each of the FAA regions. These representatives coordinate AF-FAA matters within each region. For example, matters originated by USAF commands that concern airspace under FAA jurisdiction are processed through the Air Force representatives. The FAA Special Use Airspace Program provides for a continuing review of all airspace assignments. The FAA special use airspace teams coordinate their review with the AF representatives. Similarly, where the operational situation is such that continual FAA-AF coordination is required, the FAA will provide a permanent representative at an AF location (HQ ATC, for example).

The Air Force also has personnel assigned to the FAA Headquarters. For example, the current DoD liaison officer to FAA's Separation Assurance office is an Air Force officer. The Air Force also actively participates in joint DoD-FAA committees. One such committee is the FAA-DoD Engineering and Development Coordinating Committee. Formal agreement establishing this committee was consummated in early 1977. Thus far the committee has established the following panels:

- Approach and Landing Systems
- Wind Shear
- Separation Assurance
- Command, Control, and Surveillance
- Space Systems

Although the Panel on Separation Assurance has not existed long enough to permit a judgment of its value and relationship to the MAPS Program, it should aid FAA-AF coordination relative to midair collision prevention.

The Air Force and DoD advocate joint research and development activities with the FAA. The FAA-DoD Engineering and Development Coordinating Committee is one mechanism that fosters joint research and development. However, because there are military needs peculiar to air warfare, including combat training, related equipment needs, and military operations not under U.S. territorial jurisdiction, the Air Force retains responsibility for planning and managing programs uniquely concerned with military operations. In fulfilling this responsibility, the Air Force needs to maintain an active role in coordinating FAA-DoD efforts in all facets of airspace use, and in collision avoidance systems in particular.

2.3.2 National Transportation Safety Board

The National Transportation Safety Board (NTSB) investigates all U.S. civil aviation accidents either directly or by delegation to FAA. It also conducts special studies and makes recommendations on matters pertaining to aviation safety and aviation accident prevention. Recommendations to Congress on proposed legislation are included. The NTSB also maintains an

automated data base on civil aviation collisions; however, collisions between military aircraft are not included. No direct use was made of the NTSB automated file during this effort, but future MAPS phases should consider it as a data source.

2.3.3 NASA Aviation Safety Reporting System

Under a 1975 Memorandum of Agreement between NASA and FAA, NASA's Ames Research Center initiated and manages the NASA Aviation Safety Reporting System (ASRS). The system is operated by Battelle's Columbus Division, Mountain View, California. The purpose of the system is to identify problems requiring correction. To encourage reporting, the FAA has agreed to waive disciplinary action for violations of the Federal Air Regulations. As a result, the ASRS has been successful in obtaining numerous reports describing human errors in the system. Copies of the previously discussed HATR reports are made available to the ASRS by the Air Force Inspection and Safety Center. Summary data and results of special analyses are published in NASA quarterly reports. For example, the third quarterly report (Reference 4) included an analysis of failures in communications between pilots and controllers. Because of the relatively short time span on the MAPS effort described here, no use was made of the ASRS; however, future MAPS phases should find this system a valuable data source in validating requirements for systems or evaluating recommendations.

2.3.4 National Associations

Several national associations are expected to influence the workability of any proposed solutions to midair collision prevention, particularly those proposing new regulations or mandatory aircraft equipment. The influence that the associations exert on proposed legislation is significant. Possible recommendations or solutions resulting from future MAPS efforts may require endorsement from the following partial list of concerned national associations:

- Air Transport Association
- Airline Pilots Association
- Aircraft Owners and Pilots Association
- Aviation Distributors and Manufacturers Association
- Commuter Airline Association
- National Business Aircraft Association
- Soaring Society of America

2.3.5 DoD Advisory Committee on Federal Aviation

The Air Force is the lead service on the DoD Advisory Committee on Federal Aviation. This Advisory Committee, made up entirely of DoD organizations, reviews aviation matters in all areas and develops positions

that consider and coordinate the needs of all DoD components, including the Joint Chiefs of Staff. One recent example of the work of this committee was an analysis of the impact on DoD if the proposed FAA Beacon Collision Avoidance System (BCAS) should become mandatory. Although advisory in nature, the DoD Advisory Committee on Federal Aviation would be the organization most likely to promulgate a consolidated DoD position on any MAPS Programs impacting on or relating to Federal aviation matters.

2.3.6 Army Aviation Organization

Several Army organizations are responsible for aviation activities which either currently relate to the MAPS Program or may relate to the MAPS Program in subsequent phases. One of these is the U.S. Army Agency for Aviation Safety located at Ft. Rucker, Alabama. This organization is similar in operation to the USAF Safety Center. Army coordination with the FAA and most aspects of Army policy on Air Traffic control procedures and equipment are handled by the Aeronautical Services Office of the U.S. Army Communications Command. Equipment development is the responsibility of the Electronics Command (ECOM) at Ft. Monmouth, NJ. Future MAPS efforts which relate to equipment development should be coordinated with ECOM to prevent unwarranted duplication. The Army now has some exploratory development under way on equipment which may be related to the MAPS effort(e.g., equipment for control of helicopter air traffic forward areas).

2.3.7 Naval Aviation Organization

Within the Navy, two offices in the Deputy Chief of Naval Operations (CNO) organization are primarily involved with safety and air traffic control. These are the Deputy CNO for Aviation Safety (NOP-OSF) and the Air Traffic Branch (NOP-513). The first office, along with the Naval Aviation Safety Center in Norfolk, Virginia, fulfills responsibilities similar to those of the Air Force Safety Center. The Air Traffic Branch has the responsibility for Navy-FAA coordination. From the equipment standpoint, the development of ground equipment for air traffic control is the responsibility of the Surveillance and Navigation Systems Division within the Naval Electronics Systems Command. Airborne equipment is developed within the Avionics Division of the Naval Air Systems Command. Although the Navy monitors FAA's collision avoidance equipment development, it does not have a specific program to address midair collision potential.

2.4 SUMMARY

This chapter has discussed the numerous organizations involved in various aspects of midair collision avoidance efforts. They will interrelate in varying degrees in future MAPS phases. A summary matrix of the organizations and their responsibilities are shown in Figure 2-2. Awareness of the organizations and their responsibilities is needed in conducting future midair prevention efforts.

Organization	Responsibilities/MAPS Coordination
Air Force General Officer Panel for Safety Matters (AFIGI)	Assigns tasks related to midair collision prevention and monitors status of actions
DCS/Plans and Operations Air-space Management Branch (AFXOO)	Establishes Air Force airspace management policy, revises Air Force operational procedures, acts as primary Air Force contact with FAA
DCS/Research and Development Avionics Division (AFRDP)	Directs development of new equipment, updates MAPS PMD
Air Force Inspection and Safety Center (AFISC)	Investigates Air Force accidents, operates HATR program, maintains data on near and actual midair collisions, appraises effectiveness of new programs
Air Force Systems Command (AFSC)	Provides overall management of MAPS program, coordinates MAPS development activities between AFSC Divisions
Air Force Avionics and Aircraft Accessories SPO	Manages MAPS Program
Air Force Communications Service (AFCS)	Operates Air Force air traffic control facilities, prepares and updates TRACALS plan
Air Force Logistics Command (AFLC)	Provides logistics support planning and life cycle cost data for MAPS Program, has engineering responsibility and configuration control for TRACALS equipment
Air Force Major Air Commands (MAJCOMS)	Identify operational requirements, problems unique to their commands, and MAPS system constraints
Federal Aviation Administration (FAA)	Develops and operates air traffic control system, proposes and enforces air regulations
National Transportation Safety Board (NTSB)	Investigates civil aircraft accidents, maintains data base, and makes recommendations regarding aviation safety
National Aeronautics and Space Administration (NASA)	Manages operation of Aviation Safety Reporting System, identifies problems in aviation system, and makes recommendations for safety improvement
National Associations	Present unified position of association members relative to aviation matters, influence aviation-related legislation
DoD Advisory Committee on Federal Aviation	Develops coordinated DoD position on matters related to Federal aviation

Figure 2-2. ORGANIZATIONAL RESPONSIBILITIES/MAPS COORDINATION

CHAPTER THREE

DATA ANALYSIS AND PROBLEM DEFINITION

3.1 INTRODUCTION

Chapter Two described the numerous organizations interacting directly or indirectly with the MAPS Program. Visits were made to as many of these organizations as possible, especially the major operating commands, to identify and define the Air Force potential midair collision problem. Chapter Three will treat the data collection process and the results of the ARINC Research data analysis. The problem that the Air Force faces in midair collision avoidance, as indicated by the analysis, will be discussed.

3.2 DATA COLLECTION

3.2.1 Literature Search

The data collection phase began with literature searches performed at the Defense Documentation Center and the National Technical Information Service. The ARINC Research team was aided considerably by prior literature searches completed by ASD's Equipment Engineering Directorate in the course of its "ASD Strobe Light Evaluation" (Reference 5). Copies of prior bibliographies and, in many cases, copies of the reports cited in them were made available to project personnel. The literature search revealed that a major study of near midair collisions had been completed in 1968 (Reference 6) and that an analysis of actual midair collisions had been completed in 1973 and updated in 1974 (References 7 and 8). Although some consideration was given to military aircraft in these reports, they dealt primarily with civil aviation and did not examine the unique military environment and operational requirements. One report that did address the Air Force situation was prepared in 1976 by the Directorate of Aerospace Safety at the Air Force Inspection and Safety Center (AFISC). This report (Reference 9) summarized all Air Force midair collisions from 1965 to 1975. That report, coupled with two others primarily concerned with civil aviation, served as the starting point in collecting additional data.

3.2.2 Air Force Inspection and Safety Center Data

A trip was made early in the project to the Air Force Inspection and Safety Center to discuss the availability of data from its automated files. The Center maintains two separate files relative to midair collisions. The first contains data on actual midair collisions; the second contains near midair collision data collected under the Hazardous Air Traffic Report (HATR) Program.

The HATR Program, established in June 1976 under Air Force Regulation 127-3, reports and investigates all near midair collisions and air traffic conditions considered to be hazardous. Under the HATR system a near midair collision (NMAC) is defined as "an unplanned event in which the aircrew of an aircraft took abrupt evasive action to avoid a midair collision, or would have taken evasive action if circumstances had permitted" (Reference 3). No attempt is made to incorporate a precise "miss distance" into the definition. The Directorate of Aerospace Safety at the AFISC administers the HATR Program and assures that the reports filed are investigated fully. AFISC also maintains an automated file of the reports, summarizes the data, and recommends measures to prevent accidents.

Although the HATR Program did not formally begin until July 1976, data on NMACs in 1975 were available and entered into the HATR file. At the time of our visit to the AFISC, the automated file was still being established. As a result, special programming had to be completed to search the file and retrieve certain data elements. The AFISC personnel were most cooperative and considered the output requested as the first real test of the file.

Data on the actual midair collisions, as opposed to the NMACs discussed above, were obtained from a separate automated file at the AFISC. It would have been ideal for comparison purposes if the two files had been identically structured, but they were not. The files were established at different times and understandably reflect different emphases. For example, in the actual midair file, the most readily available printouts were by aircraft type. Special searches were conducted for project personnel to provide as much automated sorting as possible.

We reviewed, sorted, and categorized the computer printouts. The results of this review and analysis are described below.

3.3 ANALYSIS OF NEAR MIDAIR COLLISION DATA

Before presenting the data analysis, some additional introductory comments are in order. The remainder of this chapter contains numerous tables and figures that categorize both near and actual midair collision data. Some of the categories are traditional in midair analysis, as, for example, categorization by altitude and type of flight plan. Other categories are unique to the Air Force problem, as, for example, by command and by low-level routes. Several of the categorizations did not yield significant results and permitted no conclusions. The objective of Phase I of the

MAPS effort was, in part, to identify the characteristics of near and actual midair collisions; therefore, as many characteristics as possible have been presented. Some of them are inconclusive, while others are of such significance that further study or recommended action is in order. However, this report contains all the results of the data analysis. In those instances where the data presented are inconclusive, it is presented with the expectation that follow-on MAPS researchers will review the data and judge independently whether or not a particular aspect merits further study.

One discrepancy was noted in the HATR file and should be explained before the summarized results are presented. The discrepancy pertains to the total number of near midair collisions in the file. Some searches indicated a total of 351 NMACs while other searches indicated a total of 376. This difference was discussed with AFISC personnel but the discrepancy could not be clarified. Project personnel suspected that the discrepancy might have resulted from the differences in format between the 1975 data and the HATR system file set up in 1976. For example, the HATR system contains more data elements for each NMAC than does the earlier file. A search against a data element common to both files would therefore pick up all records whereas a search against a data element not common to both files would result in a smaller number. It is also possible that 25 records were not coded for the geographical areas of the continental United States (CONUS), U.S. Air Force Europe (USAFE), or Pacific Air Forces (PACAF). All searches by unique data element and geographical location totaled 351 NMACs, whereas all searches by unique data element, regardless of geographical location, totaled 376 NMACs. Because the time available for analysis was limited, and because the differences between the two numbers was only about 7 percent, it was agreed that the discrepancy would not significantly affect the outcome. Therefore, depending on the data elements presented, the subsequent data analysis figures may show the total number of NMACs to be either 351 or 376.

3.3.1 NMACs by Geographical Area

Because it operates all over the world, the Air Force must be concerned with the midair collision problem everywhere, not just in the CONUS. Therefore, the NMAC data were categorized by geographical area. The results are shown in Table 3-1.

Table 3-1 includes all NMAC reports in the HATR file covering the period from 1 January 1975 through approximately 20 June 1977. Although the data file had not been in existence long enough to establish long-term trends, an additional breakout for 1975, 1976, and for the two years combined, does indicate the relative magnitude of the NMAC situation within the three areas. This information is shown in Table 3-2. The data presented also show the total flying hours and the average flying hours per NMAC reported. For example, in 1975, USAFE reported one NMAC for each 4,334 hours flown, while in the CONUS the Air Force experienced 45,987 flying hours between reported NMACs. Similar results are shown for 1976 and the total file period combined. The relatively smaller number of NMACs

Table 3-1. NUMBER OF NMACS BY GEOGRAPHICAL AREA	
January 1975 - June 1977	
Geographical Area	Number of NMACs
CONUS*	257
USAFE	83
PACAF	11
Total	351
*Includes Alaska and Hawaii because they have about the same air traffic control procedures as CONUS.	

in USAFE through June 1977 is not the result of a reduction in midair threat, but, rather, is caused by the administrative and investigative time required to process European NMACs into the file.

Before the data described above were obtained, AF personnel familiar with the USAFE area had estimated that the midair problem in USAFE was probably five to ten times greater than that in CONUS. The lower range of this estimate is confirmed by Table 3-2. Dividing the total CONUS average flying hours per NMAC in Table 3-2 by the comparable USAFE and PACAF rates indicates that the midair problem in USAFE is about 5.8 times greater than in CONUS, with PACAF being about 1.3 times as great. Because of the special USAFE situation, a member of the ARINC Research project team visited the USAFE area and investigated the principal causes of the higher USAFE midair threat. The results of that trip are discussed in Section 3.3.9.

3.3.2 NMACs by Category of Aircraft Encountered

Figure 3-1 presents the total NMACs by category of the number two aircraft. With very few exceptions, the number one aircraft, i.e., the one filing the NMAC, was an Air Force aircraft and the number two aircraft was the one encountered by the Air Force aircraft. (Air carriers in the table include both scheduled and unscheduled airline aircraft, and general aviation includes both business and private aircraft.) As noted in Figure 3-1, the majority of NMACs were with civil aviation (75.2 percent). General aviation aircraft (61.4 percent) predominated. The percentage rises to 69.3 percent when both CONUS and foreign general aviation aircraft are included. NMACs with domestic and foreign air carriers accounted for only 5.9 percent of the total figure.

Table 3-2. AVERAGE FLYING HOURS PER NMAC BY GEOGRAPHICAL AREA

Data Element	1975			1976			1977 (through 20 June)			Total		
	CONUS*	USAFE	PACAF	CONUS*	USAFE	PACAF	CONUS*	USAFE	PACAF	CONUS*	USAFE	PACAF
Number of NMACs	67	35	7	130	43	2	60	5	2	257	83	11
Number of Flying Hours	3,081,183	151,674	126,313	2,848,455	171,285	74,577	1,481,156	89,779	40,719	7,410,794	412,738	241,609
Average Flying Hours/NMAC	45,988	4,334	18,045	21,911	3,983	37,289	24,686	17,956	20,360	28,836	4,973	21,964

*Includes Alaska and Hawaii.

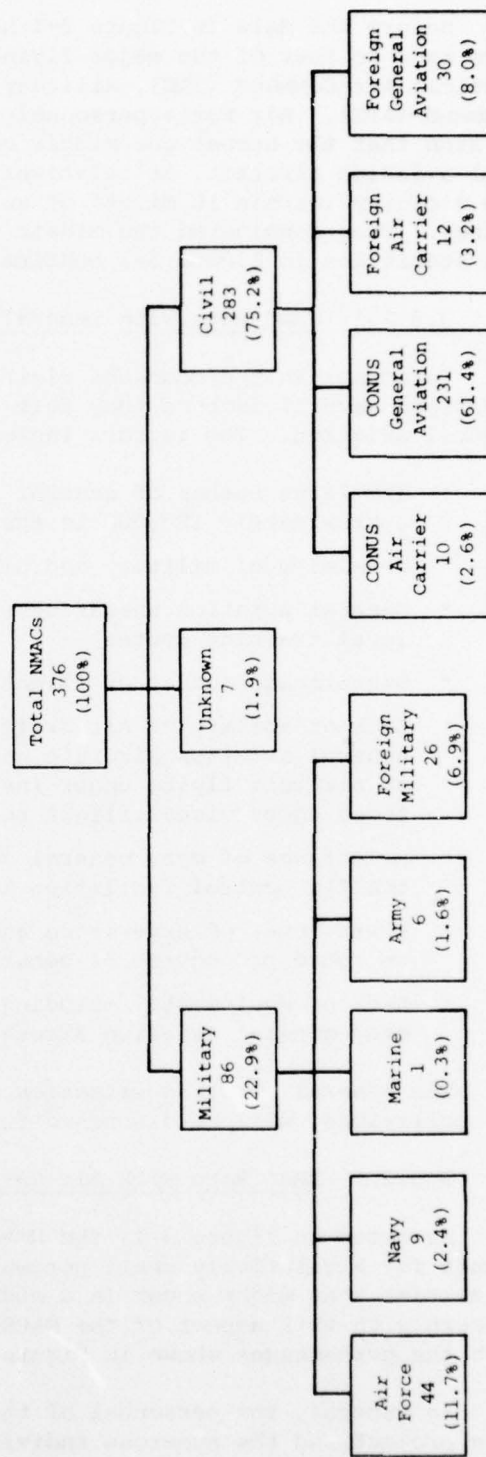


Figure 3-1. NMACS BY CATEGORY OF NUMBER 2 AIRCRAFT (JANUARY 1975 THROUGH JUNE 1977)

Before the data in Figure 3-1 had been collected and summarized, trips were made to four of the major flying commands: Strategic Air Command (SAC), Tactical Air Command (TAC), Military Airlift Command (MAC), and Air Training Command (ATC). Air Force personnel in these commands were unanimous in their opinion that the number one midair collision potential was with light general aviation aircraft, at relatively low altitudes (below 3000 feet), in the vicinity (within 10 miles) of an airport or on low-level training routes. They considered the midair threat with air carriers very small. The statistics in Figure 3-1 confirm their opinions.

