Object/Detection/Position System Functional and Operational Requirements for the HSCT: Background, Studies and Rationale

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FOREWORD

This report on the Object Detection System was performed for the External Vision System (XVS) sub-element under contract to the Boeing Commercial Airplane Group (BCAG) led by John McConnell. The work was funded under contract NAS1-20220 to NASA Langley Research Center (LaRC) covering the period of performance through September, 1995. The NASA LaRC technical monitor for the overall effort was Russ Parrish.

During preparation of this report technical monitoring was provided by Mike Norman, XVS Principal Investigator at McDonnell Douglas Aerospace (MDA). Technical guidance for the approach chosen was made by Lee Summers of the Crew Systems Technology Group. The development and implementation of the airborne collision parameters model (Appendix B) was done by Bill Miles, also from the Crew Systems Technology Group. Finally, consulting services on operational data used in this document were provided by Ken Wells, PPI Aviation Consulting.

The Planning and Control Document refers to the Object/Detection/Terrrain/Positioning (O/D/T/P) system in describing this sub-task. However, during the period of time in which this report was in development, the XVS team reached consensus that the terrain detection was not a requirement of this portion of the XVS system. Therefore, O/D/T/P became O/D/P for purposes of the present research.This report contains background, studies and rationale for requirements for the object detection system portion of the XVS. This report fulfills the requirements in the project Statement of Work, Task 8 sub-task 2.4.

CONTENTS

ILLUSTRATIONS

Figure **Page**

TABLES

Table **Page**

ACRONYMS AND ABBREVIATIONS

ADS	Automatic Dependent Surveillance
ARP	Aerospace Recommended Practice
ASRS	Aviation Safety Reporting System
ATCAA	Air Traffic Control Assigned Airspace
ATA	Airline Transport Association
ATM	Air Traffic Management
ATS	Air Traffic Services
azim	azimuth angle
cd	candela
CNS	Central Nervous System
CMT	Contrast Modulation Transfer
CPA	Closest Point of Approach
drange	difference in range
elev	elevation angle
FAA	Federal Aviation Administration
FF	Field Factor
FLIR	Forward Looking Infrared
hdg	heading
HDTV	High Definition Television
HSCT	High Speed Civil Transport
ICAO	International Civil Aviation Authority
IFR	Instrument Flight Rules
IMC	Instrument Meteorological Conditions
IR	Infrared
ISG	International Study Group
JAA	Joint Aviation Authority
kt	knots
min	minute
MSL	Mean Sea Level
MTF	Modulation Transfer Function
MTFA	Modulation Transfer Function Area
nm	nanometer
NTSB	National Transportation Safety Board
NTSC	National Television Standards Code
ODP	Object/Detection/Positioning
OTF	Optical Transfer Function
POC	Proof of Concept
RA	Resolution Advisory
rad	radians
rms	root mean square
RF	Radio Frequency
RVSM	Reduced Vertical Separation Minimum
SAE	Society of Automotive Engineers
SUA	Special Use Airspace
TA	Traffic Advisory
TBV	To Be Validated
TCAS	Traffic Collision Avoidance System
tref	reference time in seconds
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions
WX	Weather
XVS	External Vision System

Object/Detection/Position (ODP)System Functional and Operational Requirements for the HSCT: Background, Studies and Rationale

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SUMMARY

The objective of the present effort was to identify initial requirements for the object/detection/positioning (ODP) system. The ODP system is part of the External Vision System (XVS) which consists of sensors, image processing, image enhancement and object detection capabilities. Components of this total system replace transparent structures with optical properties (i.e., forward windows). The requirement of the ODP system is to fill potential performance gaps in a forward vision system that uses some combination of visual-band, high-resolution, infrared, radar sensors, image processing plus a display system. For example, ODP system requirements include detection of objects beyond the resolution and field of view of a video-based system.

The ODP system, as a component of the XVS, has the requirement to perform ground and airborne object detection and positioning functions. In order to determine the requirements for the system, a number of methods of data collection were used. Once the data were collected, an analysis was performed to determine unique ODP system requirements. The results of the data collection are presented in the findings and recommendations section of the document which provides ground and airborne requirements for detection and positioning. Integration requirements of the ODP with related technologies such as the Traffic Collision and Avoidance System and Automatic Dependent Surveillance technologies is discussed. Detailed information about research on the human visual system is given in order to substantiate ODP requirements that provide “equivalent” capability to the pilot/window system being replaced. Similarly, results of the collision avoidance parametric model and database searches are used to derive specific detection requirements.

INTRODUCTION

It has been shown that elimination of the drooped nose would provide significant economic benefits (1) and as such, the XVS is currently considered to be an HSCT design objective. The ODP system requirements include providing capabilities that have both functional and visual equivalence to the existing pilot-window combination.

XVS vs ODP System Requirements

An initial technical problem for this research was to make the distinction between a requirement of the XVS system vs. a requirement for the ODP system. Due to this, during the early stage of data collection, a “wide net” was cast for ODP system requirements. For example, the data collection[1] included ground and airborne database analyses, a review of ATC procedures (e.g., analysis of FAA Handbook 7110.65 and controller interviews), pilot interviews using “walk-through scenarios, a pilot “paper-and-pencil exercise regarding taxi procedures, and a review of applicable sections of FAR Part 25.

Once these data were available, a filter was applied to differentiate XVS and ODP system requirements. Object detection and positioning requirements were culled from the data using the following criteria:

[1] Some of these findings are reported in the present document, other components were reported in: Moore, S. Updated XVS Certification Risk List and Preliminary Identification of Concept Dependent Operational and Certification Risks, NAS1-20220, July 14, 1995.

Ground:

— objects the aircraft could collide with and cause damage, i.e., objects having vertical height above the surface (e.g., detection of a pothole or painted lines on the surface are not ODP requirements).

— moving or stationary objects that are on the runway or have the potential for being in the proximity of the runway

— objects of “sufficient” size that collision with the object would result in greater than nominal damage or injury (- sufficient is defined later in the report).

Airborne:

— all types of airborne traffic are potential targets and are discussed in the report. A very specific subset of cases are presented. At this stage in ODP system development, the requirement to (minimally) meet these “numbers” is given.

Object Detection System: The Bigger Picture

As stated above, the ODP system is part of the larger XVS system and therefore it includes many of the issues associated with the XVS. That is, the entire system must satisfy the requirements of the manufactures, the users (pilots and airline management), as well as the regulatory authorities. For airworthiness certification, the system must contribute to the demonstration an equivalent level of safety of the total XVS/ODP/Side Window/Pilot system to that of the existing pilot-window combination. Beyond airworthiness certification, the “bigger picture” includes satisfaction of economic and reliability requirements, and user acceptance that are necessary for successful Part 121 operations.

TECHNICAL APPROACH

Review of XVS Requirements

Preliminary XVS requirements have been identified (15). Some of these requirements may be met by the ODP system. Table 1 presents an summary of the XVS requirements that relate to the Object Detection system.

Table 1

XVS Requirements Related to Object Detection

XVS Requirements Document Section	**Topic**	**Comments**
Section 3	Phase and Scenario Independent Requirements	Includes issues such as workload, situation awareness, system robustness, crew errors, annunciations and alerting, automation, ATC compatibility, and flight deck integration
Section 5	Avoid Hazards	Includes discussion of avoiding terrain, atmospheric hazards, hazardous objects, surface hazards and propulsion blast
Section 6	Taxi	Avoid Hazards, Follow Vehicle or Aircraft
Section 7	Takeoff	Avoid Hazards, Clear approach path, Clear runway, Clear departure route
Section 8	Low Level Flight	Hazard Avoidance, Hazards of Air Navigation
Section 9	High Level Flight	Hazard Avoidance, Traffic Separation
Section 10	Approach	Avoid Hazards, Follow preceding traffic, Runway Conflicts
Section 11	Flare and Derotation	Hazard Avoidance
Section 12	Rollout	Avoid Hazards
Section 13	Missed Approach and Go-Around	Avoid Hazards, Avoid aircraft and Airborne Hazards

Human Visual Capability

A review of human visual capability was made. The description of the human visual system which is applicable to XVS requirements started with an overview of basic laboratory detection thresholds and the variables which affect detection. An overview of factors that change these laboratory thresholds such as the use of indirect imagery, complex fields and atmospheric affects (e.g., atmospheric attenuation and turbulence) was given. Finally, a discussion that compares the laboratory thresholds to field observations is made. This discussion included a summary of the limitations of extending laboratory findings to the field. This information on the human visual system is given in order to substantiate ODP requirements that provide “equivalent” capability to the pilot/window system being replaced which are listed in the Findings and Recommendations section. The discussion of the supporting research can be found in Appendix A. Based on material in Appendix A, the ODP requirements for equivalent visual capability are given in Table 6 of this document.

Database Analyses

Douglas Aircraft Company Database Search — Ground Object Detection

A preliminary analysis of ground incidents and accidents was done at McDonnell Douglas. In this study the company’s database was accessed to locate ground events that had been coded with the “collided with” code. The database contains events obtained from the company’s approximately 80 worldwide field representatives, FAA and NTSB reports, and UP reports. The search included events that involved at least one transport category aircraft from about 1963 to January, 1995. Because of the large number of “finds”, the analysis specifically excluded bird strikes (a separate code) unless the bird strike had been coded as “collided with” due to unique characteristics of that particular event. The analysis subsequently dropped events in which the aircraft was being towed. Chi Square tests were performed to determine if statistical significance existed with respect to event factors including movement, field of view, and object size. No relationship among these variables was found. Finally, object characteristics and event frequencies were tabulated
(See Figure 1).

Airport Surface Collision Events Data Analysis

Physical Characteristics

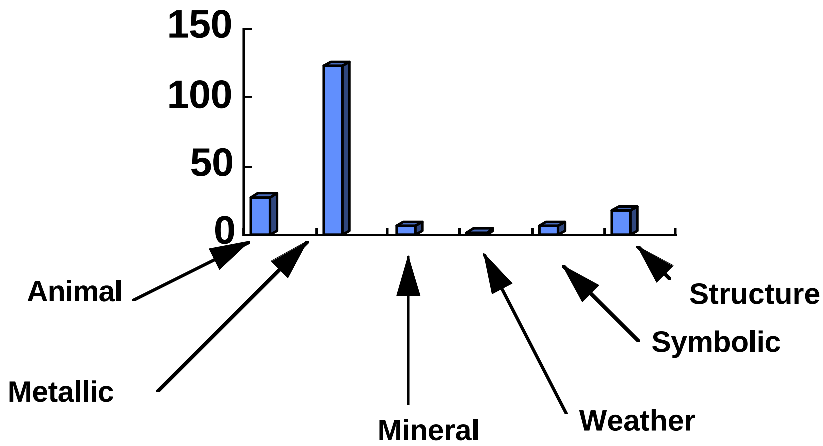

Figure 1.

In the above figure the following are examples of the given categories:

Metallic = aircraft, trucks, mowers , construction equipment, jetways

Animal = deer, bulls, rabbits, humans

Mineral = asphalt, rock

Weather = water, ice, snow

Symbolic = landing on wrong runway, taxiing on wrong taxiway

Structure = buildings

Analyses such as the one above shows that “even with windows” airport surface incidents/accidents are a significant problem. Surface operations at major airports during peak travel times can become a problem of physically running out of room for the required aircraft movement. The ODP system may assist with this problem. Specifically, given an initial set of detected objects, both static and moving, the ODP system will track these over time and estimate object positions.

Database Search — Airborne Object Detection

Research was conducted to characterize airborne object detection requirements. This consisted of a search of the Douglas Aircraft Company's databases, as well as searches performed by the Aviation Safety Reporting System (ASRS). The searches included Part 121 reports.

ASRS Search NO. 4036 (performed in May, 1995) located 281 reports referencing airborne near miss incidents. About 90% of these reports dealt with near-misses with other aircraft (gliders, general aviation aircraft, and other transports — see Appendix C). The other 10% dealt with near misses with birds and balloons. Because of questions dealing with weather balloons resulted from search no. 4036, another search was requested. ASRS Search NO. 4097 located 20 reports referencing Part 121 weather balloon incidents. Both ASRS searches are from a database containing approximately 60,000 full-form records received by the service since January, 1986.

Both the Douglas Aircraft Company search and other sources have shown that near-misses and collisions with birds is a significant problem. Worldwide, in the last twenty years there have been 1,280 bird/plane collision caused crashes with fighter planes, 696 with helicopters and 637 with transports. These are collisions; reports of near-misses are also recorded and not part of the previous figures (2).

Limitations of See and Avoid

The Airman Information Manual (1995) states that the pilot responsibilities are such that:

> "When meteorological conditions permit, regardless of type of flight plan or whether or not under control of a radar facility, the pilot is responsible to see and avoid other traffic, terrain or obstacles."

AC90-48c states:

> "(See and Avoid) requires that vigilance be maintained at all times, by each person operating an aircraft, regardless of whether the operation is conducted under Instrument Flight Rules (IFR) or Visual Flight Rules (VFR)."

Visual Separation procedures present an interesting case study for the ODP system and for the see and avoid concept. Specifically, :

> "When the destination airport is reported 'in sight' and the pilot accepts the visual approach, then the protective shielding is withdrawn and the air carrier jet airman proceeds to the landing runway in a see-and-avoid environment." (3).

The visual approach[2] is considered to be an important tool for reducing and expediting traffic in the congested terminal airspace environment. It reduces controller workload and, hence, increases efficiency while also enhancing airline operating economies. The visual approach procedure, however, has been described as having operational hazards and subtle human factors pitfalls. This observation has been supported by a study that examined about 350 distinct ASRS reports dealing with visual approaches (3). This research discusses several contributing problems regarding visual approach procedures. Some of these conclusions have ODP implications, and are given below:

• Failing to use adequate procedural steps in communicating airport/traffic sightings (e.g., reporting the airport in sight does not necessarily mean that the runway is insight).

• Problems with reporting traffic

- sighting of called traffic not accomplished
- loss of initial sighting
- non sighting of air carrier traffic that "has you in sight"
- identifying the wrong traffic as the called traffic

• Errors in the conduct of parallel runway operations, e.g.,

- overshooting/drifts into adjoining lane
- crisscrossing through adjacent lane
- lineup in the wrong lane

• Presence of uncontrolled VFR Aircraft

- "needing to deal with untargeted VFR traffic is an inherent and unavoidable feature of flying a visual approach because of two factors: first, (by definition) as visual conditions must exist, uncontrolled VFR aircraft must be expected to be sharing the

[2] The AIM states that visual approaches are initiated by ATC to reduce pilot/controller workload and to expedite traffic by shortening flight path to the airport.

> airspace with IFR traffic; and second, when the visual approach is accepted by the flight crew, even the potential “workload permitting” assistance of ATC is inexorably withdrawn with the (usually) immediate termination of radar services” (3, p. 18).

• Reduced cockpit visibility conditions

- i.e., reduced visibility due to haze, smoke, smog and glare

• Traffic mix — airspeed performance differences

• Traffic Mix — simultaneous departures and arrivals

- problems include intra-facility traffic coordination deficiencies, tendency of light plane pilots to depart VFR with early turnouts to course too soon after takeoff

- air carrier deviations from assigned altitudes

• Communication misunderstandings and errors

The above problems are encountered in current operations with aircraft with forward facing windows. These types of less than optimal procedures and conditions should be acknowledged as being part of the operational environment. Future work on the ODP system could attempt to provide solutions to these operational issues. In any case, the performance of the XVS/ODP system must not exacerbate these conditions, and must allow equivalent crew performance and workload as aircraft with forward facing windows in similar environmental conditions.

In addition to the general requirement to see and avoid given above, special operations necessitate see and avoid. For example, upon accepting a visual separation, a pilot must see the other aircraft involved and upon receiving instructions from the controller provides his own separation by maneuvering his aircraft to avoid it. This may involve following in-trail behind another aircraft or keeping it in sight until it is no longer a factor. Furthermore, after a pilot has accepted a visual separation it is the pilot’s responsibility to notify the controller if visual contact with the other aircraft is lost or cannot be maintained.

The concept of see and avoid is an outgrowth of operation under visual flight rules (VFR) where the requirement was "see and be seen". As more aircraft entered the system, "see and be seen" was replaced by "see and avoid". That is, once the pilot saw the conflicting traffic, the pilot also had the responsibility to take evasive action.

The fatal midair collision of a Mitsubishi MU-2 and a Piper Saratoga in Greenwood, Indiana in 1992 prompted an evaluation of the see and avoid concept. At the time of the midair, the weather was VMC. The National Transportation Safety Board (NTSB) determined that:

> ..." 'the probable cause of the accident was the inherent limitations of the see-and-avoid concept of the separation of aircraft operating under VFR that precluded the pilots from recognizing a collision hazard and taking actions to avoid the collision'".

That is, in cases such as the one above, see and avoid may not work and the situation can become a case of "'don't' see, can't avoid'" (4). There are many reasons that humans do not always practice optimal vigilance. These reasons can be physical, physiological or psychological. Other factors that can influence vigilance include target characteristics (e.g., size, color), task variables (such as workload and time at task), pilot characteristics (e.g., age, fatigue, visual acuity), and environmental factors (e.g., weather, clouds and glare).

Reaction time after visual acquisition of a target is also a variable in avoiding a collision. FAA AC 90-48C indicates that the total time required to see an object, to perceive the collision threat and to begin evasive action is 12.5 seconds. See Table 2 :

Table 2

See and Avoid Reaction Times

	Seconds
See Object	0.1
Recognize Aircraft	1.0
Become aware of collision course	5.0
decision to turn left or right	4.0
muscular reaction	0.4
aircraft lag time	2.0
TOTAL	**12.5**

Based on the reaction times given above, distance to react based on given parameters (e.g., aircraft positions, headings, vertical speed, azimuth angle of target, elevation angle of the target, etc.), can be estimated. This process has been performed for the HSCT using realistic scenarios and forms the basis for detection requirement (See Findings and Conclusions and Appendix B).

For HSCT operations, the risk of colliding with a non-transponder equipped aircraft exists, and should be an assumption. Between the terminal area and Class A airspace, the HSCT must pass through airspace where VFR traffic can legally operate without filing a flight plan or without being controlled by ATC. That is, ATC does not necessarily have control over VFR aircraft operating in Class E Airspace.

FAR 91.215 specifies ATC transponder requirements. The regulations permit aircraft certified with no electrical system, gliders and balloons to conduct VFR operations above, below and around class B and class C airspace.

The ODP system requirements based on the operational studies outlined above and including the inherent limitations of see and avoid (e.g., pilot vigilance and problems, "shared responsibility ", etc.) are given in the following section. Informal discussions with controllers reveal interesting problems that are not always formally documented. For example, controllers speak of “holes” in radar coverage at major terminals. For example, controllers at Dallas-Ft.Worth can have an aircraft 5 miles (north) of the field at 1000’ AGL not show up on radar. Likewise, at Houston, aircraft 5 miles offshore at 1000 AGL may not show up on radar. These “holes” are most likely caused by blockage of the ground-based radar, for example, by buildings. Also, the exact extent of airspace violations is difficult to determine; controllers sometimes do not report airspace violations due to the associated paperwork. Informally, however, controllers report that at any of the busiest U.S. airports, airspace violations for any given controller on different days can range from zero to ten incidents. The lower figure could occur on a day with poor visibility — the higher figure might occur on the Friday before a three-day weekend with good weather conditions. The XVS system will be required to detect these "cooperative" and "non-cooperative" airborne targets.

Related ODP System Capabilities

Traffic Collision Avoidance System (TCAS)

Due to a series of mid-air collisions, in 1987 congress passed legislation mandating that TCAS II be installed on all air carriers with 30 passenger seats by the end of 1993. TCAS is an aircraft-based airborne collision system that provides information independent of ground ATC of the proximity of nearby aircraft. The TCAS system provides visual , aural and voice synthesized alerts regarding intruder aircraft by monitoring position, closure rate, and altitude of nearby transponder-equipped aircraft. TCAS I provides traffic advisories (TA); TCAS II provides TA and resolution advisories (RA). If the intruder aircraft is equipped with a Mode A transponder, a written message about the intruder will be (no altitude) given. If the intruder aircraft is equipped with a Mode C transponder, TAs and RAs will be generated. TCAS II will coordinate the avoidance maneuver with a Mode S transponder-equipped intruder aircraft (5).

The alerting functions of TCAS are based on the tau concept which asserts that time-to-go to the closest point of approach (CPA) is more important than distance-to-go to the CPA. tau, then, is an approximation of the time-to-go to CPA in seconds, and is equal to 3600 times the slant range in nm, divided by the closing speed in knots (16). TCAS logic (attempts to) optimize the trade-off between necessary protection and unnecessary advisories. This trade-off is achieved by controlling the sensitivity level (SL), which controls the tau, and as a result the dimensions of the protected airspace around each TCAS-equipped aircraft. TCAS uses two primary ways to determine the operating sensitivity level. These are ground-based Mode S sensor selection and pilot switch selection. The pilot selectable modes are STANDBY, TA-ONLY and AUTOMATIC.

Since the implementation of TCAS there have been a number of "lessons learned" that have emerged regarding certification, system logic, operational use, and integration into the air traffic control system. These are summarized below in Table 3.

Table 3
Summary of TCAS Lessons-Learned

LESSON LEARNED	**CATEGORY**	**COMMENTS**
Limit Nuisance Aural Warnings	OPERATIONAL	Aural Warnings below 400 feet were eliminated
Timing of Advisory Clear message could be premature	OPERATIONAL	Advisory Clear messages were based on minimum separation only; as aircraft returned to normal flight level, repeated resolution advisories were generated.
Display of on ground intruders	OPERATIONAL	Intruder AGL reply threshold was raised to 1700 feet to reduce clutter from intruders on or close to ground
Surveillance range must exceed display range	DISPLAY	Dropouts on display can occur when Minimum Operating Performance Standards (MOPS) specified surveillance range is smaller than the display range
Adaptable variety of displays required	DISPLAY	Single display solution not possible for the many different aircraft types
Perform integrated TCAS tests in at least two aircraft	CERTIFICATION	Coordination testing with intruder requires two-way communications and is affected by equipment tolerances

In addition to the above types of "lessons-learned", other conclusions have been made regarding the design and implementation of TCAS into the aircraft and into the air traffic control system. These conclusions have possible implications for the ODP system as it becomes progressively defined. In the

1992 time frame, the FAA and National Transportation Safety Board tasked the Aviation Safety Reporting System to complete a database analysis of TCAS II incident reports in order to prepare for a congressional subcommittee hearing on TCAS II issues (6). The conclusions from this analysis included:

• Training and preparation have not been adequate

• Ad hoc fixes have been necessary

- e.g., nuisance RAs, phantom intruders, RA commands being contradicted by counter instructions from controllers, etc.

• Pilots can be in a quandary on how to respond to TCAS alerts
- Sometimes pilots must make split second decisions whether to ignore controller advisories on separated traffic or to follow RA commands

• Controllers feel conflict over the appropriate response to RA-commanded deviations.
- Controllers believe that TCAS should be used as an advisory tool for pilots and should not be used to override ATC instructions.

• There are indications of non-standard use of TCAS II by pilots — i.e., pilots using TCAS to maintain spacing.

TCAS IV[3] is in early planning stages. This capability will add horizontal resolution advisories. TCAS IV uses the GPS position and velocity of own aircraft and the target aircraft to obtain accurate bearing rate. TCAS IV uses a “TCAS cross link” to transfer the position and velocity of the target to the TCAS aircraft over the Mode S air-air link.

The ODP system provides operational capabilities analogous to the TCAS system. Ultimately as the system is defined and begins operational testing, procedures for integrating the system with other aircraft and ATC functions must be established.

ADS and Related Technologies

The ODP system must integrate with the evolving air traffic management (ATM) system which is becoming global in nature and is increasingly implementing new technologies into the system. A review

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[3] TCAS III was also envisioned to provide horizontal resolutions. It was based on measurement of bearing using an aircraft antenna. This approach has been shown to be inadequate in that very slight deformations of the aircraft skin could lead to erroneous bearing rate measurement.

of technologies envisioned for the Future Air Navigation System (FANS) which has been proposed by the International Civil Aviation Organization (ICAO), was made for implications for the ODP system. Specifically, with the use of GNSS, data link and Automatic Dependent Surveillance (ADS) a much smaller "bubble" of protected airspace around each aircraft will be needed. ATC will intervene "tactically" when there is a high probability that one aircraft will penetrate another aircraft's bubble. In the future if all aircraft had full CNS capability, the dependence on the ODP would be less. Realistically, however, not all aircraft will have full CNS equipage and as a result, the ODP is needed to deal with the mixture of aircraft capabilities and operating practices.

Air-to-ground data links plus accurate and reliable aircraft navigation systems will permit surveillance services in areas that currently lack such capability, specifically oceanic areas. Automatic Dependent Surveillance (ADS) is an Air Traffic Service (ATS) function whereby aircraft automatically transmit via datalink and communication satellites data derived from on-board navigation systems. In turn, the transmitted ADS data is processed by ATS automated systems to present a "pseudo-radar" return to the controller. In high density traffic areas ADS may be a back-up for secondary surveillance radar. As a result, the need for primary radar (skin paint) will be reduced. The need for primary radar will not be eliminated completely; it will be needed in airspace where there is a mix of SSR-equipped aircraft and non SSR-equipped aircraft. As the number of non SSR-equipped aircraft decreases, it is expected that secondary radar (Mode S and its data link, and ADS through satellite communication) will be of such high integrity that it will diminish the justification of primary radar for air traffic services for international aviation.

Initially, the surveillance function within the ICAO CNS/ATM concept will be the Automatic Dependent Surveillance (ADS) functions. The first area of use for ADS will be those areas not covered by primary radar services, such as in oceanic airspace and over remote continental areas. Data obtained from on-board navigation system about aircraft identification and four-dimensional position is transmitted to the air traffic services center. This information can be transmitted by satellite, Mode S or VHF data links. The transmission of position information to ATS does not require crew action. These automatic transmissions of position will replace pilot position reports. With ADS-Broadcast, or ADS-B, an aircraft periodically broadcasts its GPS position in an onmi-directionally. This transmission can be received by ground receivers to support ATC surveillance.

An Automatic Dependent Surveillance (ADS)/Air Traffic Services (ATS) system will need to permit message exchanges between the crew and the controller via datalink. For non-routine and emergency messages, voice communications will be used. The potential ADS/ATS data link messages are:

- Basic ADS position
- Ground vector

• Air Vector
• Projected profile
• Weather
• Short term intent
• Extended projected profile

If the above type of information is available to the crew, it should be integrated with other sources of information about traffic such as TCAS and the ODP.

Air Traffic Control (ATC) Procedures

The Air Traffic Control Handbook (7) prescribes air traffic control procedures and phraseology for air traffic controllers. The controllers handbook addresses procedures for:

1) General Control
2) Airport Traffic Control - Terminal Area
3) Instrument Flight Rules
4) Radar Control
5) Non-Radar Control
6) Visual Control
7) Offshore/Oceanic Control
8) Special Flights
9) Emergencies
10) Traffic Management Procedures
11) Canadian Airspace Procedures

The handbook clearly states that he primary function of the ATC system is to prevent a collision between aircraft operating in the system and to organize and expedite the flow of traffic. Additional services are provided by ATC in addition to its primary services. Provision of these additional services is limited by many factors (e.g., traffic, frequency congestion, quality of radar, etc.). Controllers provide these additional services based on higher priority duties and other circumstances. Provision of these additional services is required by the controller as the work situation permits. Both the *AIM* and the *Air Traffic Control Handbook* prioritize the controllers' separation responsibilities. Their primary responsibility is the separation of IFR traffic; their secondary responsibility is to separate IFR and VFR traffic. As time permits controllers have the responsibility to separate VFR traffic from VFR traffic.

The handbook was reviewed as a source of requirements for the ODP system. These requirements are given in the Findings and Recommendations section of this document. The analysis of the controllers handbook resulted in requirements for the ODP system. Where the review had implications for total XVS system, documentation of the requirement was made.

Airborne Collision Detection Scenario Development

A study was performed to provide airborne object detection guidelines for the purpose of collision avoidance requirements. The approach used in this analysis was to develop an Excel™ spread-sheet capable of analyzing a variety of potential collision situations in terms of the relative positions of two aircraft from the point of detection through a maneuver that produces a specified closest approach distance between the two aircraft. The methodology and assumptions, as well as application of the method to several typical collision avoidance scenarios, is given in Appendix B. A summary of the results is incorporated into ODP system requirements given in the Findings and Recommendations section of this document.

FINDINGS AND RECOMMENDATIONS

The objective of the ODP system is to fill potential object detection performance gaps in a forward vision system based upon a visual-band, high-resolution, sensor-display system. In addition the system is to enhance aircraft safety by improving object detection vigilance and provide all-weather object detection capability.

Ground Operations: ODP System Requirements

A major capability of the ODP system will be to detect objects on the runway. The system will be required to detect the objects while the aircraft is on the ground (preparing to taxi onto the active runway) and during the landing approach phase. The characteristics of the objects for detection include :

- Metallic (1 foot X 1 foot object at 1000 feet)
- Animal (2 feet X 2 feet (e.g., frontal section of a small deer) at 1000 feet, moving or stationary
- Mineral (1 foot X 1 foot at 1000 feet)

These requirements are based on findings discussed in the Technical Approach section of this document. The search of the Douglas Aircraft database suggests that “even with windows” airport surface incidents/accidents are a significant problem. Similarly, interviews with controllers and pilots regarding surface operations suggests that taxiing operations at major airports during peak travel times can become a problem of physically running out of room for the required aircraft movement. The situation can then become an incident/accident “waiting to happen”, if other predisposing conditions such as weather, aircraft malfunctions, etc. exist. The ODP system can assist with these problems. Specifically, given an initial set of detected objects, both static and moving, the ODP system will be required to track these over time and estimate object positions. The specifications given above for the ODP system include the requirements for object detection that for objects that are on the runway or within 1000 feet of the runway. The specified objects for detection are those that could cause damage to the aircraft if undetected.

Airborne Operations

Results of Airborne Collision Detection Scenario Development

An analysis was conducted to establish representative object detection parameters that would apply in order to successfully detect and avoid airborne objects during typical, potential collision scenarios. This study methodology and results are described fully in Appendix B of this report. This section briefly summarizes the results to indicate the general magnitude of the detection parameters that were established in response to six representative collision avoidance scenarios.

The methodology involved development of an Excel™ spreadsheet capable of analyzing a variety of potential collision scenarios in terms of the relative positions of two aircraft from the point of detection through a lateral turning maneuver of the reference aircraft (the HSCT) that produces a specified closest approach distance of not less than 500 ft. This analytical tool was then applied to six representative airborne collision scenarios developed by PPI Aviation Consulting for operational studies in the HSR Program. The scenarios analyzed are these:

1. Overtake of a business jet by the HSCT during departure.

2. Simultaneous arrivals of the HSCT and a business jet at a terminal with parallel runways.

3. HSCT encounter with a light aircraft in the landing pattern.

4. Conflict between the landing HSCT and a light aircraft departing another airport.

5. Conflict between the HSCT and subsonic transport at high altitude during an emergency descent—head-on aspect encounter.

5a. Same as Scenario 5, except both aircraft traveling in the same direction.

The initial conditions for each of these scenarios are detailed in Table 4.

Table 4

Collision Scenario Initial Conditions

Scenario No.		Aircraft speed (kts)	Vertical speed (fpm)	Target angle from collision point (deg)	HSCT pitch attitude (deg)	Flight path angle (deg)
1.	HSCT:	250	+1,500	—	10	+3.4
	TARGET:	210	+500	0	—	+1.3
2.	HSCT:	210	0	—	8	0.0
	TARGET:	210	-900	120	—	-2.4
3.	HSCT:	170	-990	—	8	-3.0
	TARGET:	90	-500	90	—	-3.1
4.	HSCT:	150	-800	—	8	-3.0
	TARGET:	90	500	93	—	3.1
5.	HSCT:	860 (M1.5)	-10,000	—	-4.6	-6.6
	TARGET:	460 (M0.8)	0	180	—	0.0
5a.	HSCT:	860 (M1.5)	-10,000	—	-4.6	-6.6
	TARGET:	460 (M0.8)	0	0	—	0.0

In all of the analyzed scenarios, the two aircraft are initially assumed to be on straight line flight paths defined by the speeds, vertical speeds and angle between the HSCT and target aircraft flight paths (see Figure B-1, Appendix B). The target aircraft continues on this straight path through the collision point. The HSCT detects the target, analyzes its trajectory, decides that a collision is imminent, and takes avoidance action in the form of a 1.25g normal acceleration level turn (0.75g lateral acceleration). The maneuver is initiated at such a point that the distance at closest approach is no less than 500 ft. The spreadsheet analysis for each of the scenarios determines the position of the two aircraft at the last possible time of detection that would guarantee a successful avoidance maneuver by the HSCT.

The results are presented in terms of range to the target and elevation and azimuth angles with respect to the HSCT's axes (Figure B-2, Appendix B). The latter angles are the gimbal angles any sensor would have to assume to place the target in the center of its field of view at the point of initial detection. The angles, closing velocity and ranges at detection for the six scenarios are shown in Table 5.

Table 5

Required Detection Parameters for the Collision Avoidance Scenarios

Scenario No.	Range (ft [nm])	Azimuth (deg)	Elevation (deg)	Initial Closing Speed (kts)	Time to closest approach (sec)
1.	1,300 [0.21]	0.0	+4.3	39	13
2.	9,642 [1.59]	30.2	-5.5	362	16
3.	4,994 [0.82]	28.4	-8.2	190	16
4.	4,651 [0.77]	31.0	-11.0	177	16
5.	35,585 [5.86]	0.0	+0.3	1,318	16
5a.	10,970 [1.81]	0.0	-9.5	406	16

Scenario 5 represents the greatest resolution challenge for the sensor in view of the extreme range. As noted in Appendix B, if the sensor were an eyeball-equivalent, a narrow body transport at that range and from a nearly head-on frontal aspect would be nearly at the eye-limiting resolution of one arc-minute, while a smaller business jet would be below the limit. Scenario 5, however, is the one most likely to be augmented by TCAS. The off-angle scenarios (2, 3 and 4) are somewhat challenging for a fixed axis/fixed FOV sensor that meets the current XVS requirements if the target aircraft is on the opposite side of the aircraft as the viewing pilot. The XVS lateral FOV currently specified is only 25°, which would place the targets in these three scenarios outside the sensor FOV. However, it would still be visible in each case through the side windows by the pilot on the same side of the HSCT as the target. In elevation, there does not appear to be any problem for the fixed axis/fixed FOV XVS sensor, since the elevation angles are well within the FOV of the sensor in the vertical plane. In general though, low altitude, look down or low closure scenarios are the most challenging for radar sensors.

The results suggest that the 12.5 seconds for detection as put forth by the earlier referenced source (4) is not adequate for **minimum** time for detection of the ODP system. The analyses given in Appendix B, suggest a higher required time of at least 16 seconds. Because these data are not validated, it seems reasonable to use an additional safety factor of 1.5 to derive a **minimum** time for detection of 24 seconds.

Airborne Operations: Other ODP System Requirements

Airborne the system is required to detect up to 30 intruder objects with closure speeds between 100 knots and 1800 knots. The system is required to detect target aircraft composed of metal, metal/composite, or composite construction. The intruder aircraft may be uncooperative . The system is also required to detect flocks of birds (within 3 miles having a visual cross section of 5 square meters between 1000 feet AGL and FL400). The system is also required to detect airborne balloons (weather and hot air) with a diameter of 3 square meters at 1000 feet. The above specifications are inferred from the results of the database searches, procedures used by controllers as identified in the Controllers Handbook (7110.65), plus pilot and controller interviews (TBV).

In addition to the requirements derived from the aircraft collision parameters model, Table 6 summarizes airborne and ground object detection requirements for the ODP system.

ODP System Requirements Summary

Table 6

ODP System Requirements

Requirement	Specification (Minimums)	Comments
Target co-operative device	Targets shall not require a co-operative device for detection by the ODP system	Difference from TCAS operation which requires co-operative device for intruding aircraft to be detected in an operationally useful manner
Display	Capability for a dedicated or integrated display	The ODP system display may be dedicated, integrated with the XVS displays or integrated with a "traffic display system" used to support advanced National Airspace System (NAS) procedures (e.g., "free flight")
Mode Annunciations	Normal and Failure Mode annunciations will be required	Implies data processing capability
Alerting, Ground	The ODP system shall be able of detecting the animal, metallic and mineral objects specified in the ground object detection section of this document.(TBV)	The ODP system shall be capable of producing a ground traffic alert while the aircraft is on the runway, preparing to taxi onto the runway, or on the landing approach.
Requirement	**Specification (Minimums)**	**Comments**
Alerting, Airborne	The ODP system shall be capable of producing an airborne traffic alert with approximately 24 seconds of the closest point of approach (TBV)	Collision Parameters Model assumes minimum detection requirements for the sample scenarios of 16 seconds; a 1.5 safety factor is added.

Alert Inhibits	ODP system alerting shall be integrated with alerting logic of TCAS, ADS and other traffic display systems	For example, TCAS RAs are inhibited above 44,000 feet, below 1200' in Takeoff and 1000' on approach
Interference Limiting	ODP system equipment shall control its interrogation rate or power to limit interference effects	TCAS lesson-learned
Surveillance Range, Airborne	30 nm	(TBV)
Surveillance Range, Ground	2000 feet (TBV)	Based on types of objects to be detected, likely speeds of own aircraft and target and to importance to proximity to runway.
Bearing Accuracy, -10 to + 10 Degrees Elevation	bearing error shall not exceed 10 degrees rms or 30 degrees peak over all azimuth angles (TBV)	These are minimums; they are comparable to TCAS MOPS; ODP system should do better than this (8).
Bearing Accuracy, +10 to +20 degrees elevation	bearing error shall not exceed 15 degree rms or 45 degrees peak over all azimuth angles (TBV)	These are minimums; they are comparable to TCAS MOPS; ODP system should do better than this (8).
Closure Rate	1800 kts (TBV)	Considers possible closure rates of two HSCT’s below FL 400.
Number of Targets, Airborne	30 (TBV)	Comparable to TCAS
Number of Targets, Ground	30 (TBV)	Comparable to TCAS
Requirement	**Specification (Minimums)**	**Comments**

Type of Targets, Airborne	• All types of aircraft (cooperative and non cooperative) • Bird flocks (within 3 miles having a radar cross section of 5 square meters between 1000 feet AGL and FL400 • Weather balloons 3 square meters radar cross section at 1000 feet • hot air balloon/Wx Balloon 3 square meters radar cross section at 1000 feet	See Tables 4 and 5 e.g., ATC Traffic Advisory: “Flock of geese, one o’clock, seven miles, northbound, last reported at four thousand” ASRS reports 4036 and 4097
Type of Targets, Ground	• Metallic — 1 foot X 1 foot object at 1000 feet • Animal — > 2 feet X 2 feet at 1000 feet, moving or stationary • Mineral — 1 foot X 1 foot at 1000 feet	Based on Database Analyses
Detect ground traffic called out by ATC on runway or near (100 yards - TBV) of runway.	• Detect relative position of traffic, e.g., “Mower left of Runway Two Seven” • Unsafe runway conditions • Airport Activity, e.g., “Disabled aircraft on runway”	Source: Controllers Handbook, 7110.65 These are a small subset of requirements - a larger set exists for the total XVS system.

Requirement	Specification (Minimums)	Comments
Provide equivalent visual capability comparable to human performance in the field, specifically:		
Static Visual Acuity, at infinity, uniform luminance (5 cd/m^2)	Target size = 1 min of arc with a contrast ratio of 4.8.[4]	Based on laboratory detection results times field factor established by Blackwell (14) Note: Visual acuity changes with luminance level and viewing distance
Spectral Sensitivity, (photopic/scotopic vision)		
at 350 nm wavelength	40 decibels/20 decibels	
at 550 nm	- 20 decibels/ 5 decibels	
at 750 nm wavelength	40 decibels/40 decibels	
Detection Time	24 seconds	Based on 16 seconds derived from collision model X 1.5 safety factor

[4] Based on 1/3 second exposure time, 5 cd/m^2 luminance, and target size of 1 arc min. See Blackwell reference, p. 325. Antilog (-.502) X a field factor of 15 = 0.32 X 15 = 4.8 contrast ratio.