3.3.2.1 NMAC Rate with General Aviation

Personnel in the commands visited during the course of this project described several factors they felt contributed to the high NMAC rate with general aviation. The factors include:

- The large number of general aviation aircraft, estimated to be approximately 180,000 in the CONUS
- Proximity of military and civil airports
- General aviation unawareness of military air refueling and low-level training routes
- Significant number of flights conducted without flight plans
- Lack of ability of Air Traffic Control (ATC) radars to "see" small general aviation aircraft not in the ATC system, i.e., the mixture of aircraft flying under instrument flight regulations (IFR) and those under visual flight regulations (VFR)
- Reluctance of many general aviation pilots to call FAA or Air Force traffic control facilities to receive traffic advisories
- Lower level of experience and training in flight plan filing and en route procedures of general aviation pilots
- Lack of equipment, including two-way radios and transponders, in many general aviation aircraft

The general aviation situation, as it relates to NMACs and actual mid-air collisions, will be discussed further in subsequent sections.

3.3.2.2 NMAC Rate with Air Carriers

As noted in Figure 3-1, the NMAC rate with air carrier aircraft accounts for a relatively small percentage of the total. Because of the fatalities that might occur in a midair collision with a wide-body jet, concern with this aspect of the MAPS Program is understandably much greater than the percentages shown in Figure 3-1 would seem to merit.

In general, the personnel of the Air Force commands visited during this project and the numerous individual pilots interviewed believe that the probability of a midair collision with an air carrier is extremely

small. There are two reasons. First, as indicated by the numbers in Figure 3-1, the air carriers are not often involved in NMACs. Second, the pilots know the air carriers operate under rigid air traffic control with the best equipment and highly qualified pilots. Nevertheless, between January 1975 and June 1977, 22 NMACs did occur with air carrier aircraft.

Table 3-3 shows the altitudes at which the air carrier NMACs occurred. The most surprising aspect of the data seen in this table is that 10, or approximately 45 percent of the air carriers' NMACs, occurred above 25,000 feet. This fact is contrary to the overall NMAC situation where only 4.3 percent of the total NMACs occur above 25,000 feet (see discussion in Section 3.5.5). The major reason for the disparity becomes obvious when the primary cause of the NMACs with air carriers is ascertained (Table 3-4).

Altitude (in feet)	January 1975 - June 1977			
	CONUS	USAFE	PACAF	Total
Below 2,000	1	1	1	3
2,001 - 5,000	2	1	0	3
5,001 - 10,000	3	0	1	4
10,001 - 15,000	1	0	0	1
15,001 - 24,999	0	1	0	1
24,999 and above	3	7	0	10
Total	10	10	2	22

Primary Cause	January 1975 - June 1977			
	CONUS	USAFE	PACAF	Total
Controller Error	6	7	1	14
Pilot Error - Non-AF	2	1	0	3
Pilot Error - AF	1	0	0	1
System Deficiency	1	1	0	2
Failure - See-and-Avoid	0	1	1	2
Total	10	10	2	22

Controller error, particularly in assigning two aircraft the same en route cruise altitude or in erroneously instructing one aircraft to descend or climb through the other's altitude, accounted for 14, or 63.6 percent of the NMACs with air carriers. Non-Air Force pilot errors were caused primarily by descents below assigned altitude. The one Air Force pilot error occurred when the pilot saw the air carrier, incorrectly perceived it to be at the same altitude, and in attempting to avoid it descended toward it.

All but one of the USAFE and PACAF controller errors involved the host country controllers. In the CONUS, the six controller errors were equally divided between FAA and AF controller personnel.

While the potential of NMAC with air carriers represents a small percentage of the overall NMAC threat, the number of fatalities that could occur dictate that this aspect continue to receive emphasis in the MAPS Program.

3.3.2.3 NMACs Rate with Other Military Aircraft

As indicated in Figure 3-1, 86, or 22.9 percent, of the NMACs were with other military aircraft. Of these, 26 were with foreign military aircraft, primarily in the USAFE area. Of the 44 AF NMACs with other AF aircraft, 21 occurred in the CONUS. Of these, controller error was the primary cause in 14 of the occurrences, AF pilot error in 4, and system deficiency and IFR-VFR traffic mix in 3.

The number of AF-AF NMACs may very well be higher than indicated in Figure 3-1. No NMACs are reported for formation flying, or air refueling, and very few for flight in the terminal areas. Although close proximity flying is expected in these operations, situations undoubtedly occur where the aircraft fly closer than planned and have to take abrupt evasive action to avoid a midair collision (see definition of NMAC in Section 3.2.2). When such an event occurs, and the two Air Force aircraft involved are from the same organization, the corrective action is probably taken locally and no further reports are made.

3.3.3 NMACs by Command

Table 3-5 presents NMAC data for the major Air Force flying commands. Commands such as AFLC, AFSC, and AFCS, which had a relatively small amount of flying time and a correspondingly small number of NMACs, are not included. In addition, some of the NMACs from 1975 (prior to implementation of the HATR system in 1976) did not provide a breakout by commands, resulting in the lower total number of NMACs shown on the table. The average for all commands combined was one NMAC for every 22,688 flying hours. As seen in the table, the USAFE, when its average was compared to that of all the major commands, had 4.56 times more NMACs than the average; TAC had 1.06 times more; and ADC had 0.56, or about half the average.

Table 3-5. NMACS PER FLYING HOUR BY COMMAND: JANUARY 1975 - JUNE 1977

Command	Number of NMACs	Flying Hours	Average Flying Hours/NMAC	Ratio of all Commands' Average to Average of Individual Commands
U.S. Air Forces Europe (USAFE)	83	412,738	4,973	4.56
Air Training Command (ATC)	61	1,508,401	24,728	0.92
Tactical Air Command (TAC)	50	1,069,673	21,393	1.06
Military Airlift Command (MAC)	51	1,700,843	33,350	0.68
Strategic Air Command (SAC)	26	925,538	35,598	0.64
Air National Guard (ANG)	25	948,006	37,920	0.60
Pacific Air Forces (PACAF)	11	241,609	21,964	1.03
Alaskan Air Command (AAC)	7	43,642	6,234	3.64
Air Force Reserves (AFRES)	7	323,755	46,251	0.49
Air Defense Command (ADC)	6	244,867	40,811	0.56
Total	327	7,419,072	22,688	

Several factors account for the wide disparity in the NMAC rates experienced by the commands. The USAFE is obviously unique both in terms of operations and its air traffic control environment. The USAFE situation is discussed further in Section 3.3.9.

The Alaskan Air Command (AAC) situation is also unique. This command provided data in addition to that contained in the HATR file. From January 1974 to August 1977, AAC reported 17 NMACs involving military aircraft, seven of which occurred between January 1975 and June 1977. The significant points regarding these NMACs are that all involved general aviation aircraft; all occurred below 3,000 feet; and all took place within 25 nautical miles of Elmendorf AFB. The FAA has established special Terminal Area Rules for the Anchorage area (which includes Elmendorf AFB), and the FAA General Aviation District Office (GADO) and the Air Force Wing Safety Office conduct a general aviation pilot education program. While most of the emphasis must be on "see-and-avoid" techniques, command personnel believe that some type of aircraft airborne proximity warning system is also needed.

Visits were made to several of the other commands and individual situations discussed. The Tactical Air Command, for example, while concerned about the midair threat with general aviation, is becoming particularly concerned about the increasing potential for midair collisions between TAC aircraft. The threat increase has been caused by the following:

- Projected increase in the number of TAC fighters and air combat training sorties
- Painting of new aircraft to reduce their conspicuity
- Use of smokeless engines
- Higher maneuver rates

For example, TAC is projected to have 729 F-15s that will fly approximately 500 sorties per day. Each sortie will entail about four close passes to other high performance aircraft. The result will be a total of 2,000 passes with a high potential for midair collisions each day for the F-15 fleet alone. In addition, more than 1300 F-16s will be coming into the TAC inventory. TAC anticipates that ground attack training missions for the F-16 will account for about 40 percent of the total sorties and air-to-air engagements for about 60 percent. The projections for the F-16 fleet are:

$$\begin{aligned} &60 \text{ percent A/A passes} \times 1388 \text{ a/c} \times 0.8 \text{ availability} \times 4 \text{ passes/flt} \\ &\quad \times 2 \text{ flight/day/acft} = 5330 \text{ A/A passes per day} \end{aligned}$$

This type of projection, underscored by the February 1977 F-15/F-5 midair collision, is of major concern to TAC. The command is constantly examining training and operational procedures to reduce the potential for midair collisions, but recognizes that no one solution exists. The high number of air-to-air training flights being conducted makes midair collisions inevitable. The objective must be to minimize the number of these occurrences.

Within the Air Training Command, the number of student pilots is considered to be at a rock-bottom level now. Approximately 1,000 undergraduate pilots will be trained this year. The number will increase to approximately 1,900 in 1979. Each student pilot currently receives 250 hours of flying time; however, ATC will soon be using simulators for instrument training. Seventy hours of simulator time may be substituted for 40 hours of flying time, resulting in 210 hours total flying time per student.

To help reduce the near midair collision potential, ATC uses a more rigidly controlled training procedure whereby each aircraft is, in effect, given a volume of airspace. The aircraft is required to remain in its assigned "box" for training and must obtain radar coverage to and from the training areas. It has been estimated that 20 to 25 percent of the available training time is significantly degraded by air traffic control procedures. Air Training Command personnel have expressed concern that these teaching methods give student pilots no opportunity to develop the independent judgment needed to become effective in air operations. Under the controls now in effect, the students are told what heading to turn to, altitude to climb or descend to, etc. Examples of student pilots not knowing how to cancel an IFR clearance and make a VFR approach and landing were cited. While everyone agrees that instrument training is needed, Air Force personnel believe overall training is being degraded, as 98 percent of the student pilot training is under IFR control. In addition, the see-and-avoid concept is degraded.

Within the Military Airlift Command, the aircraft inventory has increased substantially as helicopters, C-130s, and T-39s have been absorbed from other Air Force units. MAC anticipates that the number of NMAs within its command will increase as a result of the additional aircraft. With the exception of the helicopter operations and some of the tactical low-level missions, all MAC flights are IFR. The operation of MAC is quite similar to that of commercial air carriers. Because of their worldwide mission, however, they frequently operate in overseas areas where air traffic control is not as effective as in the CONUS, and they may therefore be exposed to a greater threat of midair collision.

MAC has no formal crew midair collision prevention training in its school curriculum. It does publicize the midair collision potential through such publications as the *MAC Flyer*. When possible, MAC also assigns an extra crew member to occupy the jump seat and act as traffic observer in flights below 10,000 feet. Although it is not a checklist requirement, crew briefings stress the need for traffic observation, particularly on climb-out, descent, and during all low-level operations. However, when the C-141s and C-5s are equipped with dual inertial navigation systems (INS) units, MAC plans to remove navigators from crews. Although final crew procedures have not been worked out in detail, MAC believes an increased pilot workload and reduced traffic observation will result.

The Strategic Air Command, like the Military Airlift Command, operates primarily under IFR in large multi-engine aircraft such as the B-52 and KC-135. It uses extra crew members as observers whenever possible. Maximum use is made of the instructor pilot's (IP) seat as an observer position. SAC also concentrates on reducing "in-cockpit duties" to a minimum to provide better pilot clearing ability. Although SAC operates mostly IFR, it does fly low-altitude training routes known as Olive Branch routes. The routes are unique to the Strategic Air Command and are discussed below.

3.3.4 NMACs on Low Altitude and Olive Branch Training Routes

To train for wartime conditions, the Air Force flies low-altitude, high-speed training routes. These routes are flown by several of the different operating commands. Within SAC they are known as Olive Branch (OB) routes. Other commands' low-level activities include high-performance jets in TAC and the Air National Guard (ANG), and tactical cargo aircraft in MAC and the AFRES. The OB routes have been a matter of concern to the military and the general aviation community for some time. With the exception of terminal areas, the low-level routes account for the greatest mix of Air Force and general aviation flying activity. The low-level routes are flown both IFR and VFR. The FAA publishes all-weather low-altitude IFR routes, including altitudes and times of operation, in Part 4 of the *Airman's Information Manual* (AIM). However, publication by DoD of the military VFR low-altitude training routes (TRs) has been on an informal basis only.

Individual Air Force bases with approved TRs have taken several steps to make the general aviation community aware of these routes. The Air Force representatives have, for example, visited local civil airports and provided copies of charts depicting the route structure and hours of use. Some bases have also prepared brochures describing their military operations and distributed copies to all civil airports within the route area. Many bases have conducted "Fly-Ins" at which general aviation pilots were invited to fly to a base and receive briefings and a tour of the base and its operations. The idea was to promote an understanding of military operations and to publicize the low-level training routes. Such promotion is beneficial and should be continued.

TAC, at Nellis AFB, has employed a different approach. It has chosen to educate the military on general aviation operations and training areas. Air Force personnel using a light aircraft visited local airports in the Nellis flying area and documented general aviation's operations and training areas. They discovered, for example, that one of the military low-level routes made a descent in an area where considerable general aviation flight training was being conducted. The descent point was subsequently changed with negligible impact on military training but a significant reduction in potential military-general aviation traffic conflict. The concept of educating military pilots on general aviation training locations in their local flying areas deserves further analysis by the Air Force.

The FAA has also taken action to ensure that military TRs are publicized. The *FAA General Aviation News*, published by FAA and distributed by subscription to the general aviation community, contains numerous articles on the subject.

The actions described above have undoubtedly aided in reducing the midair collision potential on military low-level routes. Additional actions were required, however, to further reduce the midair collision threat. In June 1977 the FAA issued Order 7110.77, which prescribes new criteria and operating procedures for military training routes. This order, the result of extensive DoD-FAA coordination on military low-altitude training routes, will reduce the number of routes. All routes will be formally published in appropriate civil IFR and VFR charts. A transition period will allow time for all existing TRs to be converted to the new FAA-published routes by 1 January 1979. Information concerning route utilization will be available from the FAA Flight Standards Service (FSS) within 200 miles of each route. However, improvement in reducing the military-general aviation midair collision potential under the new FAA order will still, in part, be dependent upon an action that can be taken only by the general aviation pilots; that is, these pilots must call the FAA along their intended route of flight and ascertain what military use is being made of the routes.

As discussed above, the low-altitude training routes have been a matter of concern for some time. An objective look at the NMAC data indicates, however, that within the Air Force's total NMAC threat, the low-altitude training route threat may be overemphasized. Of the total of 376 NMACs in the HATR file, a first analysis indicated that 54 occurred on either Olive Branch or other TRs. A subsequent breakout showed that of the 54, 32 were on OB routes and 22 on TRs. A further breakout showed that of the 22 TR NMACs, 10 occurred in the CONUS and 12 in USAFE. The exact number of NMACs which actually occurred on the low-level portion of OB routes could not be ascertained from the data available. The NMACs are coded by flight activity but up to three activity codes are assigned. For example, the overall mission may be an Olive Branch route; however, an NMAC may occur on takeoff, en route, or in landing. Of the 32 NMACs credited to OB routes, many apparently occurred during phases other than the low-level portion of the missions. An examination of the narrative descriptions of over 255 NMACs revealed that only 11 could be confirmed as occurring during low-level flight. An NMAC occurring on take-off or landing was completely unrelated to whether the ultimate purpose of the mission was an IFR air refueling mission or a VFR low-level OB route. ARINC Research project personnel reviewed the data and estimated that no more than 20 NMACs actually occurred during the low-level portion of the OB routes. These NMACs, coupled with the 10 CONUS NMACs that occurred on other low-level routes, account for less than 10 percent of the total NMACs experienced by the Air Force. Project personnel do not wish to minimize the OB-TR midair collision potential, but, rather, to put it in proper perspective relative to the total Air Force NMAC situation. The analysis shows that the OB-TR NMAC situation is certainly an important part of the overall threat, but it has received a greater emphasis than it deserves. The validity of this statement will become evident in the following section, which addresses NMACs by flight activity, and in Chapter Four, which reports on discussions with the Aircraft Owners and Pilots Associations.

3.3.5 NMACs by Flight Activity

The entire NMAC file was specially searched to determine what phase of flight activity the number one aircraft was engaged in when the NMAC occurred. Results are shown in Figure 3-2. As reported above, as many as three separate flight activities were assigned to some NMACs. For example, the aircraft might be on arrival (flight activity 1), in the traffic pattern VFR (flight activity 2), and on final approach (flight activity 3); or, it might be on departure (flight activity 1), on a published IFR standard instrument departure (SID) (flight activity 2), and climbing (flight activity 3). These different reported activities required some subjective analysis and categorization to enable us to arrive at the results depicted in Figure 3-2. The significant point regarding the breakout in that figure is the total number of NMACs that occurred during takeoff and departure (70), and arrival and landing (170). This total (240) accounts for 63.8 percent of all NMACs.

The relatively high percentage of NMACs occurring during these phases of flight was not altogether unexpected. Other studies, as well as experienced pilots, had reported that the periods immediately after takeoff and before landing are critical periods for NMAC occurrence. An article in the September 1976 issue of *Aerospace Safety*, entitled "The Critical 11 Minutes", addressed this aspect of the NMAC threat. As described in the article, during a 3-minute period after takeoff and an 8-minute period before landing, pilots are extremely busy with checklists, radio calls, transponder and radio frequency changes, etc., leaving little time for watching for other aircraft. Table 3-6 compares the relationship between NMACs occurring after takeoff and before landing and the critical 11 minutes. The 8 minutes before landing make up 73 percent of the critical 11 minutes and 71 percent of the 240 NMACs, while the 3 minutes after takeoff make up 27 percent of the critical 11 minutes and 29 percent of the 240 NMACs. As indicated in the referenced article, SAC has undertaken a study to improve checklists and reduce the hazards that result from cockpit distraction. A similar effort by the entire Air Force would probably aid in reducing the NMACs during these critical phases of flight activity.

3.3.6 NMACs by Type of Flight Plan Filed

Figure 3-3 breaks out the 376 NMACs by type of flight plan filed. Information presented in the top half of the figure refers to the number one aircraft; the lower half of the figure pertains to the second aircraft. As shown, the number one aircraft was on an IFR flight plan in 286 cases. Of these events, the number two aircraft was also IFR in 53 cases, VFR in 83, and had no flight plan in 8. In 142 cases, the type of flight plan was unknown. The majority of the unknown flight plans involved general aviation aircraft. They represented cases in which an NMAC occurred but the general aviation aircraft involved were not identified. It is safe to assume that, in most cases, a flight plan had not been filed, and, in some cases, that the aircraft was on a VFR flight plan.