Certification: ODP System Issues

The Object Detection and Positioning (ODP) system may be part of the External Vision System. It provides basic and enhanced XVS functions. The extent to which the system provides basic vs enhanced capability is a major factor in determining certification risk. For example, TCAS is required for Part 121 operations. To the extent that the ODP system is required to provide basic XVS capability, it will be required for Part 121 operations also. A first approximation of Part 25 airworthiness certification requirements are given below in Table 7. Satisfying the requirements of FARs 25.1301 and 25.1309 (especially 25.1309) will be important and potentially the most challenging.

Table 7

Preliminary Part 25 Requirements for the ODP System

Para.	**Sub-Para**	**Requirement Title**	**Comments**
25.253	a (1) (iii)	High-Speed Characteristics	Buffeting must not impair pilots ability to read instruments
25.581		Lightning Protection	Metallic and non-metallic components of the A/C must be protected such that the A/C is protected from catastrophic effects from lightning.
25.611		Accessibility Provisions	Components must be located to permit required inspections
25.631		Bird Strike Damage	Bird-Strike testing is done on windows/radome. Sensor location in radome an issue. For example, Bird-Strike on e.g., Glide Slope antenna locations have been done by analysis.
25.771	a,c,e	Pilot Compartment	Duties must be performed without unreasonable fatigue or concentration and must be controllable from either crew station
25.777	a	Cockpit Controls	Controls must be located to prevent inadvertent operation. A section will have to be added to address XVS controls e.g., manual vs automatic control of camera shutters.
25.779		Motion and Effect of Cockpit Controls	A section for XVS (ODP) controls may be required.
25.781		Cockpit and control knob shape	A section for XVS controls may be required.
25.903	d	Engines, Rotor Burst	Rotor Burst Analysis must not show ODP sensors to be compromised (e.g., loss of sensor or due to loss of electrical power)
25.1301	**all**	**Function and Installation**	**Compliance will require a data trail of issue papers, analysis and testing**
25.1303		Flight and Navigation Instruments	Para may need modified to include XVS requirements or a new separate para may be added
Para.	**Sub-Para**	**Requirement Title**	**Comments**

25.1309	**all**	**Equipment, Systems, and Installations**	**Also, DO-178 for software reliability. Compliance with this para. may pose the greatest certification risk. See findings and recommendations section.**
25.1321	a,e	Arrangement and Visibility	Section to address XVS instrumentation may have to be added.
25.1322	all	Warnings, caution and advisory lights	None of the concepts at this point preclude the capability to provide processing for warning, caution or advisory annunciations
25.1351	d	Operation without normal electrical power	The XVS must be able to operate safely in VFR conditions for at least five minutes without normal electrical power at maximum altitude
25.1382		Electrical Supplies for Emergency Conditions	
25.1419	a,b	Ice Protection	
25.1431	all	Electronic Equipment	Critical environmental conditions must be considered; operation of one part of system must not interfere with other parts of system
Sub-Part G		Operating Limitations	These must be established for the ODP.
25.1523 & App D	all	Minimum Flight Crew	Includes workload issues and effects of synthetic imagery on concentration and fatigue
25.1585		Operating Procedures	Para may need to be supplemented with ODP operating procedures

APPENDIX A
VISION AND ACQUISITION

Introduction

Understanding the visual system has been of interest to researchers for nearly a century with more effort expended in study of this sense than the other human senses. This emphasis is largely due to the estimate that of the human's five senses, vision is credited with providing about 75% of the total input to the brain about the environment (9).The study of the visual system has typically concentrated on one of three processes. **Detection** is the awareness of existence of local difference energy; that is, the ability to detect the presence of something in a uniformly illuminated field. **Recognition** is the awareness that the object belongs to a particular class. **Identification** is the ability to specify that the object is a certain one within the class. Object detection, recognition and identification are not discreet events but rather fall on a continuum in the visual acquisition process.

Much of the research on the visual system has been done in laboratory settings which provides the necessary experimental controls for distinct factors to be studied. Due to obvious limitations of applying these "raw" laboratory findings, other researchers have performed field studies where controls are much less stringent. Applicability of theses results to the HSR's External Vision System at a minimum, however, requires understanding of the numerous factors which "degrade" the laboratory findings for estimation of visual performance "in the field". Another consideration for the XVS and ODP systems is the impact of indirect imagery on the visual acquisition process.

The following discussion of the human visual system which is applicable to XVS requirements starts with an overview of basic laboratory detection thresholds and the variables which affect detection. An overview of factors that change these laboratory thresholds such as the use of indirect imagery, complex fields and atmospheric affects (e.g., atmospheric attenuation and turbulence) is given. Finally, a discussion that compares the laboratory thresholds to field observations is made. This discussion includes limitations in extending laboratory findings to the field.

General Factors that Influence Seeing

There are several factors that influence the ability to see. The first of these is the available energy. The human visual system is optimized to natural (sunlight) illumination. The unaided human visual system is sensitive to wavelengths from 0.4um to 0.7um with peak sensitivity at around 0.55um. Aided viewing in the infrared range has advantages due to the relative freedom from atmospheric attenuation plus the fact that this range compares with the peak thermal radiation for objects at the ambient temperature.

The characteristics of the object (stimulus) also affect seeing. These object characteristics include size, shape, form, contrast to surrounding, texture, edge sharpness.

In addition to the available energy and stimulus characteristics, other factors that affect visual performance include exposure time, search requirements, motion, atmospheric effects (such as scattering and refraction) and the complexity of the scene structure. These above factors deal with the variable of the stimulus and environment. When considering the many possible interaction effects, the impact on visual performance is not precisely defined. Finally, variables within and across different people adds another level of imprecision when defining the human visual performance capabilities.

Basic Properties of the Human Visual System

The human visual system adapts to the very large range in natural viewing conditions by the use of two types of receptors. The cones, with individual receptors to the brain and relay color information, are concentrated in the foveal area of the retina. This area covers a circular portion of the visual field which subtends a 10-20 mrad diameter. Rods which have mostly blue sensitivity are grouped together into neural networks are absent in the fovea and increase in concentration towards the periphery. Rods operate for night vision at luminance levels where the cones are not responsive; they are progressively more concentrated out to an angle of 0.35 rad from the fovea.

Variations in pupil diameter are such that the pupil adopts a diameter where it is most able to compensate for the most likely sudden changes of scene luminance. In terms of naked eye viewing, data plots exist which describe the line spread function or the modulation transfer function[A-1] of the eye as a function of pupil diameter. For example, it has been shown that the frequency of response is largely independent of pupil diameters below 3 mm and to fall off rapidly for pupil diameters above 3 - 4 mm. Diffusion in the retina also occurs which results in additional image degradation. This diffusion results from scattering caused by the layers cells and linkages which are on top of the retina receptors.

The overall quality of the visual system depends on the characteristics of the refraction optics, retinal diffusion, the state of accommodation, involuntary eye movements and the distribution of the visual receptors. Early studies and description of the visual system typically define visual performance in terms of single forms of resolution criteria. More recently discussion visual system performance has made use of

[A-1] The modulation transfer function (MTF) is the percentage response to a sinusoidal modulated spatial bar pattern as a function of spatial frequency of the modulation.

the spatial and temporal frequency responses similar to the Modulation Transfer Function (MTF) used to study refraction optics. The contrast sensitivity function is derived by repeating at various frequencies presentation of a spatial bar pattern of variable frequency and sinusoidal spatial modulation with the modulation depth being altered until the bar can no longer be seen. These functions are then plotted with an ordinate of the reciprocal of threshold contrast.

Visual Acuity

The eye's ability to detect detail — the resolving power of the human eye is referred to as "visual acuity". Visual acuity can be described in terms of photopic and scotopic vision. Scotopic vision is better farther from the foveal area of the retina while photopic vision is better in the foveal region.

Another measure of visual acuity is the visual contrast sensitivity which relates field brightness and minimum perceptible brightness. Acuity depends on the shape of the object, wavelength, illumination, luminance, contrast and the duration of the stimulus.

Table A-1 shows visual acuity thresholds of different types of test patterns (11).

Table A-1

Visual Acuity vs. Different Types of Test Patterns

Test Target	**Task**	**Acuity**
Disc	Detect presence	30 arc sec
Tri-bar	See as three and detect orientation	70 arc sec
Gratings	Detect Separation	35 arc sec/bar
Snellen Letters	Read	48 arc sec
4 square checkerboard	Detect Pattern	60 arc sec

Note: In cyclical targets (i.e., repetitive features) acuity is often reported as spatial frequency and given in cycles/mm at 250mm.

The results of visual acuity studies show considerable variation. This is because the test conditions reflect the many differences present in the environment of the observer during actual task performance. The variations in observers in these studies reflects differences in subject "confidence" such as cautious vs guessing, criteria of visibility such as clean or blurry, viewing conditions, such as target contrast, illumination, etc.). Where other field conditions exist such as vibration and image motion visual acuity would be worse.

Visual acuity depends on the ability to see edge difference — black and white stimuli measured at high illuminance levels. However, "true" measures of visual resolution capabilities depend on other factors relating to contrast sensitivity which differs with differing viewing fields. People vary in their ability to discriminate the field from the background (e.g., field dependence measures). Contrast sensitivity assesses visual resolution through ranges of spatial frequency and contrast. Contrast sensitivity is the plotted reciprocal of the contrast threshold function.

Visual Acuity as a function of Exposure Time

For a static target, visual acuity improves with exposure time between 300-600 msec. This limit is somewhat general in that visual acuity is influenced by luminance level, viewing distance and exposure time, etc.

Visual Acuity as a function of Viewing Distance

Visual acuity and stereoacuity (discrimination of depth differences), both improve as viewing distances increase through an intermediate range (~5-10 m) and then decline.
Stereoacuity improves as a target recedes; however, it declines when the target reaches optical infinity. Similarly, stereoacuity declines when the eyes are accommodated and converged at different distances. Research has shown that visual acuity at one distance is a poor predictor of visual acuity at another distance (12).

Visual Acuity as a function of Viewing Distance and Luminance Level

Visual acuity (as determined by the smallest resolvable bar pattern), is best for target distances between ~.5-1 m; acuity decreases at longer and shorter distances. Viewing distance is more significant (on acuity) at low luminance levels than at high luminance.
See Table A-2.

Table A-2

Visual Acuity vs. Viewing Distance and Luminance Level

Smallest Resolvable Bar Width (minutes of arc)	**Infinity**	**1 meter**	**1/2 meter**
Luminance = 50 cd/m^2	.74	.7	.60
Luminance = 5 cd/m^2	1.05	.95	.98
Luminance = 0.5 cd/m^2	1.5	1.35	1.3

Visual Acuity: Target Motion, Direction of Movement and Luminance Level

Visual resolution of a moving target (dynamic visual acuity) decreases as the angular velocity of the target increases. Horizontal vs vertical direction of movement does not matter. Increases in target illumination improve visual acuity up to about 5400 lux. Note: This is much more than required for adequate static acuity.

For direction of movement, for an angular velocity of 20 degrees per second, the visual acuity is about 2 minutes of arc for both vertical and horizontal movement. At 120 degrees/second, visual acuity is about 5.5 minutes of arc for both types of movement. Sensitivity is higher for both vertical and horizontal orientations than for oblique orientations (with lower sensitivity for high vs low spatial frequencies).

At an angular velocity of 20 degrees/second, visual acuity is about 1.5 minutes of arc with 1345 lux luminance level. At 120 degrees/second, acuity is about 17 minutes of arc with .43 lux luminance level.

Contrast Sensitivity Factors

Contrast threshold is the minimum luminance contrast between the lightest and darkest parts of a spatial pattern where the subject can a pattern for a given percentage of trials.
Contrast sensitivity is the reciprocal of the contrast threshold. Contrast sensitivity is frequently measured using sine-wave gratings (bar patterns). Factors that influence contrast sensitivity include: accommodation, adaptation, border gradients, location in the visual field, masking, mean luminance, number of luminance cycles, orientation, pupil size, size of viewing field, spatial frequency, target characteristics, and temporal frequency.

It must be recognized that the laboratory results described above apply for conditions where the signal is known; uncertainty reduces contrast sensitivity. Also, absolute contrast sensitivity varies widely between subjects.

Note: For people > age 40 years, the contrast sensitivity function shows a significant decline at spatial frequencies > 2 cycles/deg. Also, about 10-15% of the population is estimated to have low contrast sensitivity for low to middle range spatial frequencies (1-8 cycles/deg.) In large population studies, contrast sensitivity varies with spatial frequency, peaking at ~4 cycles/deg.

The anatomy of the eye is such that all light that enters the eye does not reach the retina. That is, the eye both absorbs and scatters light — the amount of which is a function of wavelength. The observer’s eye moves to center the image on the fovea which is centered in the macula lutea , located about 5 degrees in diameter. Light absorption by the macula lutea results in differences in color matching between the fovea and the periphery of the retina.

The refractive power of the eye is different for different wavelengths which means that not all wavelengths of light can be in focus at the same time (chromatic aberration) but this phenomena has not been shown to reduce visual acuity (12).

Rods (low-intensity light for black-gray-white vision) and cones (colored and bright light) are the two types of light sensors on the retina. There are about 120 million rods and 10 million cones. Photopic vision occurs under high illumination conditions (above .1 lux); scotopic vision occurs under low illumination (below .01 lux) where the luminosity function is determined by the rods; mesopic vision occurs under intermediate illumination (between .01 and .1 lux—e.g., dusk or dawn).

Night vision can result in particular phenomena. For example, if the horizon has few to no visual cues, the lens relaxes and focuses at a distance of about 1 to 2 meters. As a result it can be difficult to perceive far objects (night myopia). Also, night vision capabilities deteriorate with lack of oxygen (e.g., at 2000m the deterioration is about 20%) (10).

Sensitivity to Light

The density distribution of rods and cones varies. Cone density , as already mentioned is greatest at the fovea and falls to a minimum by ~10 degrees from the point of fixation. Rods are most dense in the near periphery out to ~18 degrees. Table A-3 summarizes photopic and scotopic visual characteristics.

Table A-3

Photopic and Scotopic Visual Characteristics

Type of Vision	Photopic	Scotopic
Receptor	Cones (~ 7 million)	Rods (~ 120 million)
Peak Wavelength	555 nm	505 nm
Dark Adaptation	~ 7 minutes	~ 40 minutes
Color Vision	Trichromatic	Achromatic

Spectral Sensitivity

The human's ability to detect light is a function of wavelength. For example, at night, the relative threshold (spectral sensitivity) with a wavelength of 350 nm is about 20 decibels. The relative threshold is about 40 decibels for photopic vision at this wavelength. At 550 nm the relative threshold for the two types of viewing conditions are - 20 decibels and 5 decibels, respectively. At 750 nm, delectability is comparable for photopic and scotopic vision, and is about 40 decibels.

The above data points are based on laboratory data collection. In these conditions, the size, duration, the location of the target on the retina is held constant, and the target is presented to the observer at a known time.

Visual Performance: Visual Acuity vs Contrast Sensitivity

Visual acuity (Snellen) is not a sensitive measure of visual human performance at lower contrast levels. A more accurate method of determining of visual acuity is the contrast sensitivity function which measures the contrast threshold over a range of spatial frequencies. Specifically, these authors report on findings that about 10-15 % of the population have good (Snellen) acuity but low contrast sensitivity for low and mid-range spatial frequencies. In simulated air-to-ground target detection and in actual ground-to-air target detection contrast sensitivity has been found to be a better predictor than the use of visual acuity tests (12).

Ginsburg et al., 1983, (as cited in (12)) examined the detection of an approaching T-39 aircraft in field trials using 84 Air Force pilots where visibility conditions ranged from 0.5 to 15 miles. Visual capability was measured using the Snellen acuity test and contrast sensitivity tests. These visual capability scores were then correlated to aircraft detection range. The researchers found that contrast sensitivity correlated significantly with detection range in eight out of the ten trials. Visual acuity correlated with detection range in three out of ten trials (in one trial visual acuity had a significant negative correlation with detection range — under rapidly changing visibility due to fog). The average difference in detection range and time between the least and most sensitive pilots, in all visibility conditions was 2.2 miles and 56 seconds. Table A-4 gives sample findings from the Ginsburg study.

TABLE A-4

Average Pilot Detection Range of a T-39 Aircraft in Different Visibility Conditions

Visibility (miles)	**Ave Pilot Detection Range (mi)**
1-2 mi (Foggy)	1.0
15+ (Bright Sun)	8.6
13 (Some Haze)	10.26
0.5-3 (Very Foggy)	0.38
5-7 (Rapidly Changing VIS)	5.04
15 (Late Afternoon Sun)	8.5

These authors continue to discuss the contrast sensitivity approach with respect to quantifying display systems. They believe that the limitations of display system resolution standards are similar to the limitations of acuity for vision standards. Specifically, they believe that one limiting resolution value cannot be used to define detection capabilities of varying sizes and contrasts of targets.

Indirect Image Issues

Many distortions of visual information about an object occur when indirect vision is used. The use of visual aids such as binoculars, telescopes, microscopes and of photographic and television media create issues about aided vision. The distortions include softening of profiles, modification of scene contrast and noise.

Another issue regarding indirect images and human visual performance is: “How good is good enough?” For example, researchers (13) examined the impact of screen resolution on a simple visual recognition task. These authors question the use of “imitation of reality” as the criterion for evaluation of rendering techniques. They looked at the effect of image quality which they defined in terms of spatial resolution and the presence or absence of spatial alaising artifacts.[A-2] The authors found that there appears to be a

[A-2] Images computed using sub-pixel sampling are referred to as antialaised images. Alaised images are those for which a single sample determines the shade for the tile.

difference between ratings of image quality in terms of how closely the image approximates the physical realism versus how effectively rendered images assist in performing a specific task. The authors also discuss a study in which a prototype of an air traffic control station was used to examine an aircraft recognition task. This system used no antialaising. The spatial artifacts of the rendering algorithms were found to interact with the movement of the airplanes such that a temporal pattern emerged for each type of aircraft. In the study it was found that each type of airplane, for example, on final approach, had its own characteristic “click” that allowed it rate of descent to be distinguished from the other aircraft.

Other factors which deal with the assessment of image quality fall out of the work beginning about fifty years ago which applies the concept of the Optical Transfer Function (OTF — a measure of the degradation in sharpness due an optical system) to the visual system. Shortcomings in the application of the OTF to visual performance were realized due to the unknown effects of coupling between the optical component and the eye plus the incomplete understanding of the relationships between visual performance when looking at periodic functions vs isolated objects. Due to limitations of the OTF other measures of image quality have been sought. One of these is the Modulation Transfer Function Area (MTFA) which is defined as the area between the MTF curve of a lens system and the detection threshold curve for optimally-viewed photographic images of the American 3-bar resolution test target. See Figure A-1.

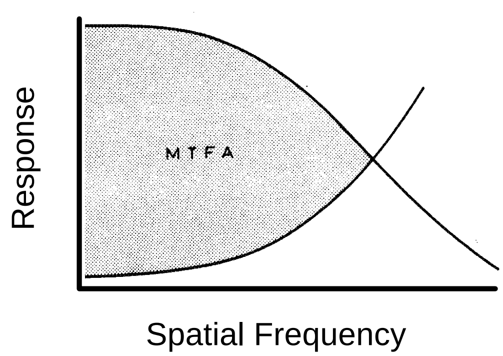

Figure A-1

MTFA shown as area between the MTF (top curve) and Threshold Detection Curve

Other measures of image quality take into account the chain of optical and photographic components in many systems (e.g., camera lens, camera film, projector lens, the display and the observers eye.) This measure has been described as the contrast modulation transfer (CMT) acutance:

$$\text{CMT acutance} = 40 \log (6.67 \text{ MTC area}_{(syst)})$$

where, MTC is the area, in units of mm^{-1}, under an experimentally determined MTF curve for the component of interest (9).

The CMT function has been shown to highly correlate with subjective ratings of image sharpness as optical degradations due to defocus, aberrations, photographic adjacency effects, halation, etc. where varied. CMT acutance is closely related to the MTFA.

Detection and Recognition Thresholds in the Field

Transfer of the information learned from laboratory studies about visual acquisition is not always easy. Acquisition of objects in real life does not involve simple, structureless objects viewed against plain fields. There are many factors which differ in complex viewing situations from that in the laboratory. These factors include the luminance structure of the target, the background structure, textural effects, requirements for structured search such as when the observer must discriminate the object of interest from related objects and not just from noise, and finally fro a dynamic structure which is changing with time.

Blackwell (14) characterizes the visual acquisition as an information assimilation system; that is, visual performance is defined in terms of the rate at which information is assimilated. The capacity to assimilate, in turn, is a function of illumination, size and contrast of the target, etc. The problem for experimental research of the visual system has been to specifically define the amount of information assimilated. Blackwell's research defines the assimilations per second (APS) or "pieces" of information to quantify visual capacity. The presence or absence of a luminous disc (not considering other features such as size, shape or color) is considered one item of information. In laboratory trials, Blackwell determined threshold contrast curves for various exposure duration and disc target diameters using a forced-choice technique and a 50% accuracy requirement and the subjects having advanced information about the target. He found, for example, that for a 60-minute disc presented at a high luminance for one second that the threshold contrast was .0073.

Blackwell recognized that a 50% accuracy requirement in the field is not adequate and that a much higher value such as 99% must be used. In addition he devotes considerable emphasis in determining the "field factors" to apply to the laboratory threshold contrasts. Laboratory results are influenced by "psychological factors" such as availability of advance information on the target. For this **one** factor, Blackwell determined using a Field Task Simulator, that a field factor of 1.4 must be applied to the laboratory threshold contrast values. Using the Field Task Simulator in many separate studies he systematically determined the differences between laboratory conditions and those found in everyday use.

An example of a standard visual performance curve is one based on a four-minute standard disc target for a visual capacity of 5 APS, a field factor of 15 (a multiplier to be used with laboratory values which consider all field differences) an accuracy level of 99% and uniform luminance.

Other Field Factor Issues

Additional factors that complicate recognition thresholds in the field are due to optical imperfections of the atmosphere. The first of these is atmospheric attenuation which is due absorption and to the scattering of light from small particles or moisture droplets in the air.

The effects of absorbing agents such as water vapor, carbon dioxide, nitrous oxide, ozone, etc. are greatest in the infra-red and ultra-violet regions of the spectrum. In the visible region the effect of absorption is minimal on a clear day when the water content of the atmosphere is low. However, where the atmosphere is polluted absorption can be a significant factor. In order to capture more and more realistic viewing conditions, various models have been developed to consider viewing paths (horizontal and slant path viewing) as well as the effects of structured illuminance of the viewing path such as the implications of the object against a broken cloud cover.

Atmospheric turbulence also results in an optical effect that is an issue for field detection. The shimmering of objects near the ground on a hot day or the twinkling of lights at a distance are examples of atmospheric turbulence. The resulting optical effect is temporal fluctuations in the apparent position of the object and changes of refraction across the
 as viewed by the two eyes. Basically, as a result of atmospheric turbulence, the refractive index becomes a function of position and time. As an optical signal moves through a turbulent atmosphere its interaction with the atmosphere results in random variations on the amplitude and phase of the signal. These optical effects are variously referred to as “shimmering”, “image motion”, “dancing”, “beam steering” (due to deviations of the entire beam from the line of sight), “blurring” (interaction of image motion and pulsation of different point of a distant object), and “scintillation” (rapid fluctuations in intensity of point sources of light)

Two types of field studies that have been conducted look at air/ground approach and ground/air approach. The first type of study looks at the object in cluttered surrounding with fixed field luminance. Ground/air studies look at the object detection in uncluttered surroundings with possible temporal luminance distribution differences. A myriad of problems arise when conducting these types of field studies in that accurate information about factors such as atmospheric attenuation along the viewing path, object contrast, terrain screening, accuracy of the observers response, etc., must be known to permit generalization of results.

It has been found by one author (10) that the effective slant path visibility for viewing aircraft from the ground can be significantly greater than horizontal ground visibility. A representation of this finding is shown in Figure A-2.

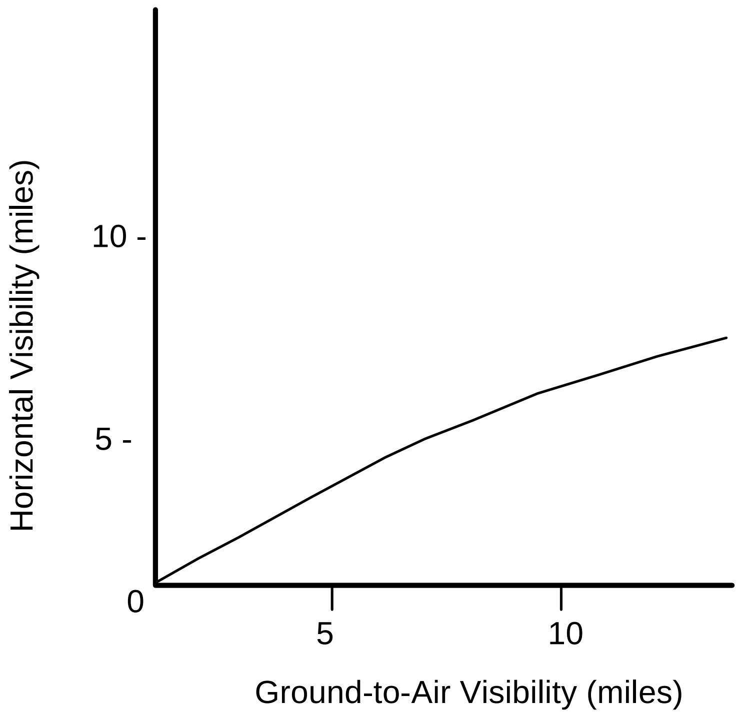

Figure A-2

Horizontal Visibility at Ground Level vs. Slant Path Visibility
(Between ground level and 200 m altitude)

In air to ground viewing, due to the downward viewing path, the existing atmospheric effects are closer to the object being viewed rather than to the observer. These types of studies have shown that in the field detection of "simple" objects could be predicted from laboratory data whereas "detection" of complex targets in the field more closely resembled "recognition" results in the laboratory. That is "the field factor necessary to degrade Tiffany (Blackwell) data to field detection for simple targets is similar to the factor necessary to degrade forced choice laboratory thresholds to the free choice thresholds" (9, p.343).

Summary

Several conclusions and recommendations can be made from the above material:

• Visual acuity is a function of a number of variables including viewing distance and luminance level. Visual acuity is also a function of target motion. For application purposes, visual acuity should be related to a given target size with a given contrast ratio. See Table 6.

• Visual acuity (e.g., Snellen) is not a sensitive measure of human visual performance at lower contrast levels. A more accurate method of determining of visual acuity is the contrast sensitivity function which measures the contrast threshold over a range of spatial frequencies.

• At night, with few visual cues on the horizon, the lens of the eye relaxes and night myopia can occur.

• Aircraft detection studies have shown that detection success correlates better with contrast sensitivity tests than with Snellen acuity tests

• Contrast Sensitivity should be used in quantifying display systems

• Laboratory data on recognition is a reasonable estimate on field detection capability. The visual acuity requirement stated in this document (Table 6) was determined by stating an exposure time, luminance level and target size and applying a "field factor" to determine the needed contrast ratio for detection in the field.

• There is a difference in detection capability even in "select" populations (e.g., Ginsberg study).

• "Imitation of reality" has been questioned as being necessary in all applications of display systems.

• Imperfections in the atmosphere influence visual capability (e.g., atmospheric absorption, atmospheric turbulence).

Many of the above conclusions have (e.g., visual acuity needed) direct application to the specifications of the ODP. Other factors listed above will be variables to control in some of the research projects identified for investigation beyond FY95.

APPENDIX B
EMERGENCY COLLISION AVOIDANCE PARAMETRIC STUDY

A study has been undertaken to provide airborne object detection guidelines for purposes of collision avoidance. The approach used in this analysis was to develop an Excel™ spread-sheet capable of analyzing a variety of potential collision situations in terms of the relative positions of two aircraft from the point of detection through a maneuver that produces a specified closest approach distance between the two aircraft. The methodology and assumptions are discussed in the next section, followed by an application of the method to several typical collision avoidance scenarios.

Methodology and Assumptions

The analysis begins with a potential collision geometry, an example of which is shown in Figure B-1. The *HSCT* is flying on an arbitrary straight (not turning) flight path. The *target aircraft* follows a straight flight path that intersects the HSCT path at a point where a collision would occur if neither aircraft took any avoidance action. The flight paths of either

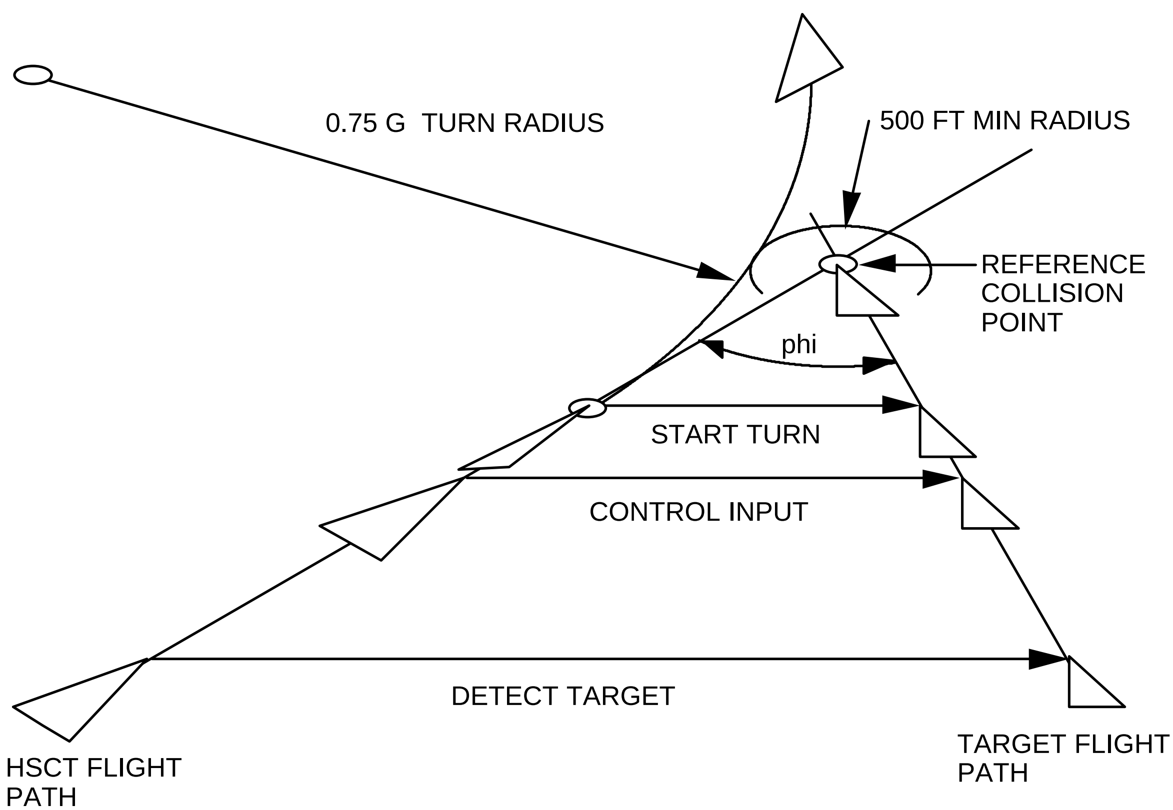

Figure B-1. Collision avoidance analysis geometry

aircraft may be climbing, descending or level, but both are assumed initially to be straight lines, and to intersect at the collision point. The angle between the vertical plane of the HSCT flight path and that of the target aircraft may vary between zero (directly in line, traveling in the same direction) and 180° (in line, traveling in opposite directions), including all angles between these extremes. True (inertial) speeds must be specified for each aircraft and, once specified, are assumed to be constant throughout the analysis. Similarly, vertical speeds (positive for climb, negative for descent and zero for level flight) must be specified for each aircraft and are likewise assumed to be unvarying.

In the analysis, it is assumed that the target aircraft makes no avoidance maneuver and continues on its original path through the collision point. The HSCT, in some unspecified manner, detects the target aircraft and delays action for a period of time during which it is assumed that some processing takes place to recognize the impending collision and a decision to take action is made. Then a control input is made and the HSCT performs an avoidance maneuver that produces a closest approach to the target aircraft of no less than 500 ft. (this distance is arbitrary and can be specified at any value).

In defining the avoidance maneuver, it was assumed for this class of large transport aircraft that the maximum permissible normal acceleration (in the aircraft vertical plane) would be a positive 1.25g. If the selected avoidance maneuver were a simple vertical pull-up, this would provide a net effective maneuver acceleration of only 0.25g. On the other hand, if the 1.25g is applied in a level turn, the net effective maneuver acceleration is 0.75g (bank angle of about 36°). For this reason, it was assumed that the most effective maneuver—i.e., that providing the greatest curvature of the flight path in the least time and distance—would be a level 1.25g turn. Accordingly, the spreadsheet calculates the avoidance maneuver as a level turn with 0.75g central acceleration. To complete such a turn, of course, the HSCT would have to roll to the required bank angle. We have assumed a constant roll rate for this analysis that requires 3 seconds to reach the maneuver bank angle from a wings-level attitude and, for simplicity, that no flight path curvature takes place until the end of the roll-in period.

The previously noted period for detection, analysis and decision to act was set at 6 seconds, which is consistent with previous studies on human reaction time in visual (“see and avoid”) collision avoidance situations (4). This is not intended to imply, however, that the detection and avoidance scenario depends on human capabilities. Different assumptions about the latency period between detection and the beginning of control input can be accommodated by linear interpolation/extrapolation from the present zero time (initial) point.

A typical example of the analysis spreadsheet is shown in Exhibit B-0. The parameters that are constant are listed and defined on the top half of Sheet 1. Those parameters in **bold** type must be input by the analyst. The others are calculated from the input values. Among these parameters, the **tref** input is perhaps the most difficult to comprehend without additional explanation. **tref** is the reference time in seconds between the start of the actual avoidance maneuver (at time = 9 sec.) and the time at which the HSCT and target aircraft *would have collided if no avoidance maneuver had been initiated*. This value is adjusted by the analyst until the point of closest approach (range) is approximately 500 ft. The point in space where the distance between aircraft is closest will vary with relative aircraft speeds and the angle between flight path planes; thus, the time from the expected collision point (tref) and the associated distances of the aircraft at the point of avoidance maneuver initiation (which are likewise dependent upon tref) are adjusted by varying tref to meet the 500 ft. criterion.

The bottom portion of Sheet 1 of the analysis contains the following information:

time—the time in seconds after initial detection occurs. All columns of data relate to the time at the tope of the column.

hdg—the HSCT heading at each second of the scenario. The initial heading is always assumed to be 000° and the HSCT turns away from the direction of approach of the target aircraft after initiation of the avoidance turn.

t—the time in seconds referenced to the actual start of the maneuver, which always occurs at time = 9 sec.: 6 sec. for detection, analysis and decision, and 3 sec. for rolling to the 0.75g bank angle. During the initial 9 sec., the HSCT follows a straight line flight path as defined by V (inertial speed) and VV (vertical speed).

HSCT pos (x, y, z)—defines the HSCT position in Cartesian coordinates with origin at the point of expected collision if no maneuver were to take place. Note that, because the HSCT is always assumed to take avoidance action, it will never pass through the origin.

Target pos (xT, yT, zT)—defines the target aircraft position in Cartesian coordinates with origin at the point of expected collision if no maneuver were to take place. Note that these coordinates are simply those describing a straight line in 3-D space defined by VT, VVT and phi, the angle between the HSCT and target flight paths. This path always passes through the origin because, by definition, the target makes no evasive maneuvers. The target will always path through the origin at t + tref seconds after initiation of the HSCT avoidance maneuver, or at time = 9 + tref seconds after detection. This may or may not also be the time of closest approach (minimum range) between the two aircraft.

The remaining rows on Sheet 1 of the analysis summarize the results at each second of translating and rotating the axes so that the final coordinates **(xs, ys, zs)** give the position of the target aircraft with respect to an origin at the HSCT and with the axes parallel with the HSCT aircraft axes. The origin and axes move with the HSCT and are thus different at each second of the analysis. Note that the yaw axis rotation is only the result of successive HSCT heading change increments; no drift angle for crosswind is assumed.

Sheet 2 of the analysis calculates the positions and rate of closure of the target relative to the HSCT in terms that should be useful for a detecting and tracking system. The summary is presented in both tabular (by second) and graphic form. The data are described below and are shown for reference in Figure B-2.

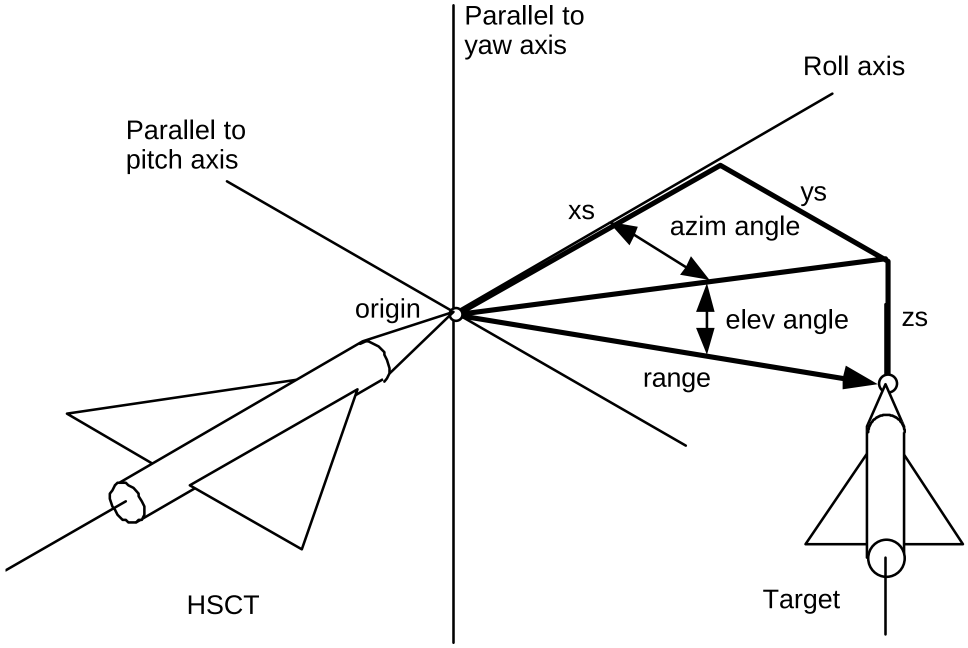

Figure B-2. Range, azimuth and elevation from HSCT to target aircraft

time and **hdg**—these rows repeat the same data from Sheet 1 to facilitate reference.

range—the direct (slant) distance in feet between the HSCT and the target throughout the entire detection and avoidance sequence. The range value at time = 0 is the range where detection must occur to assure that a successful avoidance (i. e., range no less than 500 ft.) can be accomplished within the maneuver limits assigned.

azim—the azimuth angle (angle in the HSCT waterline plane with respect to the HSCT's longitudinal axis extended forward) of the target in degrees. This is the angle that a sensor (e. g., radar) vertical axis gimbal would have to assume so that the target would be centered in the sensor field of view (FOV).

elev—the elevation angle (vertical angle from the HSCT waterline plane) of the target in degrees. This is the angle that a sensor horizontal axis gimbal would have to assume in order that the target would be centered in the FOV.

drange—the difference in range (ft.) between the two aircraft in two adjacent seconds (drange = $range_t - range_{t-1}$). This value is used to calculate closure velocity.

Vc—the closure velocity (knots) between the HSCT and target. When Vc is positive, the two aircraft are closing (range is *decreasing* with time); when it is negative, the two aircraft are separating (range is *increasing* with time).

The curves shown on Sheet 2 of the exhibit summarize the data graphically for range and range rate (drange/dt in ft. per sec.), and for elevation and azimuth (deg. from the nose), as functions of time. The range starts at the detection distance (about 5,800 ft.) and decreases linearly until the 9 second point, where the control input begins to take effect. Then the range function becomes nonlinear until, at about 16 seconds, it begins increasing. The range rate, which is essentially the derivative (slope) of the range function (not explicitly defined mathematically in the analysis), is constant through the first 9 seconds, then decreases until, at about 16 seconds, it becomes negative. This is the approximate point at which the HSCT stops closing on the target and thus represents the point of closest approach.