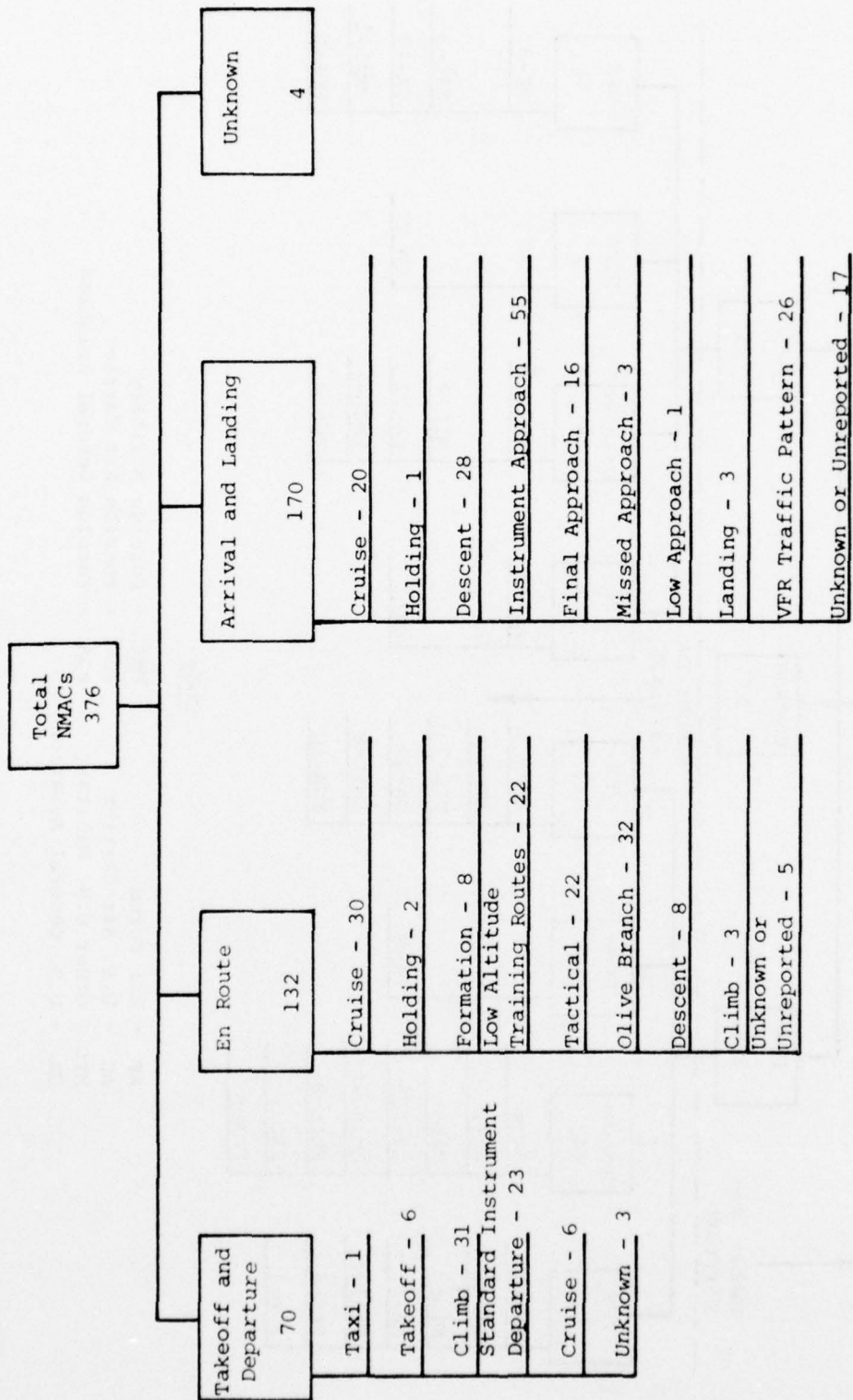


Figure 3-2. NMACS BY FLIGHT ACTIVITY, NUMBER 1 AIRCRAFT (JANUARY 1975-JUNE 1977)

Table 3-6. COMPARISON OF CRITICAL ELEVEN MINUTES AND NMACS JANUARY 1975 - JUNE 1977				
Period	Percentage of Time	Total NMACs	Period	Percentage of NMACs
Critical 11 Minutes	100	240	Before landing, after takeoff	100
8 Minutes Before Landing	73	170	Before landing	71
3 Minutes After Takeoff	27	70	After takeoff	29

The Air Force flight plan policy is to make maximum use of IFR. VFR is to be used only when the mission absolutely requires it. There is little doubt that the added control provided under IFR reduces the NMAC potential. However, it is also obvious that even if 100 percent of Air Force flights were IFR, a significant number of NMACs would still occur because the number two aircraft involved will not have filed a flight plan or will be VFR. The Air Force crews who have filed an IFR flight plan may have a false sense of security in the belief that their IFR flight plan assures separation from other IFR traffic. Unfortunately, it does not assure separation from unknown traffic on VFR or with no flight plan. Warnings to flight crews about this danger must continue.

Attempts to encourage general aviation pilots to file flight plans and to use IFR procedures have not been very successful. There are many reasons for this situation. Filing a flight plan subjects the pilot to some element of control. When a general aviation pilot decides to go from point A to point B, he usually wants to get there his own way at minimum cost, either flying direct without any dog-legs required by ATC, or by following a highway or railroad between the two points. While this is permitted by present regulations, there is no doubt that such practices increase the NMAC threat. Pending additional FAA regulation, not likely at this time, the only alternative is for the Air Force and FAA's General Aviation District Offices (GADO) to continue exchanging information on their operations and encouraging the filing of flight plans and use of traffic advisories available to general aviation.

3.3.7 NMACs by Cause

The NMAC data available during the project had been coded according to cause by the safety office responsible for the NMAC investigation. Several factors contributed to some of the NMACs. Where this situation occurred, the project team cited the primary factor. Results of the coding are shown in Figure 3-4. As indicated in the figure, personnel errors or misunderstandings accounted for approximately one-third of the NMACs. While the

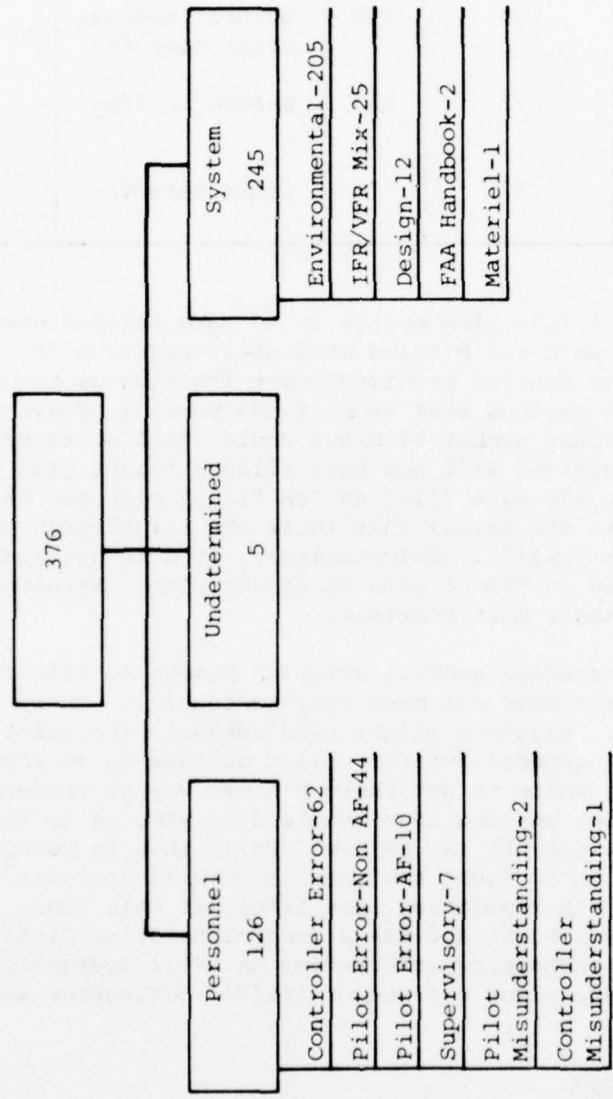


Figure 3-4. NMACS BY CAUSE (JANUARY 1975-JUNE 1977)

system's failures caused the remaining two-thirds. Terminology used in the breakout is the same as that employed by the AFISC. Environmental factors accounted for most of the NMACs (205), including a large number with general aviation. For example, an Air Force-general aviation NMAC that occurs on a low-level training route or where military and civil airfields are in close proximity is primarily the result of the environment in which the aircraft operate. In such a situation, as in all visual flight conditions, the principal tactic for preventing an NMAC must be to see-and-avoid.

3.3.8 Miscellaneous Data on NMACs

Appendix A contains some additional breakouts of the NMAC data which pertain to radar service, transponders, and factor first-sighted in the NMAC. Although there are a large number of unknown or unreported incidents contained in these data, they may be of value for future analysis. The intent in collecting the data was to determine relationships between NMACs and the use of available transponders and radar services. The matter has been thoroughly covered in several authoritative reports (e.g., References 6 and 7), and there is general agreement that greater transponder and radar service usage would significantly reduce the midair collision potential. This view is substantiated in Chapter Four.

3.3.9 NMAC Situation in USAFE

As reported in Section 3.3.1, the USAFE NMAC rate is so high in relation to the rate experienced by the rest of the Air Force that special consideration of the USAFE problem was in order. The USAFE NMAC rate is 5.8 times as high as the rate in CONUS. Even when compared to all other major flying commands, as opposed to just the CONUS, the USAFE rate is more than 4.5 times higher (see Table 3-5). The USAFE midair collision problem and NMACs were therefore subjected to a separate analysis, the results of which are presented below.

3.3.9.1 USAFE NMACs by Phase of Flight

Table 3-7 shows the USAFE NMACs by phase of flight activity and compares that experience with the total Air Force experience. Although the USAFE had a higher NMAC rate, the percentage of NMACs for each flight phase was practically the same.

3.3.9.2 USAFE NMACs by Type of Flight Plan

Figure 3-5 provides a breakout of the USAFE NMACs by type of flight plan and also compares the USAFE experience with that of the total Air Force. Again, as shown in the summary comparison, the NMAC percentages for the two different types of flight plan are approximately the same.

Table 3-7. USAFE NMACS BY PHASE OF FLIGHT JANUARY 1975 - JUNE 1977		
Flight Phase	Number of NMACs	
Arrival	37	
En Route	16	
Low Altitude Training Route	12	
Departure	10	
Tactical Range	7	
Pattern	1	
Total	83	
Comparison of Air Force with USAFE		
Flight Phase	USAFE	AF Total
Departure	13% 58%	19% 64%
Arrival	45%	45%
En Route	42%	35%

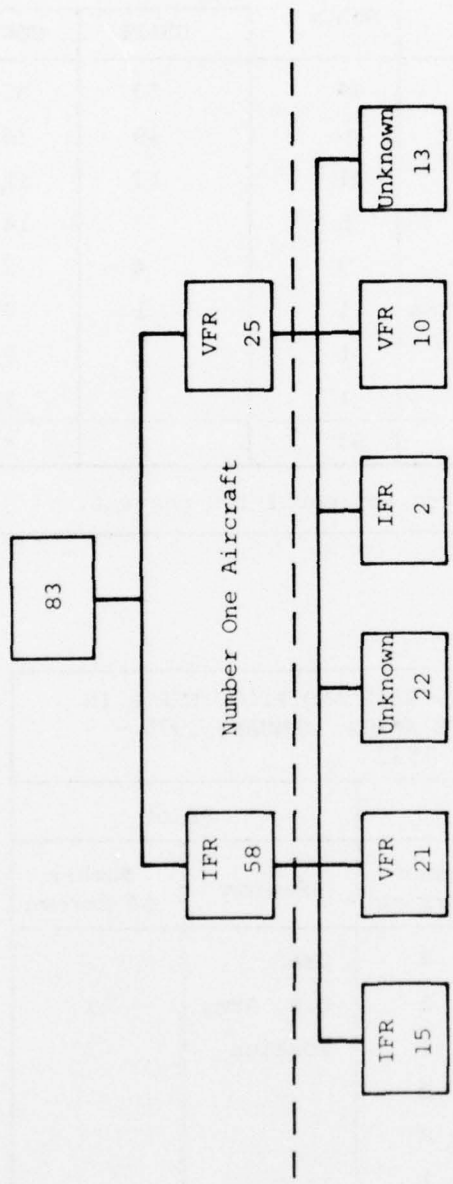
3.3.9.3 USAFE NMACs by Cause

Table 3-8 breaks out the USAFE NMACs by cause and also compares the cause rate in the USAFE with that in the entire Air Force. Although there are no significant differences, the pilot error rate is somewhat lower in the USAFE than in the total Air Force. This is not surprising, as the USAFE pilots are more experienced. The controller error percentage in Europe was slightly higher; that rate, however, includes incidents involving both USAF and foreign or host country controllers.

Table 3-9 gives additional information regarding the locations where pilot and controller errors occurred. As shown, only four of the controller errors were by Air Force controllers, and only two of the pilot errors were by Air Force pilots.

3.3.9.4 USAFE NMACs by Country

Table 3-10 shows the occurrence of USAFE NMACs by country and by year. The relatively low total for the first half of 1977 should not be interpreted as a reduction over the totals of previous years. It is probable that some NMACs that occurred in 1977 were still being investigated and were not entered into the files in time to appear in this study. West Germany and Great Britain, where the majority of the USAFE bases are located and most of the flying occurs, account for most of the NMACs. Nothing in the data explains the relative reverse in the rate of NMACs in West Germany and Great Britain between 1975 and 1976.



USAFE-Total Air Force Comparison

	USAFE	Total Air Force
IFR	70%	76%
VFR	30%	23%

Figure 3-5. USAFE NMACS BY FLIGHT PLAN (JANUARY 1975 - JUNE 1977)

Table 3-8. COMPARISON OF USAFE AND TOTAL AIR FORCE NMAC CAUSES: JANUARY 1976 - JUNE 1977

Cause	Number of NMACs	Percentage by Command	
		USAFE	CONUS
Failure - See-and-Avoid	44	53	55
Controller Error	16	19	16
System Deficiency	11	13	11
Pilot Error	6	7	14
Supervisory	3	4	2
Controller Misunderstanding	1	1	0
Avionics Deficiency	1	1	0
Unknown	1	1	1
Total	83	*	*

*Due to rounding, totals do not equal 100 percent.

Table 3-9. CONTROLLER AND PILOT ERROR IN USAFE NMACS: JANUARY 1975 - JUNE 1977

Controller		Pilot	
Region	Number of Errors	Region	Number of Errors
USAF	4	USAF	2
Great Britain	3	U.S. Army	1
West Germany	2	Foreign	3
France	2		
Spain	2		
U.S. Army	1		
Saudi Arabia	1		
Cyprus	1		
Total	16	Total	6

Table 3-10. USAFE NMACS BY COUNTRY JANUARY 1975 - JUNE 1977				
Country	1975	1976	1977 through June	Total
West Germany	8	26	3	37
Great Britain	22	10	2	34
Spain	3	2	0	5
Turkey	1	1	0	2
France	0	1	0	1
Netherlands	1	0	0	1
Cyprus	0	1	0	1
Saudi Arabia	0	1	0	1
Pakistan	0	1	0	1
Total	35	43	5	83

3.3.9.5 Factors Affecting the USAF Midair Collision Potential in Europe

The midair collision problem facing the USAF in Europe is much the same as in the CONUS except that it is more intense. The midair collision and near midair collision rates are approximately five times higher in Europe than in the CONUS. These data, coupled with the widespread feeling of those people interviewed that the midair collision danger in Europe is "worse" than in the CONUS, resulted in a special analysis of the USAFE situation. Areas of concern are discussed below.

3.3.9.5.1 Airspace Density

USAFE personnel stated that about 8 million flights of some kind occur in each year. All of them occur in airspace equivalent to the airspace of the state of Oregon. In this small space there is a mix of civil aircraft flights, more glider flights than occur anywhere else in the world, and the concentrated military operations of several NATO countries. The major air traffic control centers of the FRG handled over 900,000 clearances in 1976, and this figure does not include military exercises and flights of Army helicopters. In comparison, Denver Center -- which covers a much larger area, handled about 350,000 clearances during the same period. Midair problems, even when they are the same types as found in the CONUS, are thus amplified because of the air traffic density in Europe.

3.3.9.5.2 Low Level Training Routes

European low level training routes are a major concern to all users of the airspace. In fact, an Allied Forces, Central Europe, (AFCENT) Low Flying Working Group has been formed to work out problems associated with low level flying. Most of the group's discussions on midair collisions concentrated on low level-high speed flying. However, as was true of the CONUS data, the data on NMAC in Europe (12 of 83 NMAC on low altitude training routes [LATR], or 14 percent) do not show low level training routes to be the major problem. The AFCENT Low Flying Working Group members studied the low level midair collision problem by examining the number of sorties and the NMAC data. The Group concluded that the problem was not significant. Nevertheless, personnel in USAFE are still working to make low level flying in Europe safer by attempting to establish specific routes and flow patterns. However, since USAFE flies only about 14 percent to 17 percent of the low level flights, these efforts are unlikely to have a significant effect on the problem.

At present, the USAF is the only NATO Air Force respecting flow patterns while flying low level routes in the Federal Republic of Germany during the day. All air forces respect the flow patterns for nighttime low level flying. Adding to the number of the low level flights in the FRG are approximately 1,100 U.S. Army helicopters (soon to increase to 1,300) that fly about 150,000 hours per year. The helicopters average about one hour per mission, fly about 150,000 sorties per year, and report about 100 near misses each year.

In France, routes for low altitude training flights must be specified and arranged in advance with France by each nation. USAFE has 13 LATRs in France. The LATRs in Great Britain are controlled and well scheduled. However, they are not published and their locations are therefore usually unknown to the general aviation pilot.

3.3.9.5.3 Air Traffic Controllers

In discussions with aircrews about the midair collision potential in Europe, the problem of coordinating air traffic controllers is usually mentioned as a major concern. The ARINC Research project team's examination of NMAC causes in Europe did not show a significantly greater number of errors by European controllers than by American ones (see Table 3-8, 19 percent vs 16 percent). Language difficulties may accentuate the problem of controller coordination in Europe. If the NMAC data are correct, however, language differences may be more of an inconvenience than a problem. On the other hand, USAFE personnel have affirmed that trying to pin down controller error is extremely difficult in nations where national pride and prestige may be at stake. In some NATO nations, information about an alleged controller error is almost impossible to obtain. It may take months to get an answer to an inquiry, and no assurance exists that controller errors are properly investigated and solutions implemented.