The target elevation and azimuth functions in the second chart summarize its angular position relative to the HSCT over the same period as the range and range rate function graphic. The initial conditions at detection time for a target that is on a 90° collision course, traveling at 100 kts in a 500 fpm climb, with the HSCT at a 5° nose-up pitch attitude, traveling at 200 kts in level flight (see Sheet 1 parameters), are elevation angle of -5.7° and azimuth angle of 26.8°. These conditions remain approximately constant for the 6-second detection/processing/decision phase. At 6 seconds, however, the roll-in begins and for the next 3 seconds the changes in relative azimuth and elevation to the target are simply the result of the change in roll attitude of the HSCT. From that point on, the changes in elevation and azimuth reflect the curving flight path of the HSCT during the avoidance maneuver. These are the angles that a sensor would have to use to keep the target centered in its FOV throughout the avoidance maneuver. It is interesting to note in the particular case shown in Exhibit B-0 that, if the sensor is assumed to be the pilot's eyeball, and it is further assumed that the SAE ARP 4101 (AS 580B) vision limits are in effect, then the pilot could theoretically detect the target and keep it in sight until about the 14 second point (2 seconds before closest approach), where it would disappear below the lower vision limit (-35°) in elevation. This, of course, assumes that the target lies on the same side of the HSCT as the detecting pilot. It is not necessary, however, that the pilot or other sensor keep the target in view throughout the maneuver, only that the target be within the sensor FOV throughout the period between detection and initiation of the avoidance maneuver.

In summary, the analytical spreadsheet just described will determine the detection parameters (range, elevation and azimuth) that must be observed to avoid a collision by a radius of about 500 ft. minimum between the sensing aircraft and an uncooperative, non-maneuvering target aircraft. The results should be valid given certain assumptions about the time needed to detect, analyze, decide and act to maneuver the sensing aircraft, and others about the maximum practical maneuver accelerations. This analysis can be completed for a virtually unlimited set of initial conditions leading to a potential collision, including various speeds and vertical speeds of both aircraft and angles between the flight paths leading to the collision point.

The following section summarizes the application of this analytical tool in several typical collision avoidance scenarios.

Analysis of Typical Collision Avoidance Scenarios

Five typical potential collision scenarios were developed by PPI, Inc., our HSR operations consulting firm, to exercise the collision avoidance methodology. These scenarios and the results of their analysis are summarized below.

Scenario 1: Over-run of a Business Jet by HSCT During Departure—In this scenario, a relatively heavily loaded business jet is cleared to depart immediately ahead of an HSCT at a major hub airport. The HSCT is cleared to take off in sequence behind the business jet and directed to maintain runway heading and visual separation on the other aircraft. The business jet loses power on one engine, which substantially reduces its speed and climb performance. The pilot maintains runway heading and best rate of climb airspeed while dealing with the crisis. This places the HSCT in a direct “tail chase” overtake situation at maximum legal low-altitude airspeed (250 kts, about a 40 kt differential closing speed). The initial collision situation for the collision avoidance analysis has the following characteristics:

Parameter	HSCT	Target
Speed	250 kts	210 kts
Vertical Speed	+1500 fpm	+500 fpm
Angle from Collision Point	—	0°
Pitch Attitude	10°	—
Flight Path Angle	+3.4°	+1.3°

The question to be answered is, what range, elevation and azimuth would be the last possible point at which a collision could be avoided given the maneuver limitations discussed above.

The complete analysis is contained in Exhibit B-1. Figures 3 and 4 summarize the conclusions. As Shown in Figure B-3, detection must occur before the closure distance (range) is less than about 1,300 ft. Point of closest approach occurs between 13 and 14 seconds after detection. Figure B-4 indicates that the initial detection azimuth is 0° while elevation is a positive 4.3°. This latter result is perhaps somewhat surprising, considering that the HSCT pitch attitude is estimated to be +10°; however, due to the substantial differential in climb rate between the two aircraft, at the detection range the target initially lies *above* the waterline plane of the HSCT.

These numbers suggest that this scenario is not a particularly stressing one for a detection system, because of the low rate of closure produced by the tail chase aspect at the relatively close airspeeds.

Scenario 2: Simultaneous Arrivals at a Terminal with Two Parallel Runways—In this scenario, the HSCT arrives downwind for the southbound runways on the west side of the DFW International Airport. The HSCT is cleared for a visual approach

Range and Range Rate vs Time

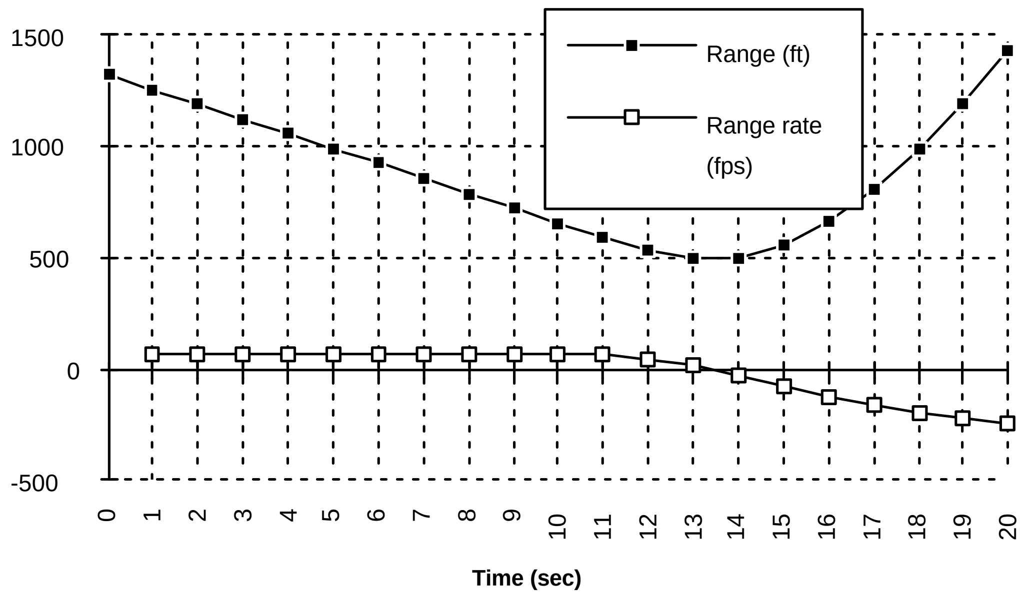

Figure B-3. Scenario 1 range and range rate vs time

Target Azimuth and Elevation vs Time

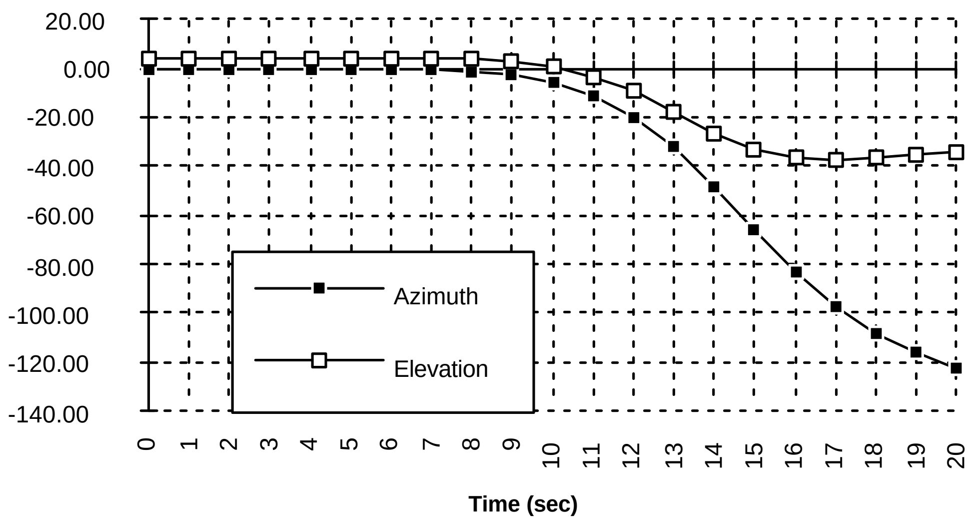

Figure B-4. Scenario 1 azimuth and elevation angles vs time

to Runway 17L, which is on the east side of the airport. Simultaneously, a business jet with similar landing performance arrives downwind on the east side of the airport and is cleared for a visual approach to Runway 18R, which lies on the west side of the airport. The HSCT is already at the final approach altitude for intercepting the glideslope at the outer marker. The target aircraft is at a higher altitude and is instructed to remain at that altitude until "established on final," thus ensuring that there will be altitude separation when the two aircraft cross paths north of the airport on their way to their respective localizer intercepts. However, the target aircraft mistakenly begins its descent early. Both aircraft end up on a collision course, the HSCT on a 120° magnetic heading, level at 3,000 ft., and the target on a 240° magnetic heading descending toward 3,000 ft. The target is unable to detect the HSCT because of low sun angle and limited (though VFR) visibility. The initial conditions for the analysis are as follows:

Parameter	HSCT	Target
Speed	210 kts	210 kts
Vertical Speed	0 fpm	-900 fpm
Angle from Collision Point	—	120°
Pitch Attitude	8°	—
Flight Path Angle	0°	-2.4°

The complete analysis is given in Exhibit B-2. As shown in Figure B-5, at the last possible instant for conducting the specified avoidance maneuver and missing the target by at least 500 ft., the range is approximately 9,500 ft. (1.6 nm). The closest approach distance occurs between 16 and 17 seconds. Figure B-6 indicates that initial elevation of the target at detection to be - 5.5°, while the azimuth to the target is

This scenario apparently requires substantial detection range capability and sensor performance. If the detection mechanism were the human eye or its electronic equivalent, it would have to resolve an aircraft the size of a business jet from a nearly head-on aspect. Assuming an average diameter for such an aircraft of about 7 ft., this target would subtend about 2.5 minutes of arc at the 1.6 nm range. The target would be just below the horizon, which has implication for its contrast ratio with the background. For reference, the human eye is capable of approximately one arc-minute resolution (i. e., "20-20" vision) with no

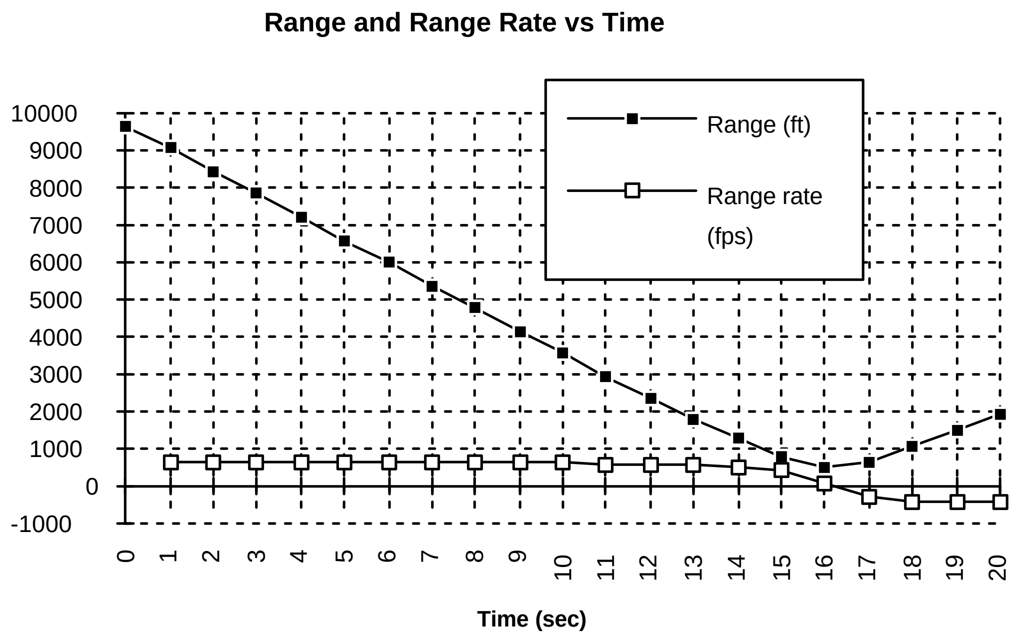

Figure B-5. Scenario 2 range and range rate vs time

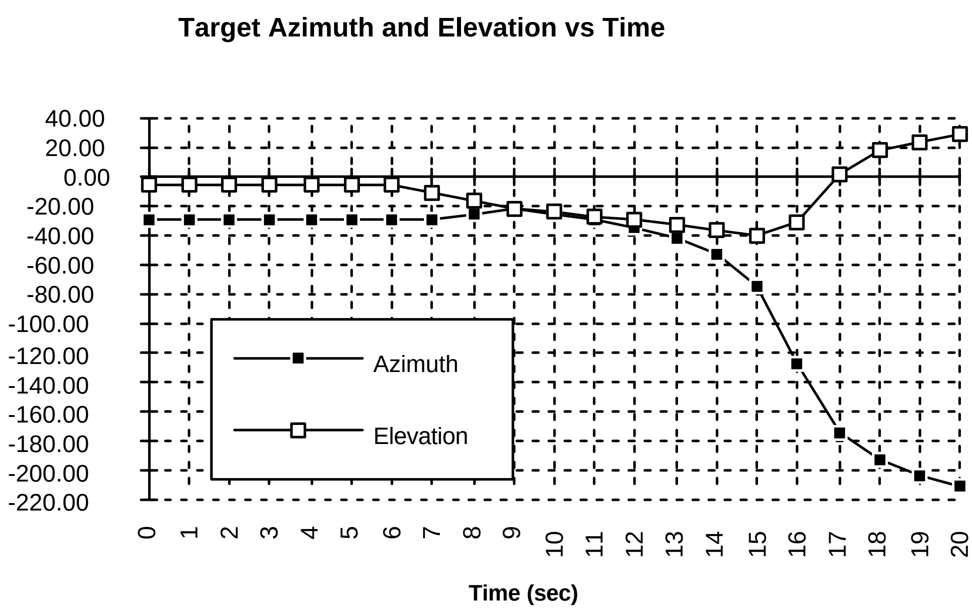

Figure B-6. Scenario 2 azimuth and elevation angles vs time

intervening filter (such as glass or an electronic imaging sensor) for targets with optimal contrast ratio.

Scenario 3: Encounter with a Light Aircraft in the Landing Pattern—The HSCT is cleared for a straight-in approach to an airport with closely spaced parallel runways. A small piston-engine general aviation (GA) aircraft (Cessna 172) flown by a student pilot is in the left traffic pattern for the left runway. The HSCT is cleared for the right runway and is descending on the 3° glideslope. At the point of impending collision, the target aircraft is on base leg, where the pilot becomes distracted and fails to turn final for the left runway, thus intruding on the HSCT's flight path. The initial conditions are:

Parameter	HSCT	Target
Speed	170 kts	90 kts
Vertical Speed	-990 fpm	-500 fpm
Angle from Collision Point	—	90°
Pitch Attitude	8°	—
Flight Path Angle	-3.0°	-3.1°

The complete analysis is given in Exhibit B-3. As indicated in Figure B-7, the initial detection range required is about 5,000 ft. Closure rate is 327 fps (190 kts). Closest approach occurs at about 16 sec. Figure B-8 shows the initial elevation at -8° and azimuth at 30° off the nose. None of these values appears to be a particular challenge for a visual equivalent sensing system, either from the aspect of resolution or position in the FOV.

Scenario 4: Conflict between landing HSCT and GA aircraft departing another airport—The HSCT is cleared for a straight-in approach to Runway 29 at Oakland International Airport. The inbound flight path passes just west of the Hayward Municipal Airport. A Cessna 172 departs Hayward Runway 28L and performs a left crosswind departure. The GA aircraft flight path crosses the HSCT's flight path at about 1,000 ft. altitude, the Cessna climbing and the HSCT descending. The initial conditions for the analysis are shown in the table following Figures 6 and 7.

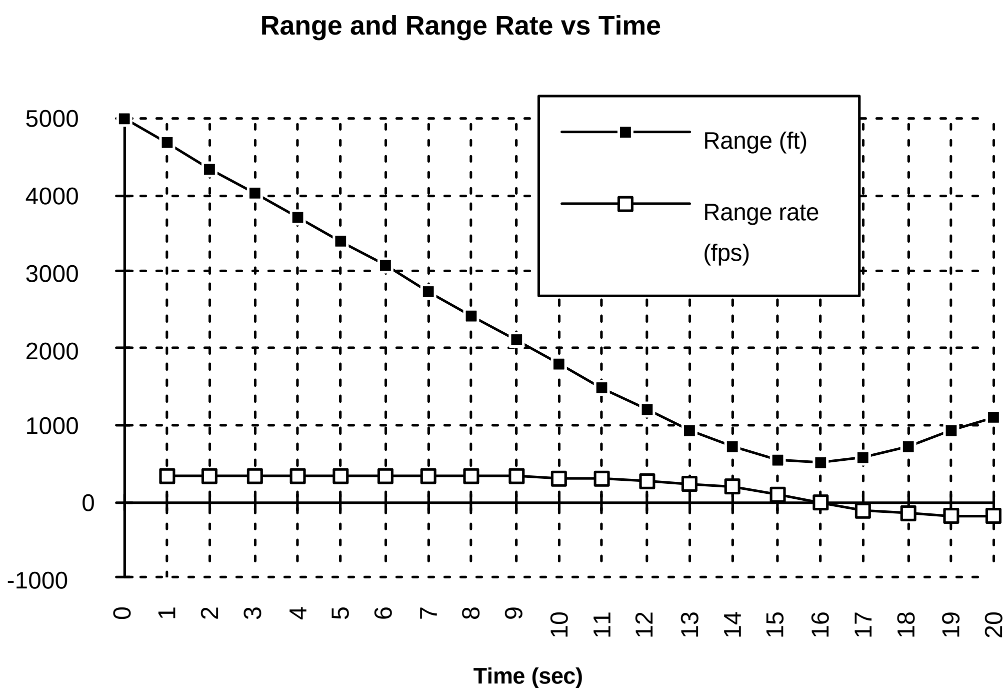

Figure B-7. Scenario 3 range and range rate vs time

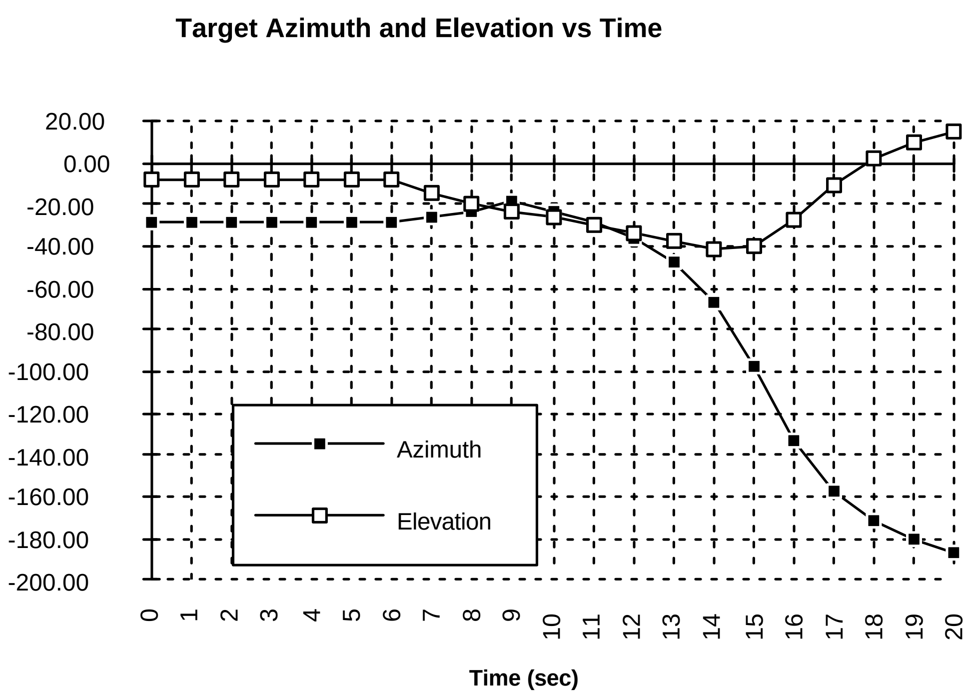

Figure B-8. Scenario 3 azimuth and elevation angles vs time

Parameter	HSCT	Target

Speed	150 kts	90 kts
Vertical Speed	-800 fpm	500 fpm
Angle from Collision Point	—	93°
Pitch Attitude	8°	—
Flight Path Angle	-3.0°	3.1°

The complete analysis is contained in Exhibit B-4. As shown in Figure B-9, the detection range must be about 4,600 ft. The elevation angle at detection and during the decision process is -10°, while the azimuth angle is 30° off the nose (Figure B-10). This scenario does not appear to present any significant detection difficulties for the HSCT.