In Germany, air traffic controller coordination was also identified as a major concern by USAFE personnel. The Temporary Reserved Airspace (TRA) in which the USAFE forces conduct their intercept training is not large enough to complete an intercept with fast moving aircraft. Many intercepts must therefore cross nonreserved airspace into another TRA. This movement requires coordination with the German civil controller responsible for traffic on airways between the TRAs. Coordination is complicated by division of responsibilities and scarcity of German civil controllers to handle the coordination of the large number of intercepts needed to train USAF aircrews and ground intercept controllers. The problem is amplified by the USAF need to conduct about 3000 intercepts per year to keep the aircrews and controllers current.

3.3.9.5.4 Radars

Several problems associated with European radars surfaced during talks with USAFE personnel. No attempt will be made here to discuss the technical aspects of the problems and possible solutions. That should be a MAPS follow-on effort. USAFE personnel did point out, however, that the equipment in the FRG was not reliably displaying transponder and mode C altitude readout information. The many ground-based radar systems (maybe as many as 100, including the German low-level radars) that are interrogating transponders are saturating them. Poor tracking and altitude information is the result. Difficulties with the data processing equipment associated with the radars has complicated the problem.

Much of the RAF military terminal radar equipment used in Great Britain for off-airways traffic under RAF control is old and has not been modified to make it compatible with modern aircraft performance.

3.3.9.5.5 Aircraft Conspicuity

The difficulty of seeing aircraft in flight in Europe represents a major problem in attempting to reduce the potential for midair collisions there. Complete radar coverage of all traffic, including low level flying, gliders, and helicopters is not considered possible. See-and-avoid tactics must therefore be an integral part of midair collision prevention efforts. Both Great Britain and Central Europe often have haze, overcasts, and other weather problems that limit visibility. The weather, together with high density traffic and the absence of airspeed restrictions below 10,000 feet, make aircraft conspicuity a major concern. As the USAF begins using aircraft with greater maneuverability, smokeless engines, and less visible paint schemes, the problem will probably get worse. For these reasons, most aircrew members interviewed in USAFE thought strobe lights or some other high intensity lights would be especially beneficial in Europe, where the weather is usually hazy. The MAPS should investigate possible techniques for visual enhancement of aircraft in Europe.

3.4 ANALYSIS OF ACTUAL MIDAIR COLLISION DATA

3.4.1 Introduction

The literature search discussed in Section 3.2.1 revealed that two major reports had previously been published on actual midair collisions. These reports are an FAA-sponsored study that analyzed all midair collisions from 1964 to 1972 (References 7 and 8) and a study by the Directorate of Aerospace Safety covering the period 1 January 1965 through 31 December 1975 (Reference 9). The AFISC also maintains an automated data file on all aircraft accidents, including midair collisions. The automated data file served as the primary source for the midair collision data discussed in this report. Most of the tables and figures in this report were completed by hand from printouts, including narrative data, obtained from that file.

Before the midair data are addressed, it is necessary to define some of the terms used throughout this section of the report. The definitions are in agreement with Air Force terminology used in Reference 9. (The latest version of AFR 127-4, Reporting and Investigating USAF Mishaps, revised these definitions. Nevertheless, the earlier definitions are used here for consistency with the periods and data being considered. The revised definitions would have no affect on the categories of near or actual midair collisions.)

- Major accident - A mishap during which a fatality occurs or during which an aircraft receives substantial damage
- Minor accident - A mishap during which an aircraft receives minor damage
- Incident - A mishap that does not qualify as an accident and that involves damage to a USAF aircraft or that meets other criteria specified in AFR 127-4, paragraph 21
- Flight - All operations between the beginning of the take-off roll and the end of the landing roll
- Formation - Flight in which crew members attempt to maintain or attain a fixed position relative to a leader with whom they have visual contact
- Associated flying - Flight involving two or more aircraft operating in a limited airspace; each aircraft is aware of the presence, but not necessarily the exact location, of the other
- Nonassociated collisions - Collisions that occur when the aircraft involved are not aware of each other's presence

3.4.2 Types of Midair Collisions

Table 3-11 gives the total number of Air Force midair collisions that occurred from January 1968 through June 1977. As noted in the table, 134 (44.5 percent) of these collisions occurred during air refueling operations. Since the contact is intentional, the Air Force normally does not count these incidents as midair collisions. Practically all of the air refueling collisions were relatively minor incidents during which a slight amount of damage was done to the boom, receptacle, or probe. Table 3-12 provides a breakout of the aircraft involved in the air refueling midair collisions. As expected, B-52, KC-135, and F-4 aircraft comprise most of the total. The narrative descriptions of all the air refueling accidents were reviewed to determine if any occurred as a result of inadequate aircraft lighting during night rendezvous. None of the air refueling accidents could be attributed to rendezvous difficulties. They all occurred when the tanker and receiver were in close visual contact. (Note: The November 1974 F-111/civil aircraft midair collision that occurred during air refueling rendezvous is included as a nonassociated MAC in this report.)

From January 1968 through June 1977, only four aircraft were destroyed by air refueling accidents. The aircraft include two F-105s that collided in Southeast Asia during turbulence just prior to hook-up, an F-4 with a student pilot who allowed his aircraft to collide with the aft tail section of the tanker, and an F-100F abandoned by its crew after the canopy was broken by the refueling basket.

Formation flying accounted for 88 midair collisions, or almost 30 percent of the total. Figure 3-6 breaks out the formation midair collisions by different phases of flight. As expected, close formation accounted for the greatest number, 30, or 34 percent of the total.

The third largest category of midair collisions was composed of accidents related in some way to combat in Southeast Asia. This category, and the two mentioned above, have no direct bearing on many aspects of the MAPS Program. They all involve high risk military operations where aircraft are intentionally flown close to each other.

The fourth largest category of midair collisions was classified as associated-military. Accidents in this category number 18, or 6 percent of the total. Of these, 12 occurred during air combat maneuver training and 6 occurred during intercepts. Associated-military training particularly concerns the Tactical Air Command (see Section 3.3.3). The instrumentation and fire-control systems in use require a considerable amount of heads-in-the-cockpit time. This, coupled with the high closure rates, permits little time for see-and-avoid tactics. Although the associated-military category accounts for a small percentage of the total midair collisions to date, that percentage could increase significantly unless training, operational procedures, and additional hardware keep pace with the increasing threat.

Table 3-11. TOTAL MIDAIR COLLISIONS JANUARY 1968 - JUNE 1977				
Category	Incidents	Major/Minor	Total	Percentage of Total
Air Refueling	129	5	134	44.5
Formation	51	37	88	29.2
Associated-Military	2	16	18	6.0
Nonassociated-Military	1	10	11	3.7
Nonassociated-Civilian	7	6	13	4.3
Combat-Related	15	22	37	12.3
Total	205	96	301	100

Table 3-12. AIR REFUELING MIDAIR COLLISIONS BY AIRCRAFT TYPE (JANUARY 1968 - JUNE 1977)			
Aircraft Type	Incidents	Major/Minor	Total
A-7	6	0	6
A-37	1	0	1
B-52	27	2	29
B-66	2	0	2
C-5	1	0	1
F-4	29	1	30
F-84	1	0	1
F-100	6	1	7
F-101	5	0	5
F-105	3	1	4
F-106	3	0	3
F-111	11	0	11
KC-97	2	0	2
KC-135	30	0	30
H-53	2	0	2
Total	129	5	134

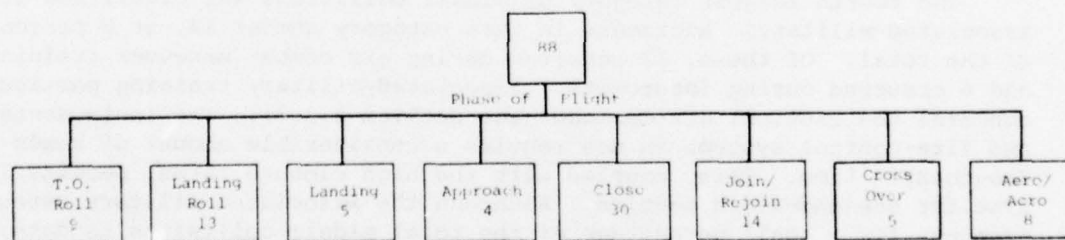


Figure 3-6. FORMATION MIDAIR COLLISIONS
JANUARY 1968 - JUNE 1977

The remaining midair collisions are all in the nonassociated-civilian category. Figure 3-7 provides a breakout of this category by flight activity. Six collisions (25 percent) occurred during takeoff and departure, four (17 percent) during en route cruise, and 14 (58 percent) during descent, approach, or landing. Figure 3-8 presents figures on the midair collisions that involved civil aviation.

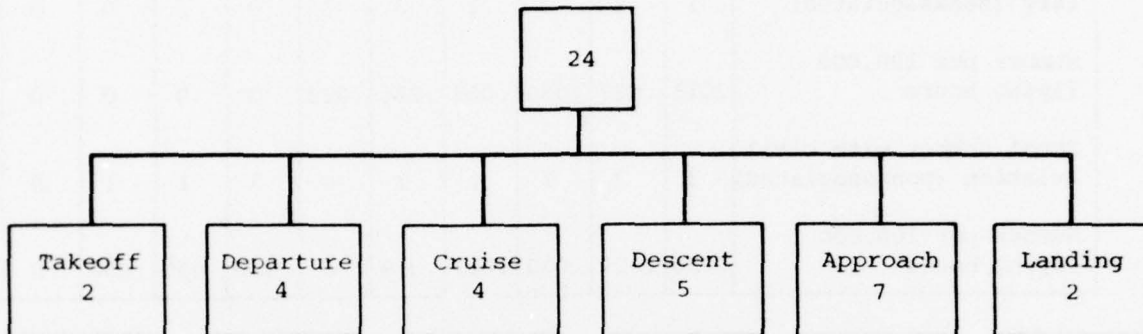


Figure 3-7. TOTAL NONASSOCIATED MIDAIR COLLISIONS BY FLIGHT ACTIVITY (JANUARY 1968 THROUGH JUNE 1977)

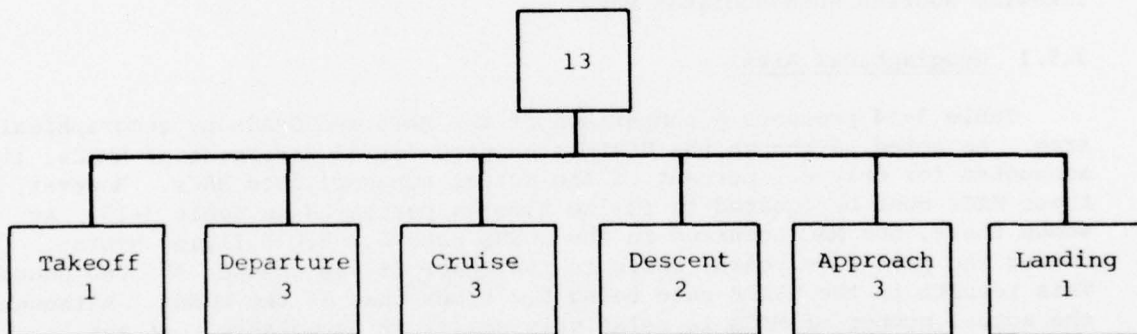


Figure 3-8. NONASSOCIATED MIDAIR COLLISIONS WITH CIVILIAN AIRCRAFT BY FLIGHT ACTIVITY OF AF AIRCRAFT (JANUARY 1968 THROUGH JUNE 1977)

Table 3-13 presents the number of nonassociated midair collisions by year per 100,000 flying hours. A separate rate is provided for military and civilian flights. While the military rate has been zero the last three full years, the civilian rate has been as high or higher during the last three years as in any of the other years shown.

3.5 COMPARISON OF ACTUAL AND NEAR MIDAIR COLLISIONS: NONASSOCIATED FLYING

As stated in Section 3.2.2, the data files on NMACs and actual midair collisions were not structured to permit a direct comparison. However, by manual sorting, some comparisons could be made between the two. This

Table 3-13. NUMBER AND RATE (PER 100,000 FLYING HOURS) OF NONASSOCIATED MIDAIR COLLISIONS

Category	Years									1st half 1977
	1968	1969	1970	1971	1972	1973	1974	1975	1976	
Total number with military (nonassociated)	1	2	2	2	3	1	0	0	0	0
Number per 100,000 flying hours	.013	.027	.030	.035	.056	.023	0	0	0	0
Total number with civil aviation (nonassociated)	2	2	2	1	1	0	3	1	1	0
Number per 100,000 flying hours	.026	.027	.030	.017	.019	0	.080	.030	.032	0

section will present the results of such comparisons. It should be remembered that no NMACs were reported for air refueling, formation or associated flying. Therefore, the NMACs all involved nonassociated flying, and it should be emphasized that comparisons in the remainder of this section will likewise address nonassociated MACs.

3.5.1 Geographical Area

Table 3-14 presents a comparison of the MACs and NMACs by geographical area. As noted, although the USAFE accounted for 23.6 percent of NMACs, it accounted for only 8.3 percent of the actual nonassociated MACs. However, these MACs must be equated to flying time as portrayed in Table 3-15. As shown there, one MAC occurred in the CONUS each 2,368,035 flying hours during the past five years, while in the USAFE it was one per 455,060 hours. This results in the USAFE rate being 5.2 times that of the CONUS. Although the actual number of MACs is relatively small, it is notable that the USAFE MAC rate here is approximately 5.2 times that of CONUS; as shown in Section 3.3.1, the USAFE NMAC rate was 5.8 times that of CONUS.

Table 3-14. MACS AND NMACS BY GEOGRAPHICAL AREA

Area	Nonassociated MACs		NMACs	
	January 1968 - June 1977		January 1975 - June 1977	
	Number	Percent	Number	Percent
CONUS	21	87.5	257	73.2
USAFE	2	8.3	83	23.6
PACAF	1	4.2	11	3.2
Total	24	100.0	351	100.0

Table 3-15. COMPARISON OF CONUS AND USAFE NONASSOCIATED MACS (1972-1976)			
Area	Total MACs	Flying Hours	Flying Hours per MAC
CONUS	8	18,944,280	2,368,035
USAFE	2	910,119	455,060

3.5.2 Category of Number Two Aircraft

Table 3-16 presents a comparison of the NMACs and nonassociated MACs by the category of the number two aircraft. Approximately three-fourths of the NMACs involved civilian aircraft, while slightly over half of the MACs during the period from 1968 to 1977 involved civilian aircraft. However, when only the last five years of MACs (Column 3) are compared with the NMACs, the percentages are approximately the same. Table 3-16 then says, in effect, that during this period, approximately three-fourths of the NMACs reported were with civilian aircraft and slightly over three-fourths of the actual nonassociated MACs were with civilian aircraft.

Table 3-16. COMPARISON OF CATEGORY OF NUMBER TWO AIRCRAFT NMACS AND MACS						
Category	NMACs January 1975 - June 1977		MACs January 1968 - June 1977		MACs January 1973 - June 1977	
	Number	Percent	Number	Percent	Number	Percent
Military	86	23	11	46	1	17
Civilian	283	75	13	54	5	83
Unknown	7	2	0	0	0	0

Table 3-17 breaks out the civilian NMACs and nonassociated MACs by category of civilian aircraft. Again, as in the case above, the actual MACs are occurring at approximately the same rate as the NMACs reported. The one significant difference is that there have not been any MACs with air carriers in the CONUS. The one foreign air carrier MAC was in Southeast Asia and was due in part to high density traffic at DaNang Airport, Republic of Vietnam.

**Table 3-17. COMPARISON OF CATEGORY OF CIVILIAN AVIATION
NMACS AND MACS**

Category	NMACs January 1975 - June 1977		MACs January 1968 - June 1977	
	Number	Percent	Number	Percent
Air Carrier CONUS	10	3.5	0	0.0
General Aviation CONUS	231	81.6	11	84.6
Air Carrier Foreign	12	4.2	1	7.7
General Aviation Foreign	30	10.7	1	7.7
Total	283	100.0	13	100.0

3.5.3 Commands

Table 3-18 compares the number and percent of NMACs and MACs by Command. TAC and USAFE show the greatest percentage difference between NMACs and MACs. In TAC the MAC rate is higher than the NMACs, and in USAFE the reverse is true. Because of the discussion of low level and Olive Branch flights in Sections 3.3.3 and 3.3.4, it should be noted at this point that the one SAC midair collision did not occur on an Olive Branch route. In fact, the only midair collision on a low level route was one of the two MACs in USAFE. Two of the TAC midair collisions occurred on tactical missions, one during descent and the other during climbout, but they were not on the low-level portions of the routes.

3.5.4 Cause

Table 3-19 compares the NMACs and MACs by primary cause. As previously mentioned, there were several factors that contributed to many accidents. In those cases we cited the one that was considered the primary factor. Section 3.3.2.3 commented on the expectation that the number of NMACs actually occurring between two Air Force aircraft was probably greater than that indicated in the NMAC data file. The higher percent of Air Force pilot error in MACs in Table 3-19 tends to support this theory also. For example, one of the nonassociated MACs involved two Air Force aircraft which collided while making clearing turns. Had it been a NMAC instead of a MAC, a report would probably not have been filed, but quite likely the incident would have been discussed between the pilots on the ground. On the other hand, several of the MACs attributed to AF pilot errors in Table 3-19 were due to failure to see-and-avoid in situations where the environment could have been a significant factor. In all cases where pilots were cited in a failure to see-and-avoid, it was attributed to the Air Force pilot although the non-Air Force pilot was equally at fault.

Table 3-18. COMPARISON OF MACS AND NMACS BY COMMAND

Command	MACs January 1968 - June 1977		NMACs January 1975 - June 1977	
	Number	Percent	Number	Percent
TAC	9	37.5	50	15.3
ATC	5	20.8	61	18.7
ANG	4	16.7	25	7.6
USAFE	2	8.3	83	25.4
MAC	2*	8.3	51	15.6
SAC	1	4.2	26	8.0
PACAF	1	4.2	11	3.4
AAC	0	0.0	7	2.1
AFR	0	0.0	7	2.1
ADC	0	0.0	6	1.8
Total	24	100.0	327	100.0

*One was actually AFSC at the time of the accident.

Table 3-19. COMPARISON OF MACS AND NMACS BY CAUSE

Category	MACs January 1968 - June 1977		NMACs January 1975 - June 1977	
	Number	Percent	Number	Percent
System-Environment	9	37.5	245	65.1
Pilot-Air Force	7	29.2	10	2.7
Controller	6	25.0	62	16.5
Pilot-Non Air Force	2	8.3	44	11.7
Miscellaneous	0	0.0	15	4.0
Total	24	100.0	376	100.0

As Table 3-19 shows, the System-Environment was cited most often for both NMACs and MACs. In a 1975 accident, for example, a general aviation aircraft on a VFR local flight collided with a military aircraft which was on a ground controlled approach (GCA) under radar control. Current system procedures allow VFR uncontrolled aircraft to operate in areas of high density traffic and thus the cause is considered the system-environment in which the aircraft operate.