Scenario 5: Conflict between the HSCT and subsonic transport at high altitude during an emergency descent—In this scenario, the HSCT has suffered a pressurization failure at cruise altitude that calls for an emergency high-rate descent to an altitude below 10,000 ft. MSL. During the high rate descent, the HSCT penetrates the upper flight levels at which subsonic transports and business jets operate. The worst case hypothesized would be one in which the target aircraft—say, a conventional narrow-body commercial transport—is operating along the same airway and encounters the descending HSCT in a head-on aspect. The initial conditions for this situation are as follows:

Parameter	HSCT	Target
Speed	860 kts (M1.5)	460 kts (M0.8)
Vertical Speed	-10,000 fpm	0 fpm
Angle from Collision Point	—	180°
Pitch Attitude	-4.6°	—
Flight Path Angle	-6.6°	0°

The analysis for this encounter is contained in Exhibit B-5. Figure B-11 shows the range at point of required detection to be about 36,000 ft. (5.8 nm). Initial elevation angle to the target is slightly above the waterline plane (due to the HSCT's negative pitch attitude), while azimuth angle is zero (Figure B-12). Closing speeds are very high (approximately

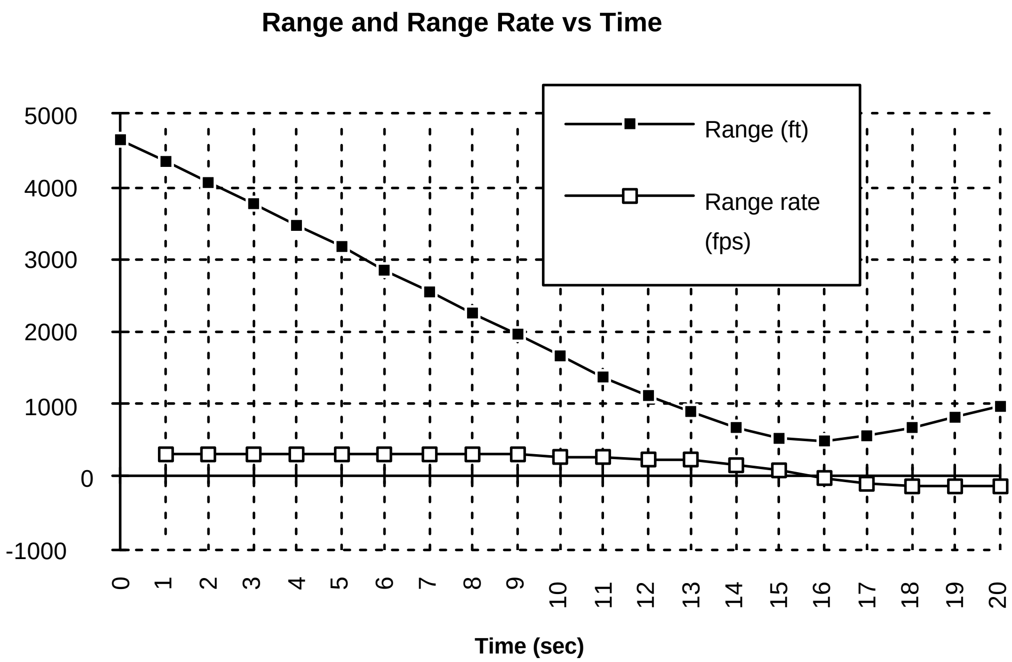

Figure B-9. Scenario 4 range and range rate vs time

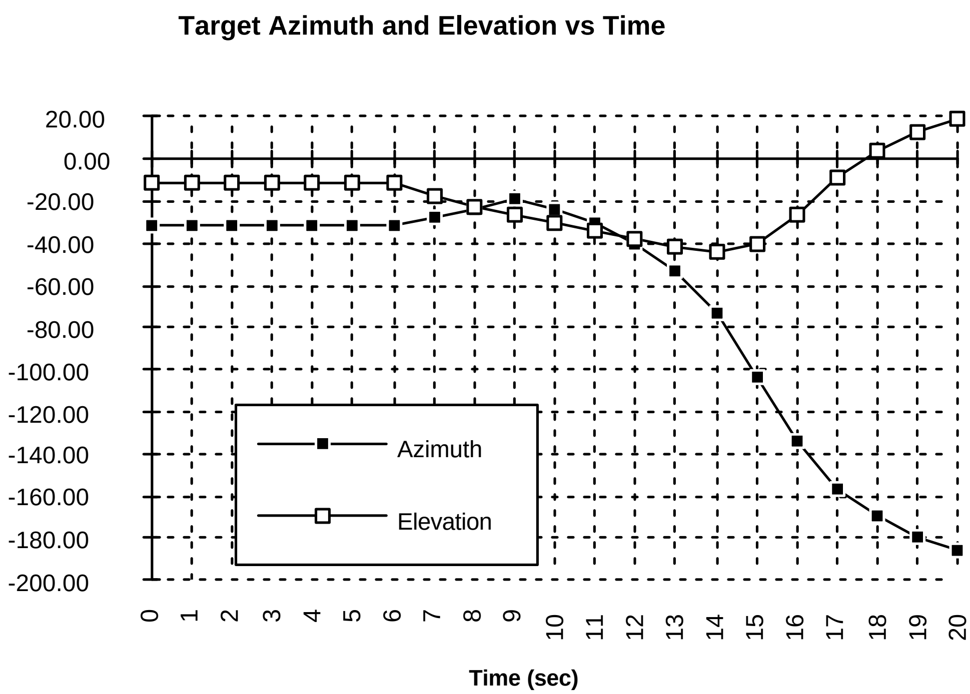

Figure B-10. Scenario 4 azimuth and elevation angles vs time

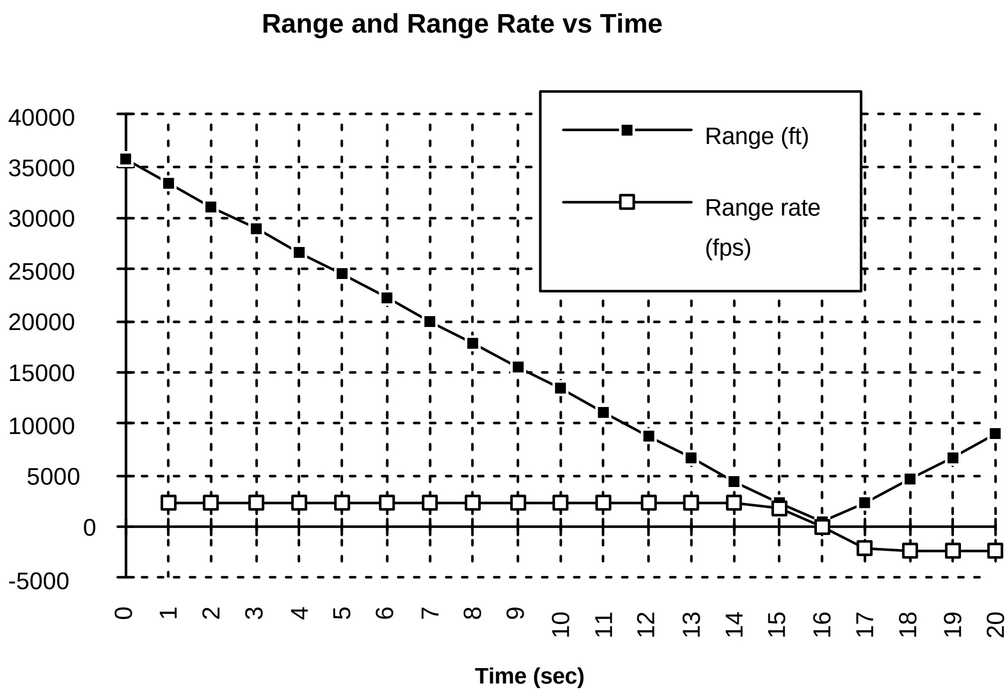

Figure B-11. Scenario 5 range and range rate vs time

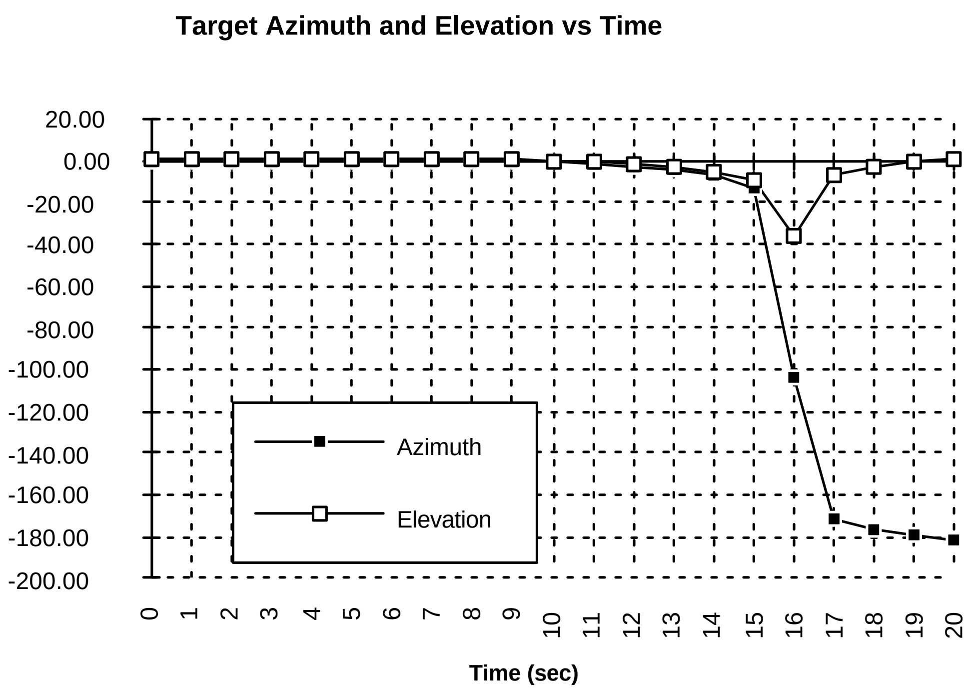

Figure B-12. Scenario 5 azimuth and elevation angles vs time

2,200 fps or over 1,300 kts). The required detection range in this scenario is fairly extreme. If an eye-equivalent sensor were to be used, it would have to detect a typical narrow-body transport in a nearly frontal aspect at about 6 nm. The angular subtense of a typical cross section (about 12 ft. diameter) at 6 nm is 1.16 arc-minutes, very close to eye-limiting resolution. A business jet of about 7 ft. diameter (which might also be encountered at these altitudes) presents a target only 0.68 arc-minutes in subtense and would thus be undetectable at eye-limiting resolution of 1.0 arc-minutes. Currently, in this situation, these aircraft would depend on TCAS and ATC for detection — the HSCT could do this as well.

If we assume that the target is traveling in the *same* direction as the HSCT during this sequence, the situation is summarized in Figures 13 and 14. The initial conditions are the same as shown in the table above except that the angle from collision point is now zero rather than 180°. The detection range is now only 11,000 ft. (Figure B-13). The initial elevation angle in this case is about 10° below the HSCT waterline plane because the target is much nearer than in the previous situation (Figure B-14). The numbers behind these figures are given in Exhibit B-5a. The same direction situation appears to present much less of a detection challenge than does the opposite direction scenario.

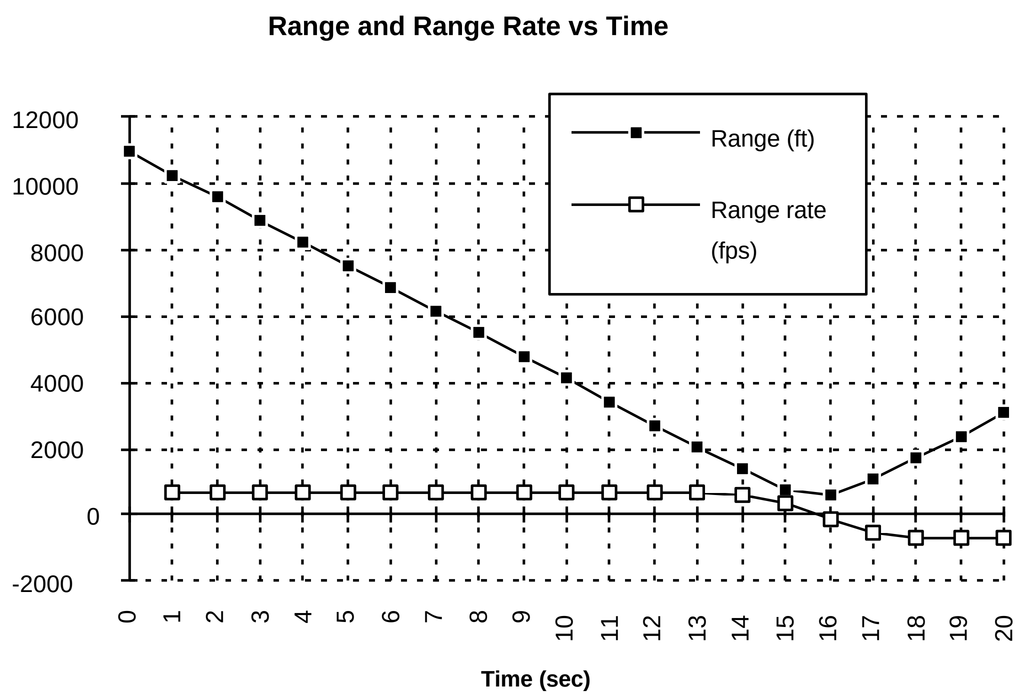

Figure B-13. Scenario 5a range and range rate vs time

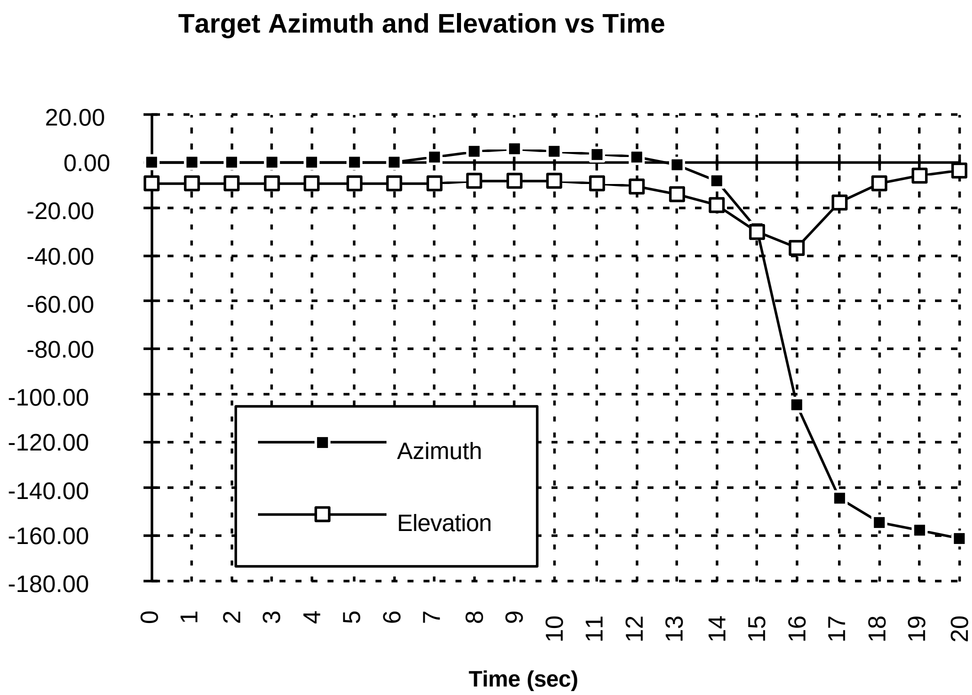

Figure B-14. Scenario 5a azimuth and elevation angles vs time

APPENDIX C

Sample ASRS Reports

Excerpts from ASRS Searches 4036 “Airborne Near Miss Reports” and 4097 “Part 121 Weather Balloon Reports” are given in this appendix. . These searches were performed in May and July of 1995. At the time of the searches the ASRS database contained nearly 60,000 records which have been received sincew January 1, 1986.

The selected reports are examples of airborne object near misses and collisions with Part 121 aircraft. The "objects" in the following examples include aircraft, weather balloon, hot air balloon, hang glider and bird encounters.

Note that the bird examples are strikes and not "near misses". Although separate interviews with Part 121 pilots indicates that they have taken "evasive" action due to visually detecting birds, these types of evasive actions do not appear in the ASRS reports. The bird evasive actions more than likely do not appear because there was not a problem. It is important to realize that pilots want to know if birds are in the vicinity. Even if there is nothing the pilot can do to avoid the strike (s), they want to be able to correlate an eventual aircraft anomaly (e.g., some type of engine problem) and subsequent action with a bird strike. That is, even if birds can not be avoided, there is still a requirement to detect their presence for subsequent troubleshooting purposes.

ACCESSION NUMBER : 189784
DATE OF OCCURRENCE : 9109
REPORTED BY : FLC; ; ; ; ;
PERSONS FUNCTIONS : FLC,PIC.CAPT; FLC,FO; FLC,SO; TWR,LC; TWR,SUPVR;
FLIGHT CONDITIONS : VMC
REFERENCE FACILITY ID : DEN
FACILITY STATE : CO
FACILITY TYPE : ARPT; TWR;
FACILITY IDENTIFIER : DEN; DEN;
AIRCRAFT TYPE : LRG; SPN;
ANOMALY DESCRIPTIONS : IN-FLT ENCOUNTER/OTHER; SPEED DEVIATION; ALT DEV/EXCURSION FROM ASSIGNED;
ANOMALY DETECTOR : COCKPIT/EQUIPMENT; COCKPIT/FLC;
ANOMALY RESOLUTION : FLC AVOIDANCE-EVASIVE ACTION;
ANOMALY CONSEQUENCES : FLC/ATC REVIEW;
SITUATION REPORT SUBJECTS : PROC OR POLICY/ATC FACILITY; PROC OR POLICY/ARPT;

NARRATIVE : LGT WAS ON A VFR APCH TO RWY 26R IN . DENVER WHEN A)WX) BALLOON APPEARED DIRECTLY IN FRONT OF THE LGT. . THE CAPT WAS FLYING AND HE TOOK EVASIVE ACTION (DOVE 300 FT) IN . ORDER TO AVOID A COLLISION WITH THE BALLOON. ALTHOUGH THE BALLOON . WAS THE CAUSE OF THE EVASIVE ACTION IT WAS NOT THE EVENT THAT WAS . OF PRIMARY CONCERN TO THE CREW AT THE TIME. THE LGT WAS TURNED . ONTO THE FINAL APCH COURSE 3 1/2 MI BEHIND AN HVT WHICH WAS MAKING . A VISUAL APCH TO RWY 26L IN DENVER. THE 2 RWYS (26L AND 26R) ARE . SEPARATED BY ABOUT 1000 FT. SINCE THE WIND AT THE ARPT WAS OUT OF . THE S (190/11 KTS) THE CAPT FELT IT BEST TO INCREASE THE SPACING . ON THE HVY ACFT AND THE LGT SLOWED TO APCH SPD. THE LGT RECEIVED A . 'TFC, TFC' WARNING ON ITS TCASII SYS. THE RADAR SCREEN SHOWED THAT . THE WARNING WAS TRIGGERED BY AN ACFT 1400 FT ABOVE THE LGT AND . DIRECTLY BEHIND IT. THE LGT CREW ASKED THE DENVER TWR IF THERE WAS . AN ACFT BEHIND IT AND WAS NOTIFIED THAT A COMMERCIAL MLG TYPE ACFT . WAS BEHIND THE LGT MAKING A VISUAL APCH TO RWY 26L. THE LAST . READING THE LGT CREW SAW OF THE ACFT FOLLOWING IT WAS 200 FT ABOVE . AND DIRECTLY BEHIND. AS THE ACFT FOLLOWING THE LGT APCHED THE . LGT'S POS, THE CAPT INCREASED THE LGT SPD IN ORDER TO AVOID BEING . OVERRUN BY THE MLG. THE TCASII GAVE AN ORAL EMER NOTIFICATION 'CLB, . CLB' AND CALLED FOR A CLB OF 3500 FPM TO AVOID A COLLISION WITH . ANOTHER ACFT. A SILVER SPHERE APPEARED IN THE WINDSCREEN OF THE . FLT (IT LOOKED LIKE A SINGLE ENG FIGHTER TYPE ACFT WITH A SINGLE . TRAILING EXHAUST) AND THE CAPT INSTINCTIVELY DOVE THE LGT 300 FT . TO AVOID A COLLISION. IN THE SPLIT SECOND AVAILABLE TO THE CAPT TO . DECIDE WHAT TO DO IN THIS SITUATION HE FEELS THAT HIS VISUAL CLUES . OVERPWRED THE TCASII WARNING. THE OBJECT TURNED OUT TO BE A LARGE . (5 FT IN DIAMETER) SILVER BALLOON (WX?) WITH A TRAILING ROPE. . SUBSEQUENT INQUIRY WITH DENVER TWR CONFIRMED THAT WX BALLOONS ARE . RELEASED FROM THE DENVER ARPT BUT THE LGT CREW WAS UNABLE TO FIND . OUT IF A BALLOON HAD BEEN RELEASED AROUND THE TIME OF THE . INCIDENT. ALSO THE CREW WAS UNABLE TO FIND OUT IF WX BALLOONS ARE . EQUIPPED WITH TRANSPONDERS. IF THEY ARE, PERHAPS THE BALLOON . TRIGGERED THE TCASII WARNING. IF THIS CREW HAD NOT ENCOUNTERED THE . BALLOON THIS RPT WOULD STILL BE A JUSTIFIABLE NASA RPT. ALLOWING . SIMULTANEOUS VISUAL APCHS TO RWYS 26 AT THE DENVER ARPT SHOULD BE . RECONSIDERED. . SYNOPSIS : ACR LGT SPD DEV AND ALT DEV EXCURSION . FROM CLRNC ALT ON VISUAL APCH TO DEN. . REFERENCE FACILITY ID : DEN .