3.5.5 Flight Activity

Table 3-20 compares the MACs and NMACs by flight activity. The most significant difference between them is the larger proportion of NMACs which occur en route. The majority of both NMACs and MACs occur in the vicinity of the airports while the aircraft are either on takeoff and departure, or descent, approach, and landing.

Table 3-20. COMPARISON OF MACS AND NMACS BY FLIGHT ACTIVITY				
Activity	MACs January 1968 - June 1977		NMACs January 1975 - June 1977	
	Number	Percent	Number	Percent
Takeoff-Departure	6	25.0	70	18.6
Arrival-Landing	14	58.3	170	45.2
En Route	4	16.7	132	35.1
Unknown	0	0.0	4	1.1
Total	24	100.0	376	100.0

Table 3-21 provides a comparison of altitudes for NMACs and MACs. The exact altitudes of some of the MACs were unknown, as for example, when the collision occurred while descending from a known altitude or climbing to an assigned altitude, but the altitude at the impact could not be precisely determined. For those events, best estimates were used to categorize the MACs into the rather broad altitude ranges shown in the table. As expected from the flight activity data, and shown in Table 3-21, the majority of both NMACs and MACs occurred at relatively low altitudes. In Table 3-21, cumulative percentages are shown to emphasize the large proportion of NMACs and MACs that occur below 10,000 feet.

Table 3-21. COMPARISON OF MACS AND NMACS BY ALTITUDE

Altitude (in feet)	MACs January 1968 - June 1977		NMACs January 1975 - June 1977	
	Number	Cumulative Percent	Number	Cumulative Percent
Below 5,000	14	58.3	240	68.4
5,000 - 10,000	5	79.2	66	87.2
10,000 - 25,000	5	100.0	29	95.4
Above 25,000	0	-	15	99.7
Not Reported	0	-	1	100.0
Total	24	100.0	351	100.0

3.5.6 Time of Occurrence

Table 3-22 presents a comparison of the MACs and CONUS NMACs by the time of day of the occurrence. The majority occurred during daylight hours; however, as noted in the table, the percent of MACs which occurred at night is greater than the percent of NMACs being reported at night. Care must be exercised in using these percentages because the day/night rates of flying in the USAF are not factored into the data. Thus the small number of night NMACs and MACs may be in proportion to the number of hours flown at night.

Table 3-22. COMPARISON OF MACS AND CONUS NMACS BY TIME OF DAY

Time of Day	MACs January 1968 - June 1977		NMACs January 1975 - June 1977	
	Number	Percent	Number	Percent
Dusk-Dawn	0	0.0	11	4.3
Day	19	79.2	224	87.2
Night	5	20.8	18	7.0
Not Reported	0	0.0	4	1.5
Total	24	100.0	257	100.0

In addition, it is quite likely that there are more near misses at night than are being reported -- i.e., the aircraft were in dangerous proximity but because of the reduced visibility neither aircraft crew was aware of the danger.

Table 3-23 provides a further breakout of the above 24 nonassociated MACs by whether the second aircraft was military or civilian and the time of day it happened. The table shows the percentages to be almost the same.

Table 3-23. MACS BY TIME OF DAY AND CATEGORY OF AIRCRAFT ENCOUNTERED

Category of Aircraft Encountered	Day		Night	
	Number	Percent	Number	Percent
Civilian	10	53	3	60
Military	9	47	2	40
Total	19	100	5	100

3.5.7 Type of Flight Plan

Table 3-24 compares the NMACs and MACs by type of flight plan of the number one (AF) aircraft. It shows that half of the MACs occurred while the Air Force aircraft was under a VFR clearance, but only 22.6 percent of the NMACs were reported while the Air Force aircraft was under VFR.

Table 3-24. COMPARISON OF AIR FORCE FLIGHT PLAN AND MACS AND NMACS

Air Force Flight Plan	MACs January 1968 - June 1977		NMACs January 1975 - June 1977	
	Number	Percent	Number	Percent
IFR	9	37.5	286	76.1
VFR	12	50.0	85	22.6
Not Reported	3	12.5	5	1.3

Some Air Force flight plans involve both VFR and IFR. For example, an aircraft may depart and proceed IFR to a tactical entry point where the flight is then continued under VFR. During the VFR portion a low-level route may be flown, or tactical operations may be conducted within an Air Force range. Following completion of the VFR portion, the aircraft then returns to a tactical exit point and returns to its recovery base under IFR. Extensive coordination is required between the aircraft crew, the Air Force organization controlling the range, and the FAA center controlling the IFR route from the range to the recovery base. As indicated in Section 3.5.3, two of the TAC midair collisions were on such tactical missions, one during descent to the range, and the other during climbout en route to the range.

Although not shown in Table 3-24, in 8 of the 13 Air Force-civilian MACs, both the Air Force and the civilian aircraft were flying VFR; in the remaining 5 the Air Force aircraft was flying IFR and the civilian VFR. In no case did Air Force aircraft flying VFR collide with a civilian aircraft which was flying IFR.

3.6 DATA SUMMARY

As indicated in the previous sections, there are many different aspects to the overall midair collision problem. Air refueling incidents account for the largest number of midair collisions, but contact here is intentional and the Air Force reasonably separates these usually minor incidents from other categories of midair collisions. Formation flying, and particularly close formation, accounts for the next highest category of collisions. This activity, like air refueling, is recognized as a high risk operation. Although air refueling and formation collisions are all AF-AF accidents, together they account for 73.7 percent of all midair collisions involving Air Force aircraft. Therefore, even though they are usually accepted as a part of high risk operations, Phase II of the MAPS Program should explore these areas in greater depth than the five-month Phase I effort permitted.

For the remaining midair collisions, the previous section compared actual collisions with NMACs reported. Although there are some differences, many of the circumstances relating to NMACs and MACs are similar. For example, exclusive of formation flying and air-refueling, the majority of both the NMACs and MACs involve general aviation aircraft, primarily at low altitudes in the vicinity of airports, during daylight hours. The Air Force aircraft is usually under some sort of air traffic control while in many cases the general aviation aircraft is uncontrolled.

Nonassociated midair collisions between Air Force aircraft occur much more frequently than would be indicated by NMAC reports. Most of them occur when both aircraft are under VFR clearances and like military-general aviation incidents, they occur at low altitudes in the vicinity of airports.

Except for one MAC with a foreign air carrier (DC-4) in Southeast Asia, there have been no Air Force midair collisions with air carriers during the period under study (January 1968 through June 1977). There have, however, been 22 NMACs with air carriers. While the system-environment has been the primary cause of military-general aviation NMACs, controller error is the primary cause of NMACs with air carriers. The air carrier NMAC potential is considered extremely small when compared to the military-military or military-general aviation risks; however, because of the potential number of fatalities and the number of NMACs that have occurred, the air carrier threat must constantly receive consideration.

Low level and Olive Branch (OB) routes accounted for a significant number of NMACs, but only one MAC (in USAFE). Because of the public discussion between military and general aviation regarding these routes, they have probably received attention disproportionate to the total NMAC problem. However, operations on these routes are perceived as a significant threat by both military and general aviation pilots.

Certain commands and the USAFE area were shown to have a NMAC threat or MAC experience significantly above the USAF average. Operational and environmental factors related to the individual commands were discussed in Sections 3.3.3 and 3.5.3. The Tactical Air Command was cited as one command which is expected to experience an increase in NMAC potential in associated flying due to the projected increase in the number of TAC fighters and training sorties.

A balance must be achieved between the system control procedures needed to minimize the midair potential and the ability of the Air Force to conduct its varied worldwide mission in an effective manner. After considering in the next chapter some of the civilian aspects related to the midair collision problem, Chapter Five will address areas which the Air Force should explore to minimize the midair collision threat portrayed herein.

CHAPTER FOUR

CIVILIAN VIEWS AND ACTIVITIES

A significant number of DoD flights occur in joint civil and military airspace under the control of the Federal Aviation Administration. Any program concerned with the prevention of midair collisions involving military aircraft must therefore take into account the views of the civilian aviation community and its plans for the future. This chapter addresses the views of both the FAA and the various user organizations (e.g., the airlines, general aviation) regarding the present system and possible improvements in it. Emphasis is placed on activities that could affect the USAF in the follow-on phases of the MAPS Program. Projects with negligible impact on the military, such as the automated terminal service (ATS) to provide automated air traffic advisories at general aviation airports, are not discussed.

The information presented in this chapter is developed from three sources: the observations of ARINC Research personnel who have been involved in various aspects of the FAA's Separation Assurance Program over the past five years; the published reports and public position papers of the FAA and user organizations; and a series of discussions with FAA, airline, and general aviation spokesmen pertaining to the MAPS Program.

4.1 CIVILIAN ASSESSMENTS OF THE COLLISION PROBLEM

There is unanimous agreement in the civilian aviation community that the risk of midair collisions should be minimized. However, when the problem is discussed in relation to other safety issues, it usually is not at the top of the list. Possible reasons for this include the fact that there are very few midair collisions, the view that a totally collision-free airspace is probably not possible, and the feeling that money might be better spent on solving other safety problems. Nevertheless, the nagging feeling that a collision could occur remains. Collisions are usually very serious, if not fatal, and it does not seem right to ignore the problem. While these views probably typify those of most of the civilian aviation community, the particular concerns of the FAA, the airlines, and general aviation vary, and are described in the following paragraphs.

The FAA is responsible for the overall safety of flight and has developed an elaborate air traffic control system to reduce the risk of midair collisions, even when one or both aircraft are not under ATC control. Naturally, the FAA examines all the statistics on midair collisions to determine the severity of the problem. Over the past 15 years (1960-1975) almost half a billion aircraft hours have been flown, and the following number of aircraft have been involved in collisions (Reference 11):

- Air carrier: 21 (18 collisions, 3 involving two air carriers)
- General aviation: 890 (496 collisions, 424 involving two general aviation aircraft)
- Military: 29 (not counting collisions involving two military aircraft)

Altogether, 928 fatalities resulted from these collisions. The annual rate of collisions and fatalities has remained about the same in recent years despite the increase in the use of the airspace. While the statistics indicate a low risk of midair collisions, there exists the possibility that two jumbo jets could collide and in a single incident nearly double the total number of fatalities. Therefore, the FAA is committed to developing an even safer system.

The airlines and their pilots are naturally very much concerned about the safety of air carrier aircraft. About 8 years ago the airline industry spent several million dollars perfecting an airborne collision avoidance system, and several airlines developed plans to equip their aircraft with this system. However, the airlines recognized that the protection they would be buying would be limited if only air carrier aircraft were to be equipped and, lacking an FAA national standard for their system, they did not proceed. Subsequently, other collision avoidance system alternatives were proposed or developed (see Section 4.3). The airlines are now awaiting the outcome of these efforts. The airlines apparently feel that their primary protection is (and will continue to be) provided by the ATC system. It appears that they are willing to install any system eventually defined as the national standard, backup collision avoidance system.

The general aviation community, while concerned about midair collisions, does not appear eager to spend a lot of money or sacrifice the freedom of flight in the interest of reducing the risk of collisions. This community seems to feel that one of the most effective ways to reduce the collision risk is to emphasize the need for every pilot and copilot to practice "see-and-avoid" techniques. For the most part, the general aviation community does not want to be forced out of airspace in which it is presently allowed through requirements for special equipment or positive control of their aircraft, or both. Furthermore, members of this community feel that any technical or hardware solutions should not require general aviation aircraft to carry any new equipment (except possibly DABS transponders as an eventual replacement for ATCRBS transponders). The general aviation community does want any hardware solution to be available to general aviation (if an aircraft owner wishes to purchase the equipment), and it would like the system

to function within and outside of the coverage area of the ground system. Regarding military operations, a general aviation spokesman* expressed concern over low-level training/Olive Branch routes (although he admitted that statistics have shown little problem in this area) and over increased military activity between 4,000 and 8,000 feet, levels heavily utilized by general aviation.

It should be emphasized that the above views represent the authors' perception of the most common mood and attitudes of the FAA, the airline community, and general aviation. Of course, these communities have many members and the possibility always exists of wide differences of opinion. Analysis of the overall views of the different aviation communities shows little concern directed specifically at military aviation. Rather, military aviation is considered just one more participant in the National Airspace System. Aviation communities outside the military believe that solutions that are applied to the airlines and to general aviation are also likely to be applied to the military.

4.2 CURRENT FAA ACTIVITIES

The FAA is endeavoring to improve present systems and procedures, develop new ATC capabilities and procedures, better inform pilots of potential collision environments, and conduct research and development to find the preferred hardware solutions. This section addresses the first three areas (i.e., those areas in which changes could occur over the next few years) while the following section reviews the many technical investigations that have been and are being pursued.

Improvements have been made to the air traffic control system since its beginning to increase its efficiency and enhance its safety. Many of the collisions of earlier years could undoubtedly have been avoided if today's ATC procedures had been in operation. The ATC system continues to become more effective as more aircraft are equipped with transponders and encoding altimeters. Recent (late 1975) near midair collisions involving commercial air carrier aircraft have led the FAA to develop a controller backup system known as "conflict alert". The conflict alert warns a controller whenever two aircraft appear to the ATC computer to be on a course that will violate airspace separation standards. To date, conflict alert monitors only en route airspace above 12,500 feet. There are plans to develop improved conflict alert algorithms for use below 12,500 feet and in airport terminal areas. Conflict alert is limited, however, in that it works only when the positions and altitudes of both aircraft are known to the system and at least one aircraft is in contact with a controller.

The FAA is also considering procedural changes as a way of reducing the risk of midair collisions. In particular, the FAA is considering increasing requirements for transponders and altitude encoders. The imposition of additional requirements for transponders and encoding altimeters to

*Victor Kayne of AOPA.

permit the ATC system to better see VFR aircraft and to automate further the handling of all IFR aircraft is being studied. For example, the use of transponders and encoding altimeters is being considered in additional airspace [e.g., all Automated Radar Terminal Systems (ARTS) III locations, all Group III Terminal Control Areas (TCA), all controlled airspace] and for additional aircraft (e.g., through licensing requirements, for all aircraft with 10 or more seats, or for all aircraft except perhaps gliders, experimentals, etc.). While this procedural change might help reduce the risk of midair collisions, it does have cost impacts that could delay or prevent its enactment.

Finally, there is one area of improvement that should be of particular interest to the military. Starting on or about January 1, 1978, the FAA is planning to publish aeronautical charts that indicate military low level training routes. It is hoped that this will make general aviation pilots more aware of military operations and will encourage them to avoid those areas when operations are in progress and to be more alert when traversing them.

4.3 RESEARCH AND DEVELOPMENT EFFORTS

This section describes past and present research and development efforts, presents user community views on these efforts, and describes the important technical issues needing resolution.

4.3.1 Historical Background

The Federal Aviation Administration, in close cooperation with the airline industry and representatives of the general aviation community, has been involved in investigating and developing a separation assurance system that would meet the safety requirements necessary for an orderly air traffic control operation and would still be economically feasible for the majority of airspace users.

Since the early 1970s several concepts have been formulated and thoroughly evaluated by the FAA and other branches of the government. Among the more promising were the Airborne Collision Avoidance System (ACAS); the Discrete Address Beacon System with Intermittent Positive Control (DABS/IPC); and the Beacon Collision Avoidance System (BCAS); the last in both passive and active modes. Additional systems that have been proposed but have not yet been evaluated are: the air-to-air mode of DABS, and a single-site BCAS. Some systems, such as the proximity warning systems, have been proposed by manufacturers but, for various reasons, have not been subjected to detailed evaluation.

The system eventually recommended by the FAA as a national standard for separation assurance should meet the requirements dictated by the user communities and the regulatory agencies. Ideally, the system should provide timely and safe avoidance of midair collisions by the equipped aircraft.

It must be free of false alarms resulting in unnecessary maneuvers, yet provide a pilot with adequate information to allow maneuvers that will not cause additional unsafe situations. It must be capable of proper operation at all altitudes and geographical locations. Finally, it must be economically attractive to both the high-performance class of aircraft and to the low-performance single engine aircraft. No single system now exists that meets all of the noted requirements. The more promising concepts, their operational requirements and present status in the consideration for a national standard, are discussed below.

4.3.1.1 Airborne Collision Avoidance System

The Airborne Collision Avoidance System (ACAS) concept was proposed in three variations by three manufacturers (Honeywell, McDonnell-Douglas, and RCA) as an independent system operating without ATC intervention or dependence. After an extensive performance and cost evaluation of each of them, the FAA decided to recommend the Honeywell AVOIDS concept as the preferred airborne CAS. The Honeywell AVOIDS concept is a simple interrogate-response system using a clear frequency dedicated to ACAS operation. Unfortunately, this concept and the other two ACAS alternatives are fully cooperative systems requiring both participants in a potential midair collision to be equipped with CAS avionics. Although technically sound, the concepts would require every aircraft to be fitted with CAS avionics. Of course, this would mean a long delay before full protection to each aircraft could be assumed. The FAA is therefore seeking an alternative approach. Nevertheless, prototype hardware has been built and tested, and the AVOIDS concept is available should Congressional action mandate ACAS installation on all aircraft.

4.3.1.2 Discrete Address Beacon System with Automatic Traffic Advisory and Resolution Service

The FAA has sponsored the development of the Discrete Address Beacon System (DABS) as an improved surveillance system intended to replace the present Air Traffic Control Radar Beacon System. This system would provide both the information required to detect potential midair conflicts and a data link to inform the threatened aircraft of the conflict. The DABS/ATARS (formerly DABS/IPC) concept uses the DABS surveillance information to maintain aircraft tracks, identities, and altitudes and, with the aid of computers, determines the appropriate proximity warning information and collision avoidance commands. The concept and prototype hardware required to implement the concept have been evaluated through controlled experiments. Additional hardware is being manufactured for preliminary system implementation at selected dense traffic environment locations. The system is capable of conflict prediction of any aircraft equipped with either an ATCRBS or DABS transponder and an encoding altimeter system. However, the Automatic Traffic Advisory and Resolution Service (ATARS) service can be provided only to DABS-equipped aircraft possessing the attendant ATARS displays.

The FAA intends the DABS/ATARS concept to be the separation assurance system used where DABS ground sites and IPC computers are available. The DABS/ATARS concept, however, cannot operate outside of DABS radar coverage, limiting its operational capability to a portion of the continental United States.

4.3.1.3 Beacon Collision Avoidance System

The development of collision avoidance systems has been hampered by the need for new electronics for all participants (cooperative systems). The investigation and development of the Beacon Collision Avoidance System (BCAS) has been pursued to circumvent this problem by making use of the existing signals-in-space transmitted by aircraft in response to ATCRBS interrogations. These signals, when properly detected and decoded, can provide, as a minimum, the relative range and altitude between aircraft. Successive decoding of aircraft ATCRBS replies will provide the relative closure rate between the two aircraft.

Two possible versions of this concept have been considered: an active mode and a passive mode. The active mode of BCAS generates ATCRBS interrogations (i.e., the same interrogations as a ground radar) to elicit transponder replies from all aircraft within listening range. Based on the time of arrival of a reply, the relative range of an intruder can be calculated. The passive mode, as the name implies, does not require on-board interrogation. Rather, it listens for both ground interrogations and the ensuing aircraft replies. Through geometric calculations using the relative time-of-arrival measurements, from two radar sites, the passive BCAS can evaluate the range and bearing of aircraft within radio listening range. Both BCAS concepts require extensive on-board computer systems to identify and track every aircraft within range. The computer must be able to extract the desired data from the continuous streams of normal ATCRBS surveillance interrogations and replies. The passive system, in addition, must perform the necessary geometric computations to obtain the desired data.

Development of the BCAS concept has been slowed by inability to detect and track through the clutter of undesirable interrogations and replies all aircraft within radio range of the BCAS-equipped aircraft. Technical improvements such as variable power BCAS interrogations, receiver desensitization, active DABS interrogations, and a single-site passive BCAS using simplified geometric computations, are therefore being evaluated to arrive at a configuration that will be physically, economically, and technically practical for present-day aircraft.

4.3.1.4 Pilot Warning Indicators

The FAA has considered several types of Pilot Warning Indicators (PWI) systems that would alert a pilot to the presence of another aircraft. However, these systems do not tell the pilot how to avoid that aircraft. The idea behind PWI is that the pilot would be alerted, see the intruding aircraft, and make the necessary avoidance maneuvers. Both electronic (e.g., transponder listen-in) and optical (e.g., strobe detection) systems have

been considered. The results show that a PWI is apparently as costly or more costly than some of the collision avoidance methods being investigated. The FAA is therefore not pursuing the development of a stand-alone PWI at present.

4.3.2 Current Programs

The FAA has identified the DABS/ATARS and BCAS programs for research and development. These programs are viewed as complementary solutions to separation assurance since their operational limitations prevent introduction of only one concept to satisfy the demands of the aviation population in the existing airspace. DABS/ATARS is being proposed for use in terminal areas and dense traffic environments where BCAS appears to fail because of excessive tracks and synchronous garble problems. DABS also provides the necessary ATC controller coordination and information mandatory for procedural maneuvers in terminal areas, which might be interpreted as collision threats by CAS logic.

The DABS schedule, as best defined now, calls for the airborne transponder contract to be awarded in mid CY 1979 with test articles to be delivered in mid CY 1980. Ground installation in the northeastern U.S. is scheduled to begin in CY 1979. The schedule has slipped in the past, but this estimate is the best at present.

BCAS is proposed for operation in the passive mode in areas not served by DABS/ATARS but within the line of sight of ground interrogators. The passive mode of BCAS is expected to benefit aviation safety by minimizing the generation of additional fruit (undesired interrogations and replies) that could adversely affect present ATCRBS surveillance operations. However, in areas not covered by ground ATCRBS (or DABS) interrogators, the BCAS system will automatically switch to the active mode and generate the necessary interrogations for range, range rate, and altitude determination.

The FAA office of Research and Development (SRDS) is actively pursuing the development of DABS ground systems and avionics. Deployment of three DABS sites for additional test and evaluation in a real traffic environment is planned for the northeastern United States. The FAA is concurrently supporting and sponsoring efforts by MITRE/METREK (active BCAS) and Litchford (passive BCAS) to develop and evaluate the BCAS concept. Figure 4-1 illustrates the most recent schedule of R&D activities defined by the FAA in the BCAS.

4.3.3 User Community Views

The FAA summarized the views of various airline and general aviation organizations at an April 20, 1977, Beacon Collision Avoidance meeting. All organizations expressing views on the DABS program were supportive. While the airline community was also supportive of the ATARS concept that would be coupled to the DABS, the general aviation community appeared to favor a "wait-and-see" attitude. All organizations were supportive of the

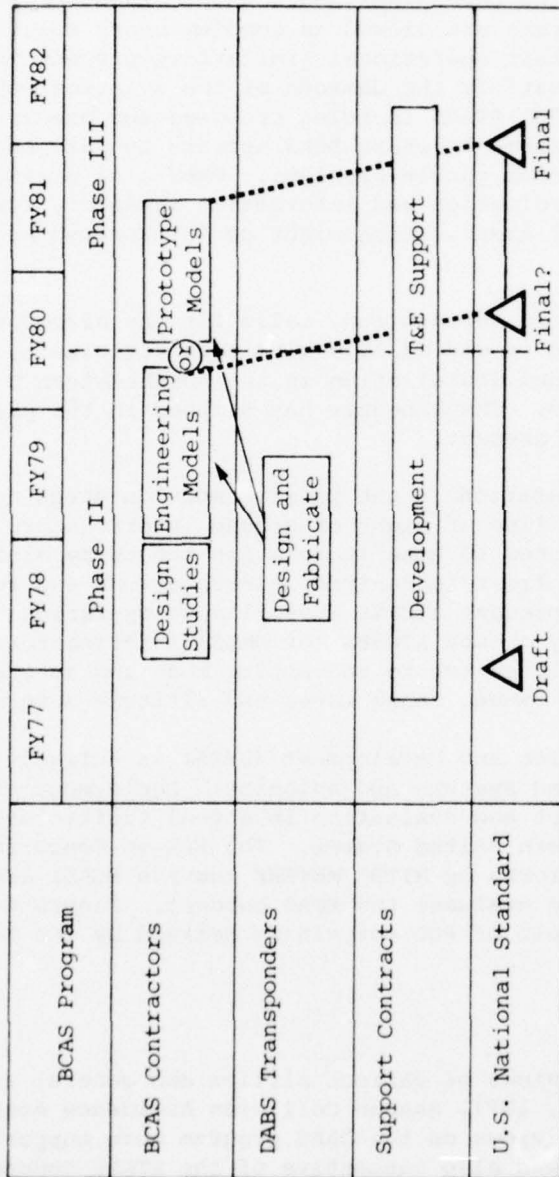


Figure 4-1. BCAS PROGRAM R&D SCHEDULE

BCAS efforts; however, the airline community favored the active BCAS and opposed a combined active-passive BCAS. For the most part, there was opposition to the ACAS and PWI concepts because of the requirements to fully equip all aircraft and the potential for performance limitations.

4.3.4 Technical Considerations

While the above sections have described overall research and development efforts, there are still a number of key technical issues that must be recognized. These issues include basic system performance, threat detection, threat resolution, and cost. Some of the more important technical issues are highlighted and briefly discussed to provide an insight into the magnitude of the decision process. These include:

- Passive vs. active approaches to BCAS
- Single-site vs. multiple-site interrogators in the passive BCAS
- Threat boundaries and alarm rates
- Vertical vs. horizontal maneuvers
- Directional antenna systems for BCAS
- ATARS complexities
- Costs

4.3.4.1 Passive vs. Active Approaches to BCAS

Two categories of intruder detection form the BCAS concept. They are: the use of active interrogations by the threatened aircraft to solicit replies from the intruder, which can be processed to determine range, range rate (closure rate), and altitude; and the use of passive techniques to listen to existing signals in space and determine a threat.

The active systems generate a large volume of fruit in maintaining relative information on all aircraft in sight. They do not provide information to ATC controllers of any intended avoidance maneuver. They also require relatively sophisticated on-board processing equipment to track all aircraft of interest effectively. However, these systems are independent of the primary ground-controlled ATC system and therefore act as a backup to the ground ATC system in the event of mechanical or human error. In addition, the active systems are not limited by land-based interrogators and will perform the threat detection function over oceans where no primary ATC surveillance capability exists at present.

The passive systems provide benefits difficult to obtain in the active mode. The two key examples are information about the relative bearing of an intruder and the absence of additional fruit generation. All passive systems, however, suffer from geographic location limitations requiring visibility to one or more ground interrogator sites to detect threats and evaluate them. These systems will not provide separation assurance over large bodies of water or over certain terrestrial locations such as the

Rockies or Alaska. Both the passive systems require high capacity logic processors and memory systems. Finally, the passive systems operate with equipment used for primary ATC separation and surveillance. Failure of the radar systems would leave aircraft with no backup protection.

One possible solution to the performance limitations of both the active and passive BCAS is to utilize a multimodal system that would be passive where radar coverage exists and active elsewhere. However, this multimodal system would cost more than the active-only or passive-only portions.

4.3.4.2 Single Site vs. Multiple Site Interrogators in the Passive BCAS

A passive system under development recently (Litchford system) requires at least two ground interrogators within line of sight to operate in the passive mode. Moreover, the interrogators must be in a favorable geometrical configuration before accurate bearing information can be computed. There are many flight paths at various altitudes where an aircraft would be visible to only one interrogator or would lack favorable geometrical coverage, causing the system to fail or revert to the active mode. An alternate solution using a single ground interrogator has been proposed but not yet developed or tested. This system would employ more complex ground radar interrogations and a distance-measuring capability at each radar site. However, the avionics requirements could be less severe than in the Litchford approach.

Both the multi-site (Litchford) and the single-site system can provide relative bearing information on the intruding aircraft. Since the addition of bearing information to threat prediction and maneuver command is viewed by many as highly desirable, continuing investigation of those two passive concepts is being pursued. However, development and evaluation of a new concept is time consuming. A decision may have to be reached on whether to continue development of the multi-site system or the single-site concept.

4.3.4.3 Threat Boundaries and Alarm Rates

The major concerns in establishing threat logic are the amount of advanced warning provided and the avoidance of unnecessary warnings and commands. In areas of low traffic density, little problem usually exists in either of these areas. However, in the terminal environment, aircraft are routinely flown close to each other. A collision avoidance logic that projects an aircraft's position too far ahead or too much to the side in a terminal environment would constantly be receiving warnings and alarms.

The original ACAS threat logic computed the "time-to-closest-approach" using the value tau where

$$\tau = \frac{\text{range between aircraft}}{\text{closing rate}}$$

and gave an alarm if tau was less than 25 seconds. The resulting 25-second warning would give both aircraft sufficient time to maneuver. However, aircraft that might safely pass no closer than a mile or two of each other could generate warnings depending upon the relative positions of the aircraft. These problems may be solved by reducing the warning time (with its obvious dangers) or by providing data on relative positions or maneuver intentions (with a possible increase in equipment complexity). The final resolution of threat boundaries and acceptable alarm rates is actively being investigated.

4.3.4.4 Vertical vs. Horizontal Maneuvers

Escape maneuvers have been the subject of many evaluations and conferences. Proponents of vertical maneuvers have shown and proved that these are the most efficient actions that can be taken by high performance aircraft at cruising speeds, even when bearing information is available. Therefore, the vertical maneuver logic (which is similar to the logic developed in support of the airborne CAS concept with the assistance and concurrence of the airline community and airframe manufacturers) is being advocated for high speed aircraft. However, some obvious problems, such as how to limit an aircraft at low altitudes when a collision threat exists, have been noted. The development and introduction of concepts that provide bearing information has allowed consideration of horizontal escape maneuvers. Horizontal maneuvers appear to be suitable for light aircraft with insufficient power for vertical ascent maneuvers; for all aircraft at low altitudes where a descent might place an aircraft in jeopardy; and as a pilot-preferred complement to vertical commands, providing that appropriate information is presented to the other aircraft involved in the threat. Evaluations are being conducted to identify the preferred avoidance maneuver. Emphasis is on aircraft capabilities and pilot reactions to simulated situations. However, horizontal maneuvers are much more difficult to plan than vertical ones. Where horizontal maneuvers are concerned, it is difficult to decide whether each aircraft should turn left or right in a manner that will ensure complementary maneuvers.

4.3.4.5 Directional Antenna Systems for BCAS

The design and implementation of directional antenna systems in conjunction with ACAS or active BCAS avionics can reduce the number of unnecessary aircraft maneuvers through improved definition of the threat boundaries. The directional antenna is an additional option that could provide the bearing data needed for horizontal maneuvers. Leading avionics manufacturers have proposed antenna designs that would either provide bearing information or limit the communication range to areas of greater interest (e.g., ahead-look signals spread about 40°). Although technically feasible, any antenna configuration other than a conventional omni-directional antenna would result in increased costs.

4.3.4.6 ATARS Complexities

One of the systems proposed for national acceptance as a collision avoidance standard is the DABS/ATARS concept. This concept has the ability to solve the bearing, threat boundaries, alarm rates, and maneuver problems by discretely tracking every aircraft in sight and issuing advisories (PWI) and commands (IPC) to threatened aircraft. This system could provide the separation assurance for all overland flights if deployed in sufficient quantity. However, the quantity of ground sites required for total coverage would also lead to overlapping coverage with different ATARS computers evaluating the same threat and separately commanding escape maneuvers. The need for communications between computers to coordinate these maneuver commands is evident. The ATARS threat detection and evaluation logic must be coordinated with data in all other ATARS computers in a grid structure to minimize the danger of conflicting information being transmitted to an aircraft. The communications and the higher capacity computer systems present an additional economic burden which must be evaluated to determine if the cost is justified, based on the benefits provided.

4.3.4.7 Costs

In the final analysis, the economic impact of any proposed system becomes a driving force. If cost were not a factor, the best technical solution would probably be a combination of aircraft systems tailored to operate at maximum efficiency in any given geographic location. However, aircraft have neither the space nor the weight allowance to carry the best configuration. Aircraft owners are usually financially limited to essential avionics designed to provide a high degree of confidence in flight safety. Therefore, the concept chosen and recommended as a national standard for separation assurance must be the result of a compromise that best meets the technical requirements and is the most cost-effective configuration of airborne and ground equipments.

CHAPTER FIVE

BASIC CONCEPTS AND USAF ACTIONS

5.1 INTRODUCTION

In the past, collision avoidance efforts have thrust in two principal directions. First, the concept of see-and-avoid has been a mainstay of preventing midair collisions from early aviation days. Over the years various schemes have been tried to enhance the ability of pilots to see, to be seen, and to avoid each other. Visual enhancement methods, better search methods, traffic advisories, proximity warning indicators, and even airborne collision avoidance systems could all be thought of as extensions of the see-and-avoid concept. The second concept used to prevent collisions involves traffic separation techniques, and includes such practices as scheduling, published standard routings, and radar control. The two concepts have worked together fairly well in the past. The see-and-avoid concept has provided complementary midair protection to those flights without traffic separation (VFR or no flight plan) or where the traffic separation concept has failed because of errors or mixing of uncontrolled traffic. This chapter will discuss basic concepts and actions the USAF could take to reduce the threat of midair collisions.

5.2 BASIC PROBLEM

Neither of these concepts by itself is capable of assuring collision avoidance under present-day traffic conditions in many areas of operation. The two concepts provide much mutual support, but increases in air traffic and speeds have reduced the effectiveness of the two concepts.

One obvious solution is to rigidly segregate and control the IFR traffic from the VFR traffic. This is already being done in the positive control areas of the airspace. Extensions of this segregation are often suggested as a means of reducing midair collisions. Although further segregation would undoubtedly reduce midair potential, there are problems associated with it. For instance:

- United States citizens believe they have a basic right to use the airspace and any restriction or infringement on that right is bound to be vigorously resisted. Thus,

although there will undoubtedly be further restrictions on use of certain airspace, the free use of most of the airspace will continue.

- The USAF mission requires it to use portions of the airspace that probably will not be reserved or restricted for sole USAF use.
- Both VFR and IFR traffic must climb and descend through all altitudes between the ground and their flight altitudes, making completely effective altitude segregation impossible.

For these reasons, it does not appear that further segregation of IFR and VFR traffic, by either area or altitude separation, is a complete solution to the midair collision problem. The best approach for the Air Force seems to be to enhance the two basic concepts of see-and-avoid and separation assurance. Ways to augment the two basic concepts have been and are being tried. Some of these are:

- See-and-avoid concept

- Paint schemes
- Floodlights
- Rotating beacons
- Strobe lamps
- Proximity warning indicators
- Airborne collision avoidance systems

- Traffic segregation-flight plan-scheduling concept

- Airways, Communications and Navigation facilities, IFR plans
- Smooth flow scheduling
- Radar control areas, vectoring
- Standard instrument departures (SID)
- Radar beacons -- altitude encoding
- Automated air traffic control
- DABS -- Automatic Traffic Advisory and Resolution Service (ATARS)
- Automatic conflict resolution
- Military operating areas
- Restricted areas and ranges

The USAF problem of lowering midair collision potential resolves itself into finding better ways to:

- Improve the ability of USAF pilots to better see-and-avoid and for other pilots to better see USAF aircraft
- Improve traffic separation from all other air traffic, including VFR, IFR, or no-flight-plan traffic

In examining ways the USAF can meet these needs, four areas stand out as being prime targets on which the USAF should concentrate its efforts. They are:

- Equipment
- Aircrew procedures
- System-control procedures
- Training

The following sections will expand on these four subjects by proposing specific actions that the USAF could take to reduce midair collision potential. Some actions in the procedures and training section could as properly be categorized under other headings. Arbitrary judgments assigned them to one of the four categories.

These actions are further developed in a separate report to the Air Force, including specific task statements, statements of work, and schedules for each action.

The actions proposed focus on the USAF midair problems identified in Chapter Three and will complement the FAA actions discussed in Chapter Four. Recognition of the USAF's need to conduct its training and develop its tactics in as near combat-like conditions as possible has been a consideration throughout this study and in developing recommendations. The USAF midair collision problem, although an important and serious consideration in USAF flight operations, must be viewed in its proper perspective in the total USAF national defense role.

5.3 EQUIPMENT

Several potential equipment needs and developments were identified during the course of this study. Each was examined for its potential to meet USAF need. Those listed below seem to promise the most reduction of USAF midair collision potential or improvement in USAF operations without increasing midair collision potential, or both.

5.3.1 Non-Cooperative Collision Avoidance System (NCAS)

The Air Force ROC 17-71 identifies a continuing need for NCAS. Most previous studies and discussions with knowledgeable people indicate that the state of the art will not permit development of a NCAS at this time. ROC 17-71 says that a NCAS may not be technically feasible at this time and states, "until such a system [NCAS] is technically feasible, a cooperative system is required ..." Although the consensus is that an NCAS is not feasible now, the USAF needs to institute comprehensive basic research into the possible technologies that could lead to an NCAS. No evidence of such an effort was found during this study.

5.3.2 Cooperative Collision Avoidance System (CAS)

Until such time as a NCAS is technically feasible and developed, the USAF should consider using a CAS. As reported in Chapter Four, the FAA is developing a ground-based Beacon Collision Avoidance System (BCAS). ROC 17-71 states that any military CAS must be compatible with the FAA National Standard. Present FAA schedules project major activities in evaluating the BCAS design and engineering models, and in developing a national standard in 1978 and 1979. The USAF should actively participate in FAA efforts with appropriate policy, operational and engineering personnel to assure compatibility between USAF requirements and FAA developments. Additionally, as the FAA design matures, the USAF should begin integration and life-cycle-costing activities in order to be better able to evaluate the BCAS for USAF aircraft.