FACILITY STATE : CO . DISTANCE & BEARING FROM REF. : 7,,E . AGL ALTITUDE : 2200,2200 . . .

ACCESSION NUMBER : 120261
DATE OF OCCURRENCE : 8907
REPORTED BY : FLC; ; ;
PERSONS FUNCTIONS : FLC,FO; FLC,PIC.CAPT; TWR,LC;
FLIGHT CONDITIONS : VMC
REFERENCE FACILITY ID : DAY
FACILITY STATE : OH
FACILITY TYPE : ARPT; TWR;
FACILITY IDENTIFIER : DAY; DAY;
AIRCRAFT TYPE : MLG; SMA;
ANOMALY DESCRIPTIONS : OTHER;
ANOMALY DETECTOR : COCKPIT/FLC;
ANOMALY RESOLUTION : NOT RESOLVED/DETECTED AFTER-THE-FACT;
ANOMALY CONSEQUENCES : FLC/ATC REVIEW;

NARRATIVE : ON JUL/TUE/89, WE WERE ON A VISUAL APCH . TO DAY AT XA30 AM. THE WX WAS VFR, BUT HAZY. WE HAD THE APCH END . OF THE RWY IN SIGHT AND AS WE TURNED FINAL THE VISIBILITY DROPPED . WITH THE SUN ON OUR NOSE. DURING THE ROLLOUT THE VISIBILITY . IMPROVED AND AT THAT TIME WE COULD SEE ABOUT 15 HOT AIR BALLOONS . OVER AND AROUND THE DEP END OF THE RWY, AT VARYING ALTS. AT NO . TIME DID THE TWR SAY ANYTHING ABOUT THE BALLOONS. I DON'T KNOW IF . THE TWR OR THE AIR SHOW CTLRS WERE IN CHARGE OF THE OPERATION, BUT . WE SHOULD HAVE BEEN WARNED. THIS ACTION SET UP AN EXTREMELY . DANGEROUS SITUATION IF WE HAD TO GO AROUND. IF WE DIDN'T CRASH . INTO THE BALLOONS, OUR WAKE MIGHT HAVE DESTROYED SOME. THE TWR . SHOULD HAVE ADVISED US ABOUT THE BALLOONS. WE WOULD PROBABLY HAVE . TAKEN THE PARALLEL RWY INSTEAD. WHEN WE QUESTIONED THE CTLR, ALL . HE SAID WAS, HE WOULD ADD IT TO THE ATIS. NOT GOOD ENOUGH. . SYNOPSIS : APPARENTLY, AIRSHOW AT DAY INCLUDED . ABOUT 5 HOT AIR BALLOONS FLYING NEAR THE DEP END OF THE RWY. ACR . REPORTER CONCERNED ABOUT POTENTIAL CONFLICT IF HIS ACFT HAD TO . MAKE A GO AROUND. . REFERENCE FACILITY ID : DAY . FACILITY STATE : OH . AGL ALTITUDE : 0,1000 . .

ACCESSION NUMBER : 87800
DATE OF OCCURRENCE : 8805
REPORTED BY : FLC; ; ;
PERSONS FUNCTIONS : FLC,PIC.CAPT; FLC,FO; TRACON,AC;
FLIGHT CONDITIONS : MVF
REFERENCE FACILITY ID : RBV
FACILITY STATE : NJ
FACILITY TYPE : TRACON;
FACILITY IDENTIFIER : N90;
AIRCRAFT TYPE : MLG;
ANOMALY DESCRIPTIONS : IN-FLT ENCOUNTER/OTHER;
ANOMALY DETECTOR : COCKPIT/FLC;
ANOMALY RESOLUTION : FLC AVOIDANCE-EVASIVE ACTION;
ANOMALY CONSEQUENCES : NONE;

NARRATIVE : ON A CLEAR HAZY DAY WITH THE SUN TO OUR . BACKS WE WERE BEING VECTORED FOR AN APCH TO 22L AT EWR. WE WERE . HDG 010 DEG AT 6000' MSL. APCH ADVISED US OF CONVERGING IFR TFC . (SMA) AT 10 O'CLOCK 5000' NEBND. AFTER SEVERAL CHECKS IN THAT . POSITION I FINALLY SPOTTED HIM MAYBE 10 SECONDS BEFORE HE PASSED . BENEATH US. I WASN'T ESPECIALLY BUSY AT THE

TIME, AND I JUST . WATCHED HIM LAZILY DRIFT BENEATH US. WHEN I LOOKED UP AGAIN I SAW . THE SMALL CROSS SECTION AND VERY BRIGHT LNDG LIGHT OF A JET . FIGHTER ACFT AT EXACTLY 12 O'CLOCK AT VERY CLOSE RANGE AT OUR ALT. . MANY THINGS HAPPENED, BOTH MENTALLY AND PHYSICALLY DURING THE NEXT . SECOND AND A HALF! I OVERRODE THE AUTOPLT AND PUSHED THE NOSE OVER . SHARPLY. AS I WAS PULLING BACK THE THRUST LEVERS AND CURSING . LOUDLY, THE FIGHTER TURNED INTO A SILVER MYLAR BALLOON WITH A BLUE . RIBBON HANGING FROM IT! I COULD SEE WHAT IT WAS WHEN IT ZIPPED . JUST OVER OUR HEADS AND THE SUNLIGHT NO LONGER REFLECTED DIRECTLY . BACK IN MY EYES (THE LNDG LIGHT). I WAS CONVINCED IT WAS A MIL . FIGHTER, COMPLETE WITH THE USUAL TRAIL OF DARK SMOKE COMING OUT . THE BACK (THE BLUE RIBBON?). THEN I REMEMBERED THE TFC DIRECTLY . BELOW US!! I PULLED THE NOSE UP JUST AS SHARPLY AS BEFORE. . FORTUNATELY EVERYONE WAS SEATED IN THE BACK, AND THERE WERE NO . INJURIES OR DAMAGE EXCEPT FOR OUR NERVES AND SOME SPILLED COFFEE. . I STILL CAN'T BELIEVE HOW REAL THE ILLUSION WAS. OUR TOTAL ALT . DEVIATION WAS NO MORE THAN 200'. . SYNOPSIS : BALLOON IDENTIFIED AS AN FGT TYPE ACFT . AND SUDDEN EVASIVE ACTION TAKEN. . REFERENCE FACILITY ID : RBV . FACILITY STATE : NJ . DISTANCE & BEARING FROM REF. : 10,,N . MSL ALTITUDE : 5750,6000 .

ACESSION NUMBER : 285088
DATE OF OCCURRENCE : 9410
REPORTED BY : FLC; ; ; ;
PERSONS FUNCTIONS : FLC,FO; FLC,PIC.CAPT; FLC,PLT; TRACON,
FLIGHT CONDITIONS : VMC
REFERENCE FACILITY ID : PBI
FACILITY STATE : FL
FACILITY TYPE : ARPT; TRACON;
FACILITY IDENTIFIER : PBI; PBI;
AIRCRAFT TYPE : MLG; ULT;
ANOMALY DESCRIPTIONS : CONFLICT/NMAC; NON ADHERENCE LEGAL RQMT/FAR;
ANOMALY DETECTOR : COCKPIT/FLC;
ANOMALY RESOLUTION : FLC AVOIDANCE-EVASIVE ACTION;
ANOMALY CONSEQUENCES : FLC/ATC REVIEW;
SITUATION REPORT SUBJECTS : AN ACFT TYPE; A PUBLICATION(S);
NARRATIVE :

ON A VECTOR FROM THE N IN A L BANK TO INTERCEPT THE ILS 9L LOC AT PBI WHILE TURNING AROUND SOME CLOUDS. IN THE TURN I NOTICED A HANG GLIDER DIRECTLY IN FRONT IN OUR FLT PATH AND MADE A CORRECTION TO THE R TO AVOID A COLLISION. THE HANG GLIDER WAS CO-ALT AT 4200 FT, ON THE CTRLINE OF THE ILS 9L APCH AT ABOUT 15 MI. WE CONTINUED THE APCH WITHOUT INCIDENT AND RPTED THE HANG GLIDER TO APCH CTL AND AFTER LNDG TO GND CTL. I CALLED GND CTL AFTER DEBOARDING OUR PAX: SOME OF WHICH HAD SEEN THE HANG GLIDER ALSO, AND FILED A RPT WITH HIM. DURING THE CONVERSATION IT WAS OBVIOUS THAT IT WAS A 'REGULAR' OCCURRENCE AT THAT LOCATION AND THAT THERE WASN'T MUCH THAT COULD BE DONE. I DON'T THINK WE SHOULD WAIT UNTIL SOMETHING BAD HAPPENS BEFORE ACTION CAN BE TAKEN AND I BELIEVE THAT HERE IS A PERFECT EXAMPLE OF SOMETHING WE CAN PREVENT FROM HAPPENING. I'M CERTAIN NEXT WKEND OTHER HANG GLIDERS WILL BE EXACTLY AT THE SAME LOCATION AND OTHER AIRLINERS WILL BE THERE TOO. THIS SIT IS WELL KNOWN BY THE LCL CTLRS, BUT NO NOTAM OR ADVISORY WAS ISSUED ABOUT THIS. THIS NEEDS TO BE CHANGED. I'M FLYING THIS EXACT ROTATION THE REST OF THE MONTH AND I'LL BE

LOOKING FOR SOME NOTAMS OR ADVISORIES CONCERNING THIS.
SYNOPSIS : NMAC BTWN AN ACR MLG AND A HANG GLIDER IN PROX OF ARSA CLASS C AIRSPACE.
REFERENCE FACILITY ID : PBI
FACILITY STATE : FL
DISTANCE & BEARING FROM REF. : 15,270
MSL ALTITUDE : 4200,4200

ACCESSION NUMBER : 184335
DATE OF OCCURRENCE : 9107
REPORTED BY : FLC; FLC; ; ;
PERSONS FUNCTIONS : FLC,FO; FLC,PIC.CAPT; MISC,ACI.OBS; TWR, LC;
FLIGHT CONDITIONS : VMC
REFERENCE FACILITY ID : ORD
FACILITY STATE : IL
FACILITY TYPE : ARPT; TWR;
FACILITY IDENTIFIER : ORD; ORD;
AIRCRAFT TYPE : LRG;
ANOMALY DESCRIPTIONS : ACFT EQUIPMENT PROBLEM/CRITICAL; IN-FLT ENCOUNTER/OTHER;
ANOMALY DETECTOR : COCKPIT/FLC;
ANOMALY RESOLUTION : NOT RESOLVED/UNABLE;
ANOMALY CONSEQUENCES : ACFT DAMAGED;

NARRATIVE : I WAS THE FO FLYING A STANDARD TKOF FOR . A FLT FROM ORD TO DTW. JUST AS WE REACHED VR BOTH THE CAPT AND . MYSELF SAW A FLOCK OF SNOW GEESE FLY ACROSS THE RWY FROM L TO R. . AS THE MAINS OF OUR LGT BROKE GND WE FELT NUMEROUS IMPACTS AND SAW . AND FELT THE L ENG START TO SHUDDER AND VIBRATE AND LOSE THRUST. . WE CLBED TO OUR CLEAN UP ALT AND CLEANED UP THE ACFT. WE THEN . STARTED A CLB TO 3000 FT MSL AND TOOK VECTORS TO A VISUAL APCH TO . RWY 27R AT ORD. I CONTINUED TO FLY WHILE THE CAPT HANDLED THE EMER . PROCS FOR SHUTTING DOWN THE #1 ENG. WE FLEW A 8-10 NM VISUAL TO . RWY 27R WITH THE CAPT PERFORMING A SINGLE ENG LNDG. CRASH CREWS . VERIFIED NO FIRE SO WE TAXIED TO THE GATE. TOTAL AIRBORNE TIME WAS . 14 MIN. WE LATER LEARNED THAT WE WERE THE SECOND ACFT TO HIT BIRDS . THAT DAY (THE FIRST WAS NOT CRITICAL). THERE WAS NO MENTION OF ANY . BIRD THREAT ON ATIS. (THAT WE CAN REMEMBER). VISUAL INSPECTION . SHOWED SEVERAL BIRDS HITTING THE #1 ENG, THE LEADING EDGE OF THE L . WING, AND ONE STRIKE ON THE LEADING EDGE OF THE R WING INBOARD OF . THE #2 ENG. THE MOST POSITIVE ASPECT OF THIS EXPERIENCE WAS THE . EXCELLENT WAY WE AS A CREW WERE ABLE TO HANDLE THIS PROBLEM EVEN . THOUGH WE HAD NEVER FLOWN TOGETHER BEFORE THAT DAY. IT REFLECTS . VERY HIGHLY OF OUR AIRLINES TRAINING AND STANDARDS PROCS. WE HAD . AN FAA AIR CARRIER INSPECTOR ON THE JUMPSEAT OBSERVING THE WHOLE . THING. SUPPLEMENTAL INFO FROM ACN 184338. TRAINING AND . STANDARDIZATION PAID OFF IN THIS INCIDENT. . SYNOPSIS : BIRD STRIKE ON TKOF CAUSES INFLT ENG . SHUTDOWN. . REFERENCE FACILITY ID : ORD . FACILITY STATE : IL . AGL ALTITUDE : 5,5 . . .

ACCESSION NUMBER : 225535
DATE OF OCCURRENCE : 9210
REPORTED BY : FLC; ; ;
PERSONS FUNCTIONS : FLC,PIC.CAPT; FLC,FO; TWR,LC;
FLIGHT CONDITIONS : VMC
REFERENCE FACILITY ID : EVV
FACILITY STATE : IN
FACILITY TYPE : ARPT; TWR;

FACILITY IDENTIFIER : EVV; EVV;
AIRCRAFT TYPE : MLG;
ANOMALY DESCRIPTIONS : ACFT EQUIPMENT PROBLEM/CRITICAL; OTHER;
ANOMALY DETECTOR : COCKPIT/FLC;
ANOMALY RESOLUTION : NOT RESOLVED/ANOMALY ACCEPTED;
ANOMALY CONSEQUENCES : ACFT DAMAGED;

NARRATIVE : ACFT SUSTAINED MULTIPLE BIRD STRIKES ON . TKOF ROLL ON RWY 22 AT EVV. SPD AT TIME OF IMPACT WAS APPROX . 120-125 KIAS, AND REDUCED V1 WAS 123. THE BIRDS WERE PART OF A . FLOCK OF 20-30 SMALL BIRDS FLYING FROM R TO L, AND THEY APPEARED . TO STRIKE MOSTLY ON THE R SIDE OF THE ACFT. THERE WERE SEVERAL . RAPID IMPACT SOUNDS, AND A MOMENTARY SLIGHT HESITATION IN THE . ACCELERATION OF THE ACFT. BOTH SETS OF ENG INSTS APPEARED NORMAL . THROUGHOUT THE FLT. A STRONG 'BURNING BIRD' SMELL BEGAN . IMMEDIATELY, AND LASTED 5-10 MINS. ON CLBOUT, WE ADVISED EVV TWR . OF THE BIRD STRIKES. I SERIOUSLY CONSIDERED RETURNING TO LAND AT . EVV TO CHK FOR POSSIBLE DAMAGE, BUT ELECTED TO CONTINUE TO IND . ONLY BECAUSE THERE WAS NO INDICATION FO ANY ENG PROBLEM WHATSOEVER . ON THE GAUGES. FLT TO IND WAS UNEVENTFUL, AND WHILE ENRTE ARTCC . RELAYED A MESSAGE TO US FROM EVV APCH CTL THAT APPROX 2 DOZEN . BIRDS/BIRD PARTS HAD BEEN FOUND ON THE RWY. UPON ARR AT IND, WE . INSPECTED THE ACFT AND FOUND 3 OR 4 BIRD STRIKE MARKS IN THE #2 . ENG, 2 OR 3 MARKS IN THE #1 ENG, AND SEVERAL OTHER MARKS ON THE . FUSELAGE AND WINGS. THERE WAS NO VISIBLE DAMAGE TO THE #2 ENG, BUT . THE #1 ENG HAD 3 DAMAGED BLADES, INCLUDING 1 MISSING PIECE (1/2 . INCH X 1 INCH LONG) AT THE OUTER EDGE OF A BLADE, AND A SMALL NICK . IN ANOTHER BLADE. IT WAS DETERMINED THAT THE #1 ENG WOULD HAVE TO . BE CHANGED, AFTER COMPLETING THE INTERNAL INSPECTION. I HAVE SAVED . A SAMPLE OF THE BIRD FEATHERS WHICH I CAN SEND TO ANY INTERESTED . AGENCY. COMMENTS: THE ONLY THING I CAN THINK OF TO HAVE AVOIDED . THIS PROBLEM WOULD BE IF AN ARPT VEHICLE HAD PRECEDED US DOWN THE . RWY TO ATTEMPT TO FLUSH OUT THE FLOCK OF BIRDS, BUT I REALIZE THAT . IT'S PROBABLY SOMETHING THAT WILL CONTINUE TO BE A PROBLEM TO THE . AVIATION INDUSTRY. . SYNOPSIS : ACR HAS MULTIPLE BIRD STRIKES ON TKOF . ROLL. . REFERENCE FACILITY ID : EVV . FACILITY STATE : IN . DISTANCE & BEARING FROM REF. : 0 . AGL ALTITUDE : 0,0 . .