5.3.3 Discrete Address Beacon System/Automatic Traffic Advisory and Resolution Service (DABS/ATARS)

Coupled closely with the BCAS in the FAA Separation Assurance Program is the DABS/ATARS. One of its purposes is to give coverage in high density areas where BCAS may become saturated. Since the FAA is developing the BCAS and DABS/ATARS as a complementary package, the USAF needs to monitor DABS/ATARS avionics developments in much the same way as it must monitor BCAS progress. Here again, major FAA activities are scheduled in 1979 and 1980 in which the USAF should participate at the policy, operations, and engineering levels.

5.3.4 Air Training Command Collision Avoidance System (ATC CAS)

As discussed in Section 3.3.3, the Air Training Command has used controlled training flight procedures by which each aircraft is vectored to a given airspace, monitored while there, and vectored back for landing. These procedures have reduced the midair collision potential since each flight is essentially under IFR control. However, it is estimated that as much as 25 percent of the training time on each flight is devoted to these control procedures. While this is valuable instrument training it does detract from other types of training and the student's ability to independently position himself in the airspace relative to another aircraft or to the ground. As discussed previously, this lack of independent judgment is a serious concern to ATC and operating commands.

The Army had a similar midair collision situation in its high density helicopter training area and solved it by using an airborne CAS. If a low cost, small CAS could be developed for the ATC Military Operating Areas (MOAs) and installed in new training aircraft, or even retrofitted into T-37s and T-38s, if that should be cost-effective, better use could be made of training time. At least three CASs that might be cost-effective in the ATC MOAs have been tested in operation. They and any other CAS that shows promise should be examined further for USAF application.

5.3.5 Radars in Europe

USAFE has assigned a high priority to upgrading radars and associated equipment to reduce midair collision potential in Europe. The recommended action includes improving mode-C altitude readouts to provide altitude information to controllers. This Phase I study did not allow enough time to investigate those actions. The MAPS Program should evaluate any actions planned to upgrade the radar and mode-C readout capabilities in Europe to ensure that they will contribute to reducing the midair collision potential.

5.3.6 Visual Enhancement

There have been many attempts to increase the conspicuity of aircraft over the years. These have included the use of paint schemes and lights. Interviews and data and literature reviews conducted during this study have indicated that paint only marginally increases aircraft conspicuity. Furthermore, the mission of the USAF opposes the use of conspicuous paint schemes on most of its aircraft. Most commonly, the USAF uses paint schemes to make aircraft less conspicuous.

High intensity lights, on the other hand, were considered by those interviewed to significantly increase aircraft conspicuity on dull days with a low brightness background and at night. Most aircrews thought high intensity strobe lights should be put on USAF aircraft. Test data indicate, however, that strobe lights must be very bright to be effective under most flight conditions. There has been disagreement in the USAF over the use of strobe lights during the past few years. Phase II of the MAPS Program should attempt to resolve the issue by providing the necessary information on which to evaluate the use of lights to enhance conspicuity. The effectiveness of various light intensities under different weather and background brightness conditions to increase aircraft conspicuity and enhance aircrew detection should be investigated. These investigations should build on previous studies on what aircrew warning is needed to avoid midair collisions. After requirements are determined, the ability of existing developmental light sources to meet those requirements should be analyzed to determine the feasibility and effectiveness of using state-of-the-art lights to enhance Air Force aircraft conspicuity. If high intensity lights prove practical and effective in these initial studies, a program to put them selectively into service should be pursued.

5.3.7 Simulators

The use of flight simulators to reduce the potential of midair collisions shows promise in two areas. First, simulators with visual displays can be used to help train aircrews in searching for and seeing other aircraft. Secondly, simulators can be used in lieu of actually flying training missions that involve a high midair collision threat. The Air Force is searching for ways to increase the use of simulators and the MAPS Program should examine their potential for reducing midair collisions. If initial studies prove promising, a program should be undertaken to demonstrate

their capabilities and effectiveness. That program should provide the information necessary for deciding whether to develop visual simulator displays for see-and-avoid training.

5.4 AIRCREW PROCEDURES

The duties of the aircrew affect their ability to avoid midair collisions. The following subsections propose improvements to aircrew procedures that could help prevent midair collisions. These proposals respond to concern expressed by aircrews during interviews and revealed in literature searches and were correlated with MAC and NMAC data where appropriate. Section 5.6 will address the training aspects of improving aircrew techniques to reduce the potential for midair collisions.

5.4.1 Improve See-and-Avoid Capabilities

One of the problems mentioned most frequently in connection with midair collisions is that of aircrew members having their heads in the cockpit too much of the time. Since the primary method for avoiding midair collisions involving a mixture of VFR and IFR flights is see-and-avoid, a major concern of the MAPS Program should be to investigate ways to improve the aircrews' capabilities to see and avoid other aircraft. Anything that can be done to increase the time available to the aircrew to scan for other aircraft is a positive step in that direction.

5.4.1.1

Aircrews cite the large number of radio calls to command posts and to Air Traffic Control required to clear on and off ranges as major contributors to keeping aircrew eyes in the cockpit instead of looking outside for other aircraft. Since a large portion of NMACs occur during approaches and departures, it becomes even more important to keep aircrew heads out of the cockpit at these critical times. It is also important when clearing on and off ranges. Discussions with the Navy disclosed similar conditions clearing on and off ocean ranges. The MAPS Program should investigate the changes in requirements and procedures that would reduce the need for aircrew attention to radio communications.

5.4.1.2 Use Crew Member in Observer's Seat

Both MAC and SAC report making extensive use of a crew member in the observer's seat (jump seat) to watch for other aircraft while flying below 10,000 feet. The MAPS follow-on efforts should include a task to define and further expand this procedure where practical. An extra pair of eyes during critical low-level flying on training routes and near air fields may be one of the most important methods of reducing MACs and NMACs, especially those with general aviation aircraft.

5.4.1.3 Use Heads-Up-Display (HUD)

Another approach that gives the crew more time to watch for other aircraft depends on the use of heads-up-displays (HUD) to provide flight information where the pilot can see it while he is also looking for other aircraft. HUD research has increased greatly in recent years and the MAPS Program should investigate possible applications for the prevention of midair collisions.

5.4.1.4 Consider Mandatory Use of VFR Traffic Advisories

The USAF encourages aircrews to request VFR traffic advisories. Making this procedure mandatory would provide extended separation from VFR traffic that is "seen" by the controller. Since many of the MACs and NMACs are between one aircraft flying VFR and the other flying IFR, mandatory use of VFR traffic advisories by USAF aircrews, especially in climbs, descents, and around terminal areas on departures and approaches, should reduce their exposure to unseen VFR traffic and thus reduce the potential of midair collisions in high threat areas. Any investigation into requiring mandatory use of VFR vectors must start with determining the effect of such use on the USAF mission and the ability of FAA and Air Force controllers to provide the service.

5.4.2 Determine Impact of Changing Tactical Call Signs

The procedure of frequently changing tactical call signs may be causing some problems in communications between aircrews and controllers. Although no specific occasions of confusion or problems were reported, there was a general feeling among aircrews and controllers interviewed that frequent changing of tactical call signs was causing communications and recognition problems. In the past when the same call signs were used for considerable periods of time, aircrews were quick to listen for and recognize their familiar call signs. In addition, the controllers learned to recognize certain call signs and associate them with home bases, particular instrument departures and approaches, and aircraft speeds and capabilities. That familiarity probably aided the exchange of information and smoothed the flow of traffic. In view of these considerations, the effects of short term versus longer term assignment of call signs on air traffic flow (and thus midair collision potential) and mission accomplishment should be reviewed.

5.4.3 Evaluate Aircrew Workload

There was a general feeling among aircrews interviewed that many decisions affecting aircrew workload and reduced crew size were made without fully considering what effect those decisions would have on safety in general, and midair collision potential in particular. Aircrew workload requirements should be reviewed in relation to workload saturation during critical phases of flight. This review should include individual crew member tasks, checklist completion and timing, and ability to devote

time to watching for other aircraft. This same type of review needs to be institutionalized within the USAF so that future decisions regarding aircrew duties and size are given the same scrutiny before they are implemented.

5.4.4 Increased Use of Airborne Radars for Midair Prevention

More of the USAF tactical aircraft such as the F-15 and F-16 are equipped with airborne radars. These radars can be important in reducing the midair collision potential of the aircraft that have them. The merits of using airborne radars to aid in preventing midair collisions should be investigated. If their use in this way proves effective, techniques and procedures for such use should be recommended.

5.5 SYSTEM CONTROL PROCEDURES

The Air Traffic Control (ATC) system, its controllers, and its procedures are also elements affecting the USAF midair collision problems. The following subsections describe actions related to the ATC system that the USAF could take in the MAPS program to reduce midair collision potential. Some of the suggested actions can be started within the USAF, but may later require coordination with and approval of the FAA.

5.5.1 Determine Best Low Altitudes for USAF to Fly

An investigation should be made into the best low altitudes for the USAF to fly to reduce midair collision potential when mission requirements or aircraft performance require low altitude flights. Segregated bands of altitudes for various airspace users could be examined for high threat areas. For instance, in the Federal Republic of Germany lower speed, low altitude civil traffic uses a band from 1500 feet to 5000 feet MSL where high speed traffic will not operate except during climbs and descents. De facto altitude bands such as this could exist already where air traffic is segregated or less dense. The Air Force should investigate the possible existence of such bands where its aircraft would be less exposed to midair collisions. Results of the investigation could be used within the USAF to develop its own procedures or as a basis for discussions with FAA and other airspace users.

5.5.2 Determine Best Airspeeds for USAF Aircraft Below 10,000 Feet

The current FAA restriction to fly at airspeeds of 250K or under when below 10,000 feet should be examined with respect to current USAF aircraft performance and mission requirements. Trade-offs between lower speeds to aid in seeing and being seen versus aircraft maneuverability should be examined. Several officers expressed doubt that high performance USAF aircraft are maneuverable enough at 250K or below to avoid another aircraft after it had been seen. We could find no evidence that the USAF had systematically examined the 250K restriction with respect to its effectiveness or impact on operations. Results of such an investigation

would be used for developing internal USAF procedures and, if applicable, as a basis for discussions with the FAA on possible modifications to the 250K restrictions.

5.5.3 Investigate Trade-Offs Between Maximum Use of IFR Flight Plans and Using See-and-Avoid Techniques on VFR Flight Plans

The USAF has made maximum use of IFR flight plans and so has been provided positive separation from other IFR traffic. There have been very few MACs or NMACs between IFR traffic. Although using IFR flight plans obviously does not negate the see-and-avoid concept, it possibly could lead to: (1) increased aircrew workloads that reduce time to watch for other traffic, and (2) false feeling of security for the crew, believing they are separated from other traffic when in fact they are only separated from other IFR traffic. Both of these situations could possibly increase the potential for midair collisions with VFR traffic by decreasing the effectiveness of the see-and-avoid concept. The USAF should examine the advantages and disadvantages of the maximum use of IFR and see-and-avoid concepts to determine the effect each may have on midair collision potential. Trade-offs between the two concepts could be the basis for revising USAF procedures.

5.5.4 Reduce Instrument Approach Plate Complexity

Instrument approach plates have become increasingly cluttered during the last few years. Information has been added to the point that aircrews may have trouble reading them in bad weather or at night. The normal trend is to put more and more information on charts over the years as a result of accidents or incidents. Most of the information is good to have, but there comes a time when adding information becomes counter-productive. Aircrew interviews indicated that instrument approach plates may be nearing saturation.

The USAF should review the instrument approach plates with the objective of reducing their complexity. Reduced complexity would reduce possible aircrew confusion and require less time with aircrew heads in the cockpit. Both should help reduce midair collision potential.

5.5.5 Investigate the Use of Mandatory Avoidance Vectors Away from Unknown Traffic

Much of the VFR traffic and traffic without flight plans show up on controllers' radar scopes as unknown traffic; that is, flight path intentions and altitudes are not known. Advisories are usually given to the aircrew regarding this unknown traffic. Unless avoidance vectors are specifically requested by the aircrew, however, the controller is not required to issue them to provide separation from the unknown traffic. This applies even when the aircraft is in Instrument Flight Conditions and the aircrew cannot see other traffic. In Great Britain it is mandatory for controllers to provide either positive lateral separation from unknown

traffic without altitude information, or 5000-foot vertical separation from unknown traffic with mode-C readout information. The USAF should investigate the feasibility of:

- (1) Mandatory procedures for aircrews to request positive separation from VFR or unknown traffic
- (2) USAF controllers automatically providing separation from VFR or unknown traffic
- (3) FAA controllers providing USAF aircraft with separation from VFR or unknown traffic

5.6 TRAINING

Two aspects of training relate to the risk of midair collisions. First, training consumes a major portion of peacetime flying by the USAF, and how that training is conducted greatly affects the potential for midair collisions. Secondly, proper training techniques better train aircrews how to avoid midair collisions. The following subsections suggest ways that the USAF could improve both aspects of training to reduce the potential for midair collision.

5.6.1 Develop Techniques and Methods to Better Teach See-and-Avoid

During interviews at various USAF commands, we asked whether aircrews were given specific training on how to reduce midair collision potential. The answer generally was that collision prevention was covered during flight safety meetings, but no specific instructional block or grading checklist item was devoted to preventing midair collisions. Although watching for other aircraft was sometimes covered during flight checks, no specific emphasis or grading check was evident. In fact, it was brought out that the emphasis on maximum IFR makes even the proficiency flight check more of a "heads-in-the-cockpit" instrument check than a "heads-out" VFR type check. It appeared that emphasis on preventing midair collisions was subject to the individual instructor's interest or the local traffic situation and was not the result of any specific efforts to reduce midair collision potential. In light of this, the USAF should undertake a program to improve and update ways to:

- (1) Teach see-and-avoid techniques in pilot training
- (2) Emphasize and train pilots in see-and-avoid techniques on flight checks, especially on proficiency flight checks
- (3) Include see-and-avoid concepts in periodic physiological training courses

5.6.2 Teach Use of Outside Reference for Pitch, Bank, and Heading Control

The use of positive control and vectoring during pilot training and of maximum IFR flight plans thereafter may have created a generation of USAF pilots who rely wholly on their instruments for pitch, bank, and heading control. Altitude encoding transponders have probably increased this reliance on instruments by increasing the pilot's concentration on altimeters and vertical speed indicators during IFR flights. All of this further decreases the pilot's time and inclination to look out of the cockpit for other traffic. The USAF should investigate ways to reverse this trend by teaching and emphasizing methods to use outside references such as the horizon and prominent land marks for pitch, bank, and heading control. Recommended techniques and methods could be taught in pilot training, emphasized on flight checks, and stressed in operational squadrons.

5.6.3 Determine Impact of F-15 and F-16 Air-to-Air Roles on Midair Collision Potential

As discussed in Section 3.3.3, the deployment of the F-15 and F-16 into the USAF inventory brings a significant increase in the number of high-midair-collision risk air-to-air combat passes. Although F-15 and F-16 air combat passes are different than the ground controlled intercepts conducted by the Aerospace Defense Command in large numbers in the late 1950s and early 1960s, there may be lessons important to the prevention of midair collisions to be learned from those early experiences.

Compounding the F-15 and F-16 problem is the Airborne Warning and Control System (AWACS) operating scenario in which up to 150 interceptors in a relatively small area may be controlled by the AWACS under combat-like conditions. This potential midair problem was stressed by officers interviewed at HQ TAC, the AFISC, and HQ USAF. It would be appropriate for the MAPS Program to investigate ways to preclude any increase in the mid-air collision potential that might be induced by increased air-to-air combat training in TAC.

5.6.4 Examine Ways to Reduce the Potential for Midair Collisions on Low-Altitude Training and Olive Branch Routes

All commands expressed concern over the midair collision threat associated with low-level training flights. It is on the low-level training flights and operations near terminals that the USAF aircraft come in close proximity with their number one threat, the general aviation aircraft with no flight plan or on a VFR flight. However, the data do not indicate that the low-level training flights are an overwhelming midair threat (see Section 3.3.4). This is probably due to the actions already taken by the USAF in educating its aircrews and general aviation pilots about the collision threat while on or near the low-level routes. Efforts on the part of the USAF to improve these actions could continue to pay dividends in lower-than-expected MAC and NMAC rates on the low-level

training routes. The USAF should examine ways to improve its low-level training route safety record by undertaking the following actions:

- (1) Conduct a comprehensive examination into the needs for and location of the routes
- (2) Review the procedures for selecting, coordinating, approving, and using the routes
- (3) Examine ways to improve the publicity about the routes

5.6.5 Review Formation and Air Refueling Requirements, Procedures, and Techniques

Almost three-fourths of all USAF MACs occurred during formation flying or air refueling. Most aircrews and officials interviewed said that midair collisions were an acceptable risk during formation flying and air refueling, and there was no way to prevent them anyway. It may be true that equipment solutions to reducing the collision threat during formation flying and air refueling do not seem feasible, but the rate of midair collisions is too high during these types of flying for the USAF to accept without a comprehensive examination of requirements for formation takeoffs and landings and the procedures and techniques used in formation flying and air refueling.

The problem of not being able to properly maintain a lookout for other aircraft while in close formation was often stressed during interviews with aircrews. TAC is using spread formation as soon as practical after takeoff to increase the lookout for other aircraft. This would appear to be one easy, positive approach the USAF could take to improve see-and-avoid techniques. The USAF should investigate ways to increase the use of spread information and to emphasize watching outside the formation when teaching spread-formation flying.

5.7 OTHER ACTIVITIES

There are four efforts that do not fit into the above categories that the USAF could undertake to reduce the midair collision potential. They relate to the exchange of collision-related information between users of the airspace, an investigation into future drone requirements, and the checks and follow-up actions necessary to make the MAPS Program effective.

5.7.1 Investigate the Establishment of a Joint Midair Working Group

There is a Joint Air Miss (in Europe, NMACs are called Air Misses) Working Group operating in England and an Air Miss Evaluating Group in the Federal Republic of Germany. Their purpose is to bring together the various flying interests, both military and civil, to discuss and examine all the factors associated with air misses. The working group in England is thought to be especially effective in follow-up actions. Its chairman is

an FAR group captain with a staff of about five. Although the FAA, through the NASA Ames Research Center, has established an Aviation Safety Responding System (see Section 2.3.5), there is no operating body specifically working on the NMAC problem. The USAF should take the lead under the MAPS Program in examining the benefits that could be gained by establishing a Joint Midair Working Group modeled after the one in England.

5.7.2 Improve the Information Exchange Between the USAF and the General Aviation Community

One of the subjects mentioned most frequently during the interviews was that of educating the general aviation pilots about USAF operations especially on low-level training routes and near USAF bases. The other side of the information exchange problem is that of informing USAF aircrews about civil air operations in areas where the USAF may fly. Ways to enhance and broaden this two-way information exchange should be developed by the MAPS Program.

5.7.3 Drone Unique Requirements

The use of drones by the USAF may create unique problems for air traffic control and midair collision prevention. To test and train effectively with long-range drones, more airspace will be required than is available in restricted areas over ranges. The drone clearance requirements the USAF may have in the future and what the FAA would require of the USAF in the way of procedures and equipment should be investigated before allowing use of more airspace for drones. Coupled with this is the ever-present problem of losing control of a drone in restricted airspace and having it stray into unrestricted airspace. The USAF should examine both questions for ways to minimize the potential for midair collisions.

5.7.4 MAPS Program Integration

During this study, investigators found several actions that had already been started which would have a positive effect on reducing the midair threat. Some of the actions are still ongoing. These actions ranged from recommendations of the General Officer Panel for Safety Matters to individual command and base programs to reduce the midair collision potential. These actions all contained positive elements that could be effective if given the proper integration, control, and follow-up. However, the centralized management necessary to bring the many facets of an effective midair collision prevention program to focus appears to be missing. The MAPS Program needs to provide this missing control. To provide effective integration and management, day-to-day involvement in the various aspects of equipment development, changes in aircrew and traffic control procedures, and training improvement are necessary. The MAPS Program should establish a central working office, staffed to provide the interfaces, integration, allocation of resources, procurement support, program control, evaluation, and follow-up actions needed.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

Air Force aircraft were involved in 301 midair collisions during the period January 1968 through June 1977. In addition, during the period January 1975 through June 1977, Air Force aircraft were involved in 376 near midair collisions. On the basis of this experience and additional analysis contained in this report, it is concluded that the Air Force does have a midair collision prevention problem.

6.1.1 Near and Actual Midair Collision Data

The near midair collision (NMAC) data being generated by the Air Force's Hazardous Air Traffic Reporting System are extremely valuable in identifying the characteristics of NMACs and in many areas the data correlate closely with the data related to actual midair collisions. The NMAC and MAC data would be easier to use and more meaningful comparisons could be made if the two separate files were restructured to include common data elements and retrievability codes.

6.1.2 Air Force-Air Force NMACs and MACs

Air Force aircraft are experiencing a higher number of MACs with other Air Force aircraft than would be expected from the number of NMACs being reported. Approximately 75 percent of all Air Force MACs are with other Air Force aircraft. The majority of these occur during relatively high risk operations such as air refueling and formation flying. Nonassociated MACs between two Air Force aircraft during the period January 1968 to June 1977 occurred at approximately the same rate as between one Air Force aircraft and general aviation aircraft (see Section 3.5.2).

6.1.3 Air Force-Air Carrier NMACs and MACs

With the exception of one MAC with a foreign air carrier (DC-4) in Viet Nam, the Air Force did not experience any MACs with air carriers.

AD-A049 743

ARINC RESEARCH CORP ANNAPOLIS MD
INVESTIGATIONS TO SUPPORT PHASE I OF THE USAF MIDAIR PREVENTION--ETC(U)
OCT 77 F CRUM, K HASPERT, S KOWALSKI
1924-01-1-1676 ASD-TR-77-76 F09603-77-A-3104

F/O 1/2

UNCLASSIFIED

NL

2 of 2

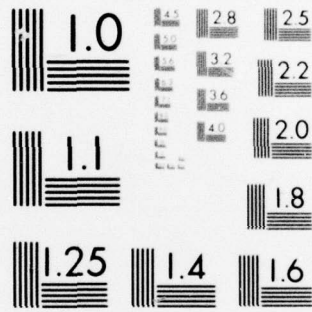
AD
A049743



END
DATE
FILMED

3-78

DDC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

However, during the period January 1975 through June 1977, the Air Force experienced 22 NMACs with air carriers, 10 of which were in the United States. Because of these NMACs and the potential fatalities that would result from a MAC between an Air Force plane and a wide body jet air carrier, it is concluded that the Air Force must consider this possibility as a part of the MAPS Program Phase II.

6.1.4 Air Force-General Aviation NMACs and MACs

Almost 70 percent of the NMACs reported under the HATR Program involve general aviation aircraft. During the period January 1968 through June 1977 general aviation aircraft were involved in 54 percent of the Air Force nonassociated MACs; and during the more recent period January 1973 through June 1977, 83 percent of all Air Force nonassociated MACs were with general aviation aircraft. Based on the data from this more recent period, it is concluded that with the exception of Air Force high risk operations such as air refueling and formation flying, the Air Force's greatest midair collision problem is with general aviation aircraft.

6.1.5 NMACs and MACs by Flight Activity and Altitude

Almost 64 percent of the NMACs and 83 percent of the nonassociated MACs occurred during the takeoff-departure and arrival-landing phases of flight. On the basis of flight activity and related data presented in Chapter Three, it is concluded that the majority of both NMACs occur at relatively low altitudes (below 5,000 feet), and in the vicinity (within 10 nautical miles) of airports.

6.1.6 NMACs and MACs On Military Low-Level Training Routes and Olive Branch Routes

Less than 10 percent of the NMACs occurred on military low-level and Olive Branch routes. Only one MAC (in USAFE) of the 24 nonassociated MACs occurred on such routes. This, coupled with the conclusion presented in Section 6.1.5 above, leads to the additional conclusion that while TR and OB routes deserve attention in the MAPS Program, they have received publicity and emphasis disproportionate to the total Air Force midair collision potential problem.

6.1.7 NMACs and MACs by Air Force Commands

Certain commands were shown to have NMAC and MAC rates noticeably above the USAF average. This was particularly true for USAFE, which demonstrated a NMAC rate 5.8 times more, and a MAC rate 5.2 times more than the Air Force average. Two other commands, TAC and ATC, were also

shown to have rates higher than the Air Force average. It is therefore concluded that these three commands deserve special attention during Phase II of the MAPS program.

6.1.8 NMACs and MACs by Cause

Almost two-thirds of the NMACs and over one-third of the MACs resulted from the system-environment in which the aircraft are operated. Pending implementation of additional control procedures or collision avoidance hardware, or both, see-and-avoid must continue to be the number one midair collision avoidance technique.

6.1.9 Formation and Associated Air Force Flying

A large portion of the Air Force MACs occurred during formation or associated flight. Most Air Force personnel contacted during this study indicated: (1) the risk is acceptable, and (2) there is no way to prevent these incidents anyway. However, because of the large number of MACs involved in these categories (20 percent formation, 45 percent air refueling and 6 percent associated), some MAPS efforts should be directed toward finding ways to reduce the midair collision potential in formation and associated flying.

6.2 RECOMMENDATIONS

6.2.1 Overall Recommendation

Chapter Three of this report indicated that the Air Force does have a midair collision prevention problem, and Chapter Five discussed concepts that could reduce the Air Force's midair collision potential. It is therefore recommended that Phase II of the MAPS Program be undertaken and that these concepts be evaluated.

6.2.2 Specific Recommendations for Phase II Activities

It is recommended that the actions listed below be undertaken during Phase II of the MAPS Program.

Equipment

- Institute comprehensive basic research into technologies that could lead to an Air Force Non-Cooperative Collision Avoidance System.

- Actively monitor FAA development of a Cooperative Collision Avoidance System and work to assure compatibility between FAA developments and USAF requirements.
- Evaluate actions planned to upgrade radars in Europe to ensure that they will provide the added capability needed to assist in reducing the midair collision potential.
- Determine the strobe light characteristics required to be effective in reducing midair collision potential under daylight conditions.
- Examine the use of simulators and their potential for reducing the midair collision problem.
- Investigate the unique requirements of drones relative to midair collision potential.

Aircrew Procedures

- Complete a review of aircrew procedures and related in-flight duties which contribute to "heads-in-cockpit." Included in the review should be checklists, radio transmissions and frequency changes, and aircrew workload requirements.
- Determine the feasibility of alternative procedures on the use of mandatory traffic advisories and vectors.
- Determine the feasibility of changing the procedures for assigning tactical call signs.
- Determine the feasibility of increasing the use of airborne radars to reduce midair collision potential.

System-Control Procedures

- Determine the best altitudes for conducting low altitude flights.
- Determine the optimum airspeeds for USAF aircraft below 10,000 feet.
- Investigate trade-offs between maximizing IFR flight plans and using "see-and-avoid" techniques on VFR flight plans.
- Reduce instrument approach plate complexity.

Training

- Develop better techniques and methods to teach "see-and-avoid".
- Refine and teach techniques for using outside references for pitch, bank, and heading control.
- Determine the effect of F-15 and F-16 air-to-air training on the risk of midair collision and develop an optimum training syllabus.
- Review actions already under way or planned relative to low-altitude-Olive Branch routes and determine additional actions necessary to reduce midair collision potential.
- Review formation and air refueling requirements, procedures, and techniques, and recommend improvements needed to reduce midair collision potential.

6.2.3 Other Recommendations

- Examine the operations and benefits of the Joint Air Miss Working Group in England, and the Air Miss Evaluation Group in Germany, and determine whether the establishment of a similar group in the USA would be productive in reducing the midair collision potential.
- Review current programs and procedures for the exchange of information between the USAF and the general aviation community, and recommend ways to broaden and enhance this two-way information exchange.
- Initiate a separate program management-integration task to ensure that the above actions are coordinated and integrated into an effective midair collision prevention program.

REFERENCES

Selected documents used in this study in support of Phase I of MAPS are listed below:

1. USAF R&D Program Planning Summary, Mid-Air Prevention Systems (MAPS), September 1976.
2. USAF Program Management Directive for Collision Avoidance Systems, 21 September 1971.
3. Air Force Regulation 127-3, Hazardous Air Traffic Report (HATR) Program, 11 June 1976.
4. NASA Aviation Safety Reporting System: Third Quarterly Report, Technical Memorandum (TM) X-3546, May 1977.
5. Aeronautical Systems Division, Strobe Light Evaluation, 20 June 1977.
6. Department of Transportation, Federal Aviation Administration, Near Midair Collision Report of 1968, 15 July 1969.
7. Department of Transportation, Federal Aviation Administration, Civil Aviation Midair Collision Analysis, January 1974 through December 1971, May 1973.
8. Department of Transportation, Federal Aviation Administration, Civil Aviation Midair Collision Analysis: 1972 Added to the 1964-71 Results, December 1974.
9. Directorate of Aerospace Safety, Norton AFB, CA, USAF Midair Collision, 1 January 1965 through 31 December 1975, 2 March 1976.
10. Directorate of Aerospace Safety, Norton AFB, CA, USAF Accident Bulletin, 1976.
11. Department of Transportation, Federal Aviation Administration, Report Number FFA-ATF-4-76-1, Consultative Planning Conference on Aircraft Separation Assurance: Presentations, dated 27 September 1976.

APPENDIX A

MISCELLANEOUS NMACS DATA

This appendix presents tables and figures that relate NMACs to various factors. The information contained too many unknowns to permit its use in this study, but it is included here with the expectation that it may be of use in later studies with different objectives. The NMACs are related to the various factors as follows:

- Table A-1 -- transponder usage
- Table A-2 -- radar service
- Figure A-1 -- radar stage available
- Figure A-2 -- factor first sighted

Table A-1. NEAR MIDAIR COLLISIONS BY TRANSPONDER USAGE

Number 1 Aircraft	Number 2 Aircraft					Number 1 Aircraft Totals
	On Mode C	On	Inoperative	Off	Unknown or Not Reported	
On Mode C	33	19	0	17	99	159
On	0	0	0	0	1	1
Inoperative	1	0	0	0	2	3
Off	2	0	0	0	4	6
Unknown or Not Reported	5	2	0	3	197	207
Number 2 Aircraft Totals	41	12	0	20	303	376

Summary

Aircraft	Transponder On Mode C/On	Transponder Off or Inoperative
Number 1	160	9
Number 2	53	20

Table A-2. NEAR MIDAIR COLLISIONS BY RADAR SERVICE

Number 1 Aircraft	Number 2 Aircraft				Number 1 Aircraft Totals
	Vectors	Monitor	Not Used	Unknown or Not Reported	
Vectors	7	16	38	60	121
Monitor	3	28	32	54	117
Not Used	3	6	33	39	81
Unknown or Not Reported	1	1	4	51	57
Number 2 Aircraft Totals	14	51	107	204	376

Summary

Aircraft	Radar Used	Radar Not Used
Number 1	238	81
Number 2	65	107

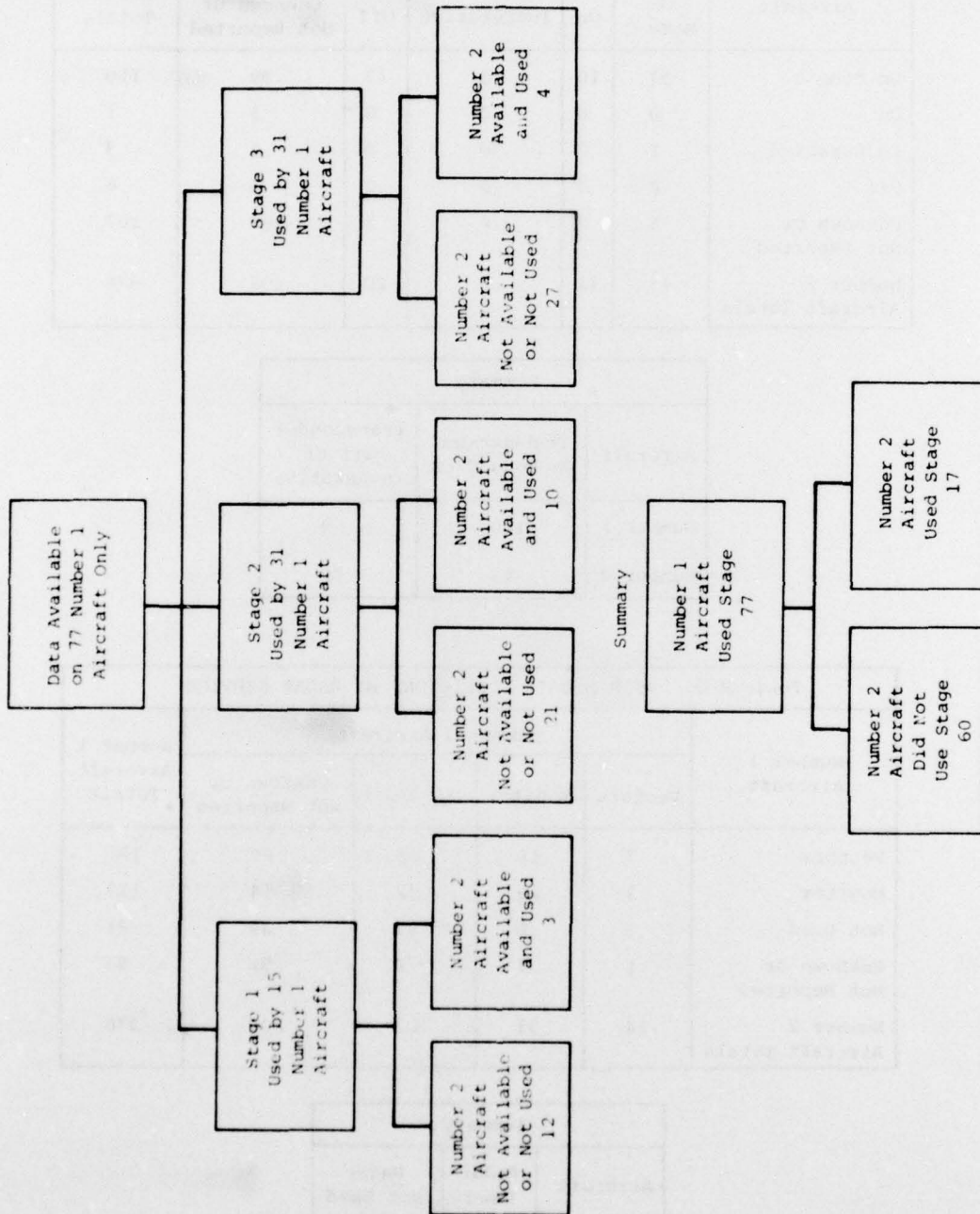
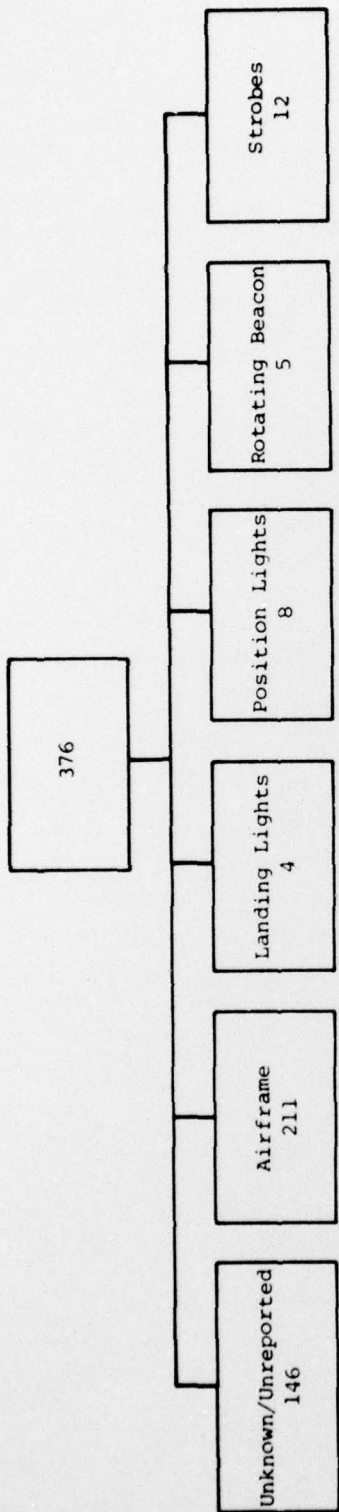


Figure A-1. NEAR MIDAIR COLLISIONS - BY RADAR STAGE AVAILABLE



Near Midair Collisions -
by Number 1 Aircraft Lighting

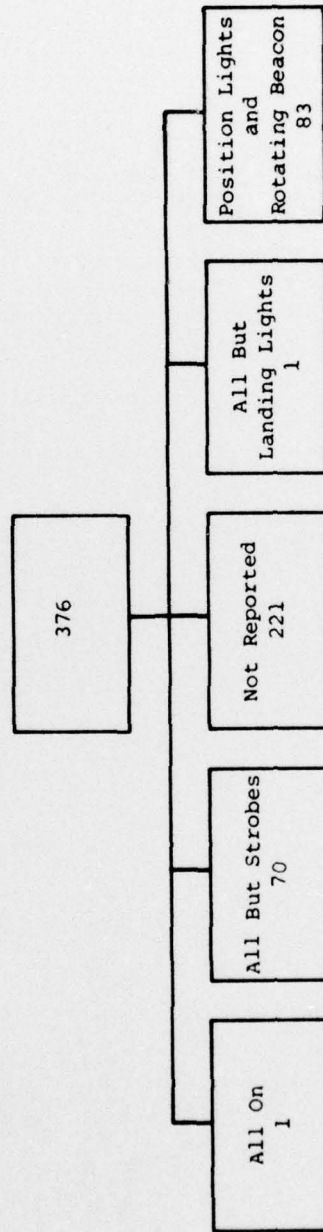


Figure A-2. NEAR MIDAIR COLLISIONS - BY FACTOR SIGHTED