ACCESSION NUMBER : 248324
DATE OF OCCURRENCE : 9308
REPORTED BY : FLC; ; ;
PERSONS FUNCTIONS : FLC,PIC.CAPT; FLC,FO; TWR,LC;
FLIGHT CONDITIONS : VMC
REFERENCE FACILITY ID : MDT
FACILITY STATE : PA
FACILITY TYPE : TWR; ARPT;
FACILITY IDENTIFIER : MDT; MDT;
AIRCRAFT TYPE : MLG;
ANOMALY DESCRIPTIONS : CONFLICT/GROUND CRITICAL; OTHER;
ANOMALY DETECTOR : COCKPIT/FLC;
ANOMALY RESOLUTION : NOT RESOLVED/DETECTED AFTER-THE-FACT;
ANOMALY CONSEQUENCES : OTHER;

NARRATIVE : APPROX 1000 FT AFTER TOUCHDOWN ACFT STRUCK APPROX 200 BIRDS THAT WERE FLOCKING ON THE RWY. ATC INFO ADVISED OF POSSIBLE BIRD ACTIVITY IN THE ARPT AREA, HOWEVER, IF I HAD KNOWN THAT THE BIRD ACTIVITY AMOUNTED TO THOUSANDS OF BIRDS IN AND AROUND THE RWY, I WOULD HAVE NEVER LANDED WHEN I DID. AIRLINE

MAINT INSPECTED ACFT AIR FRAME AND ENGS AND FOUND NO DAMAGE.
SYNOPSIS : MASSIVE BIRD STRIKE TO AN MLG ACR ACFT AFTER TOUCHDOWN.
REFERENCE FACILITY ID : MDT
FACILITY STATE : PA
AGL ALTITUDE : 0,0

ACCESSION NUMBER : 260573
DATE OF OCCURRENCE : 9401
REPORTED BY : FLC; ; ;
PERSONS FUNCTIONS : FLC,PIC.CAPT; FLC,FO; TWR,LC;
FLIGHT CONDITIONS : VMC
REFERENCE FACILITY ID : DCA
FACILITY STATE : DC
FACILITY TYPE : ARPT; TWR;
FACILITY IDENTIFIER : DCA; DCA;
AIRCRAFT TYPE : MLG;
ANOMALY DESCRIPTIONS : ACFT EQUIPMENT PROBLEM/CRITICAL; IN-FLT ENCOUNTER/OTHER; OTHER;
ANOMALY DETECTOR : COCKPIT/FLC;
ANOMALY RESOLUTION : NOT RESOLVED/UNABLE;
ANOMALY CONSEQUENCES : OTHER;
NARRATIVE : AT THE BEGINNING OF OUR LNDG FLARE AT DCA, A FLOCK OF SEAGULLS PASSED UNDERNEATH THE ACFT. ONE BIRD WAS INGESTED THROUGH THE FAN SECTION OF THE R ENG. LNDG ROLLOUT WAS NORMAL.
SYNOPSIS : FOREIGN OBJECT DAMAGE BIRD STRIKE DURING LNDG PROC FLARE.
REFERENCE FACILITY ID : DCA
FACILITY STATE : DC
AGL ALTITUDE : 50,50

ACCESSION NUMBER : 278635
DATE OF OCCURRENCE : 9407
REPORTED BY : FLC; ;
PERSONS FUNCTIONS : FLC,FO; FLC,PIC.CAPT;
FLIGHT CONDITIONS : VMC
REFERENCE FACILITY ID : CHS
FACILITY STATE : SC
FACILITY TYPE : ARPT;
FACILITY IDENTIFIER : CHS;
AIRCRAFT TYPE : LRG;
ANOMALY DESCRIPTIONS : OTHER; ACFT EQUIPMENT PROBLEM/LESS SEVERE;
ANOMALY DETECTOR : COCKPIT/FLC;
ANOMALY RESOLUTION : NOT RESOLVED/DETECTED AFTER-THE-FACT;
ANOMALY CONSEQUENCES : ACFT DAMAGED;

NARRATIVE :

ON TKOF ROLL A FLOCK OF BIRDS CROSSED . OUR PATH AND APPEARED TO CLR ACFT. LATER IN THE TKOF ROLL 2 BIRDS . CROSSED CLOSER TO OUR PATH. ON CLBOUT ALL ENG INDICATIONS WERE . NORMAL. AFTER LNDG ATL A WALK AROUND REVEALED DAMAGE TO THE FAN . BLADES OF BOTH ENGS..SYNOPSIS : BIRD STRIKE DURING TKOF..REFERENCE FACILITY ID : CHS.FACILITY STATE : SC.DISTANCE & BEARING FROM REF. : 0.AGL ALTITUDE : 0,0..

ACCESSION NUMBER : 282223
DATE OF OCCURRENCE : 9409
REPORTED BY : FLC; ; ; ;
PERSONS FUNCTIONS : FLC,PIC.CAPT; FLC,FO; TWR,LC; MISC,OTH;

FLIGHT CONDITIONS : VMC
REFERENCE FACILITY ID : ISP
FACILITY STATE : NY
FACILITY TYPE : ARPT; TWR;
FACILITY IDENTIFIER : ISP; ISP;
AIRCRAFT TYPE : MLG;
ANOMALY DESCRIPTIONS : OTHER;
ANOMALY DETECTOR : COCKPIT/FLC;
ANOMALY RESOLUTION : NOT RESOLVED/INSUFFICIENT TIME;
ANOMALY CONSEQUENCES : ACFT DAMAGED;
SITUATION REPORT SUBJECTS : OTHER; PHYSICAL FACILITY/ARPT;
NARRATIVE :

DEP RWY 24 AT ISP. AT APPROX V1 FLOCK OF BIRDS CAME FROM L ACROSS ACFT. SEVERAL HITS, 1 ON ENG NACELLE L SIDE, #2 SLAT AND INBOARD WING ROOT AREA. PROBABLY 1 THROUGH L ENG. RETURNED TO LAND ISP. BIRDS ARE A PROB IN ISP AREA. WE FLEW THE NEXT DAY, SAME FLT NUMBER, SAME WX. NOT 1 BIRD SEEN AROUND RWY.
SYNOPSIS : ACR MLG SUFFERS MULTIPLE BIRD STRIKES ON TKOF. RETURN LAND MANDATED.
REFERENCE FACILITY ID : ISP
FACILITY STATE : NY
AGL ALTITUDE : 0,0

ACCESSION NUMBER : 286161
DATE OF OCCURRENCE : 9410
REPORTED BY : FLC; ; ; ; ;
PERSONS FUNCTIONS : FLC,PIC.CAPT; FLC,FO; FLC,PLT; TWR,LC; TRACON,DC;
FLIGHT CONDITIONS : VMC
REFERENCE FACILITY ID : AZO
FACILITY STATE : MI
FACILITY TYPE : TWR; TRACON; ARPT;
FACILITY IDENTIFIER : AZO; AZO; AZO;
AIRCRAFT TYPE : MLG; SMA;
ANOMALY DESCRIPTIONS : CONFLICT/NMAC; ERRONEOUS PENETRATION OR EXIT AIRSPACE; NON ADHERENCE LEGAL RQMT/FAR;
ANOMALY DETECTOR : COCKPIT/FLC;
ANOMALY RESOLUTION : NOT RESOLVED/ANOMALY ACCEPTED;
ANOMALY CONSEQUENCES : FLC/ATC REVIEW;
NARRATIVE :

WE WERE CLRED FOR TKOF ON RWY 17 WITH A L TURN AFTER AIRBORNE. WE STARTED OUR 15 DEG BANK L TURN AT 500 FT AGL, WE THEN SPOTTED THE CESSNA 182 OR 172 IN THE R WIND SCREEN. NO TCASII WARNING! NO TFC CALL-OUT BY ATC, WHEN QUERIED ATC RESPONDED WITH 'NO TFC ON THEIR SCREEN.' NO EVASIVE ACTION TAKEN BECAUSE WE WERE PAST THE ACFT AND LUCKILY OUR TURN WAS ENOUGH TO MISS THE ACFT.
SYNOPSIS : DURING INITIAL CLB, MLG HAD NMAC WITH A SMA SEL.
REFERENCE FACILITY ID : AZO
FACILITY STATE : MI
DISTANCE & BEARING FROM REF. : 0
AGL ALTITUDE : 500,500

ACCESSION NUMBER : 286381
DATE OF OCCURRENCE : 9410
REPORTED BY : FLC; FLC; ; ;
PERSONS FUNCTIONS : FLC,FO; FLC,PIC.CAPT; TRACON,AC; FLC, PLT;
FLIGHT CONDITIONS : VMC
REFERENCE FACILITY ID : TUS
FACILITY STATE : AZ
FACILITY TYPE : TRACON;
FACILITY IDENTIFIER : TUS;
AIRCRAFT TYPE : MLG; SMA;
ANOMALY DESCRIPTIONS : CONFLICT/NMAC; OTHER;
ANOMALY DETECTOR : COCKPIT/FLC; COCKPIT/EQUIPMENT;
ANOMALY RESOLUTION : FLC AVOIDANCE-EVASIVE ACTION; CTLR INTERVENED;
ANOMALY CONSEQUENCES : NONE;
NARRATIVE : WHILE BEING VECTORED FOR A VISUAL APCH, WE WERE TOLD BY APCH CTL OF TFC THAT WOULD BE XING BEHIND US AND HAD US IN SIGHT. WE DID NOT HAVE THE TFC VISUALLY OR ON TCASII AT THAT TIME. AS I WAS DSNDING AND TURNING TOWARDS FINAL ONCE CLRED FOR THE VISUAL WE RECEIVED A RA AND A 'CLB' COMMAND. I STOPPED THE DSCNT AND BEGAN A CLB AS I CONTINUED WITH THE TURN. ON OUR TCASII DISPLAY THE RA WAS AT AN ALT OF 4800 FT MSL AND WE WERE CLBING THROUGH 5000 FT. APCH QUERIED THE SINGLE ENG CESSNA IF THEY STILL HAD VISUAL CONTACT WITH THE B-737. AFTER A SEVERAL SECOND DELAY, (WHICH INDICATED TO US THEY HAD LOST SIGHT OF US), THEY THEN SAID THEY SAW US AT THE SAME TIME WE CROSSED DIRECTLY OVER THEM AT A CONVERGING HDGS. WE DID NOT SEE THE SINGLE ENG CESSNA UNTIL THIS TIME. APCH CTL ASKED US IF WE HAD RECEIVED AN RA AND WE SAID WE DID BUT THEY DID NOT INDICATE WHETHER A NEAR MID-AIR WOULD BE FILED ON THE CESSNA. SUPPLEMENTAL INFO FROM ACN 286382: I MADE VISUAL CONTACT WITH THE CESSNA JUST IN TIME TO SEE HIM PASS DIRECTLY UNDERNEATH US. OUR TCASII INDICATED HIS ALT TO BE 200 FT BENEATH US. HE CLRLY DID NOT HAVE US IN SIGHT OR HAD LOST VISUAL CONTACT WITH US.
SYNOPSIS : TCASII RA.
REFERENCE FACILITY ID : TUS
FACILITY STATE : AZ
DISTANCE & BEARING FROM REF. : 10,,NE
MSL ALTITUDE : 4800,5000

ACCESSION NUMBER : 287202
DATE OF OCCURRENCE : 9410
REPORTED BY : CTLR; ; ; ;
PERSONS FUNCTIONS : TWR,LC; FLC,PLT; FLC,PIC.CAPT; FLC,FO;
FLIGHT CONDITIONS : VMC
REFERENCE FACILITY ID : BKL
FACILITY STATE : OH
FACILITY TYPE : TWR;
FACILITY IDENTIFIER : BKL;
AIRCRAFT TYPE : SMA; MLG;
ANOMALY DESCRIPTIONS : CONFLICT/NMAC; NON ADHERENCE LEGAL RQMT/PUBLISHED PROC;
ANOMALY DETECTOR : COCKPIT/FLC;

ANOMALY RESOLUTION : NOT RESOLVED/DETECTED AFTER-THE-FACT;
ANOMALY CONSEQUENCES : NONE;
NARRATIVE :

I WAS WORKING THE LCL CTL POS IN A VFR . TWR. SMA X HAD DEPARTED VFR EBOUND OFF OF RWY 24L. X WAS TOLD TO . MAKE A R TURN EBOUND. ANOTHER CESSNA, Y CALLED ON FREQ 10 MI E . INBOUND ABOUT 3 MIN LATER, TFC WAS ISSUED BTWN X AND Y. WE WERE . EXPECTING A C130 IN THAT MORNING AND CITY OPS HAD CALLED ASKING IF . WE KNEW WHERE HE WAS. I CALLED THE APCH CTL AND ASKED THEM IF THEY . HAD ANYTHING LIKE THAT INBOUND. APCH SAID THEY WERE JUST ABOUT TO . CALL ME WITH THAT INBOUND, AND THAT HE IS 5 MI SE. X THEN RPTED AT . 2500 FT REQUESTING A FREQ CHANGE, WHICH WAS APPROVED. THE C130 . THEN CALLED ON FREQ AND WAS TOLD TO RPT A 2 MI L BASE FOR RWY 24R. . I THEN ISSUED TFC TO Y INBOUND FROM THE E WHO APPEARED TO BE ON A . DOGLEG TO BASE ENTRY FOR RWY 24L. Y SAID HE HAD THE C130 IN SIGHT. . APCH THEN CALLS OVER AND SAYS THAT THE C130 HAS TFC AHEAD AT 2500 . FT. I THEN CLRED THE C130 TO LAND ON RWY 24R. DURING HIS . ACKNOWLEDGEMENT, HE RPTED THAT A CESSNA HAD JUST PASSED HIM L TO R . ABOUT 100 FT ABOVE. THE C130 WAS 2 MI S OF THE ARPT ON A L BASE . DSNDING RAPIDLY OUT OF 3500 FT WHEN THIS OCCURRED. THE ACFT WAS . LATER IDENTED AS X BY THE C130 PLT. SEVERAL ASSUMPTIONS LED TO . THIS OCCURRENCE. 1) THE INCIDENT OCCURRED 7 MIN AFTER X DEPARTED . THE ARPT. EXPERIENCE, AS WELL AS TIMING SEVERAL OTHER ACFT, . INDICATE THAT DEPARTING RWY 24L WITH A R TURN NE, E, OR SE . REQUIRES 5 MIN TO CLR CLASS D AIRSPACE AND BE AT LEAST 5 MI AWAY, . SINCE 6-7 MIN HAD ELAPSED WHEN X REQUESTED A FREQ CHANGE, I . BELIEVED HIM TO BE CLR OF THE AIRSPACE. 2) BOTH THE C130 AND THE . INBOUND CESSNA Y WERE IN SIGHT, AS THE C130 ENTERED L BASE. THE . CESSNA WAS IN CLOSE PROX ON DOG LEG TO BASE BEHIND THE C130. WHEN . TFC WAS PASSED FROM APCH, I BELIEVED IT TO BE IN REF TO THE . INBOUND CESSNA IN CLOSE PROX TO THE C130, WHOM I HAD IN SIGHT AND . WHO HAD PREVIOUSLY RPTED HAVING THE C130 IN SIGHT. 3) ANTICIPATING,. BELIEVING , AND ASSUMING ARE ALMOST THE SAME THING..SYNOPSIS : MIL C130 HAD NMAC WITH SMA X IN CLASS D AIRSPACE. SEE AND AVOID CONCEPT.
REFERENCE FACILITY ID : BKL
FACILITY STATE : OH
DISTANCE & BEARING FROM REF. : 2
MSL ALTITUDE : 3500,3500

ACCESSION NUMBER : 287339
DATE OF OCCURRENCE : 9411
REPORTED BY : FLC; ; ; ; ;
PERSONS FUNCTIONS : FLC,PIC.CAPT; FLC,FO; FLC,PLT; TWR,LC; TRACON,DC;
REFERENCE FACILITY ID : DEN
FACILITY STATE : CA
FACILITY TYPE : TWR; ARPT; TRACON;
FACILITY IDENTIFIER : DEN; DEN; DEN;
AIRCRAFT TYPE : MLG; SMA;
ANOMALY DESCRIPTIONS : CONFLICT/NMAC;
ANOMALY DETECTOR : COCKPIT/FLC; COCKPIT/EQUIPMENT;
ANOMALY RESOLUTION : NOT RESOLVED/INSUFFICIENT TIME;
ANOMALY CONSEQUENCES : OTHER; FLC/ATC REVIEW;
NARRATIVE :

FLT ON APCH TO DEN RWY 8R. WE WERE ON 5 . MI FINAL 2 DOTS HIGH ON GS HAVING JUST BEEN CLRED TO FOLLOW 2 JETS . TO THE RWY FOR A VISUAL APCH AND TOLD TO

SWITCH TO TWR FREQ. .   IMMEDIATELY AFTER CHK IN WITH TWR A WHITE CESSNA 172 OR 182 .   TRIGGERED OUR TCASII WARNING AT 300-500 FT BELOW US. THE CESSNA . THEN APPEARED COMING OUT FROM BELOW OUR ACFT ON THE R SIDE. WE .   WERE ON HDG 080 DEGS AND THE CESSNA WAS HEADING 180 DEGS. TWR TOLD .   US AFTER WE RPTED THE NEAR MID-AIR THAT THE CESSNA WAS UNDER APCH .   CTL DIRECTION AND JURISDICTION. I TALKED TO APCH CTL BY PHONE AND .   THEY FILED A PRELIMINARY NEAR MID-AIR RPT..SYNOPSIS : MLG HAS NMAC ON APCH AFTER BEING CLRED FOR THE APCH.

REFERENCE FACILITY ID : DEN
FACILITY STATE : CA
DISTANCE & BEARING FROM REF. : 5,,W

ACCESSION NUMBER : 290366
DATE OF OCCURRENCE : 9411
REPORTED BY : FLC; ; ; ; ;
PERSONS FUNCTIONS : FLC,PIC.CAPT; FLC,FO; FLC,SO; TWR,LC; FLC,PLT;
FLIGHT CONDITIONS : VMC
REFERENCE FACILITY ID : DCA
FACILITY STATE : DC
FACILITY TYPE : ARPT; TWR;
FACILITY IDENTIFIER : DCA; DCA;
AIRCRAFT TYPE : LRG; SMA;
ANOMALY DESCRIPTIONS : CONFLICT/NMAC; LESS THAN LEGAL SEPARATION; TRACK OR HDG DEVIATION; NON ADHERENCE LEGAL RQMT/CLNC;
ANOMALY DETECTOR : COCKPIT/FLC; COCKPIT/EQUIPMENT;
ANOMALY RESOLUTION : FLC AVOIDANCE-EVASIVE ACTION; FLC RETURNED ACFT TO ORIGINAL CLNC OR INTENDED COURSE;
ANOMALY CONSEQUENCES : NONE;
NARRATIVE :

SHORTLY AFTER TKOF FROM DCA, AS WE WERE .   CLBING THROUGH APPROX 1200 FT AGL/MSL ON THE 185 DEG RADIAL, WE .   GOT A TCASII ALERT. THE 'MONITOR VERT SPD,' AURAL SOUNDED TWICE. I .   IMMEDIATELY CHKED THE VSI AND OBSERVED A RED ARC COMPLETELY AROUND .   THE INST, FROM 6000 FPM UP TO 6000 FPM DOWN. SEEING NO GREEN FLY .   TO AREA ON THE INST, I SHIFTED MY SCAN COMPLETELY OUTSIDE AND . PICKED UP A LIGHT TWIN ENG ACFT (I BELIEVE A CESSNA), ABOVE AND .   SLIGHTLY TO OUR L. I STARTED A DSNDING R TURN, ARRESTING OUR .   CLOSURE RATE. ONCE OUR CLOSURE RATE WAS ARRESTED, WE CALLED TWR .   WHO WAS CALLING THE OTHER ACFT, AND AS SEPARATION WAS GAINED WE .   CONTINUED OUR CLB. AT CLOSEST PROX WE PASSED ABOUT 50 FT FROM THE .   TWIN, WE WERE AT LOW SPD, FLAPS 15 DEGS, LESS THAN 150 KTS, .   WAITING TO REACH CLEAN UP ALT. THE TWIN APPEARED CLEAN IN A R TURN .   CLOSING FROM L TO R. IN RETROSPECT, THE FOLLOWING CONTRIBUTING .   FACTORS PROBABLY LED TO THIS CONFLICT: NO GND BASED TA WAS GIVEN .   TO US REGARDING THE OTHER ACFT. ONCE THE 'MONITOR VERT SPD' .   WARNING WAS GIVEN, THERE WAS NO FLY TO AREA INDICATED, JUST A .   SOLID RED BAND. THE VISIBILITY IN THE B-727 IS LIMITED BY A BEAM .   BTWN THE EYEBROW WINDOW AND THE SIDE WINDOW. THE SUN WAS .   BLINDINGLY BRIGHT IN THE UPPER FORWARD PORTION OF THE SIDE WINDOW. .   THE PRIME CONTRIBUTING FACTOR, HOWEVER, WAS THE NON COMPLIANCE .   WITH CLRNC BY THE OTHER ACFT..SYNOPSIS : A NMAC OCCURS ABOUT 1200 FT AGL AFTER TKOF ON THE INITIAL NOISE ABATEMENT DEP.

REFERENCE FACILITY ID : DCA
FACILITY STATE : DC
DISTANCE & BEARING FROM REF. : 5,185
AGL ALTITUDE : 1200,1200

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