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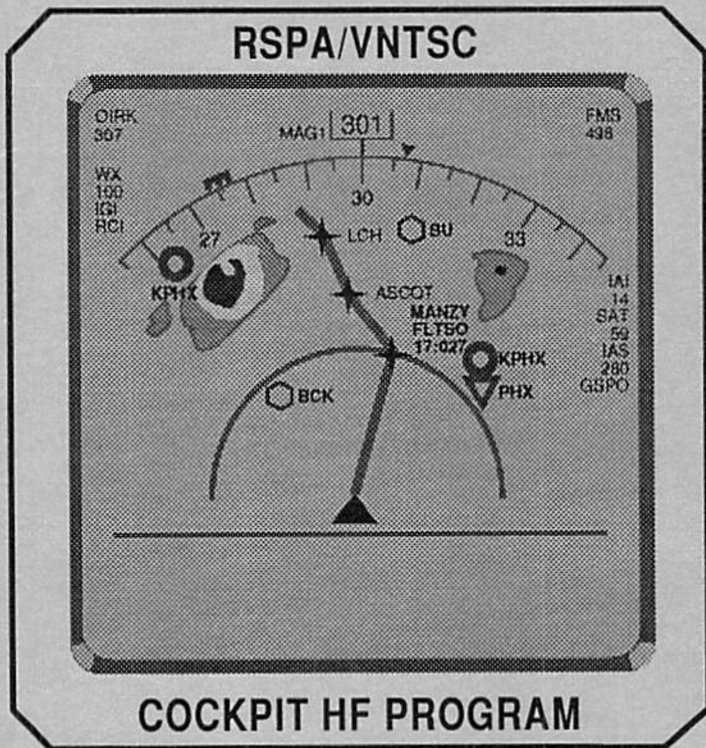
A Review and Discussion of Flight Management System Incidents Reported to the Aviation Safety Reporting System



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Final Report
February 1992

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16. Abstract

This report covers the activities related to the description, classification and analysis of the types and kinds of flight crew errors, incidents and actions, as reported to the Aviation Safety Reporting System (ASRS) database, that can occur as a result of the use of Flight Management Systems (FMSs) to fly within the national Airspace System (NAS).

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PREFACE

This report covers the activities related to the description, classification and analysis of the types and kinds of flight crew errors, incidents and actions, as reported to the Aviation Safety Reporting System (ASRS) database. These actions can occur as a result of the use of Flight Management Systems (FMS) to fly within the National Airspace System (NAS).

The material presented in this report is based on 63 reports selected from the 1989 ASRS database and 36 reports selected from the 1988 ASRS database. An additional 30 reports from the 1988 database have been selected, however, they have not been completely analyzed as of this report. It is intended that they will be added as an addendum to this report. In addition, a selected number of 1990 and 1991 ASRS reports may also be included in the addendum.

This report was completed under the direction of Volpe National Transportation Systems Center (VNTSC) Program Manager M. Stephen Huntley, Jr. Research for the report and its preparation were conducted by Robert S. Dodd, Donald Eldredge and Susan Mangold, of Battelle, Columbus, Ohio.

METRIC/ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in.) = 2.5 centimeters (cm)
1 foot (ft) = 30 centimeters (cm)
1 yard (yd) = 0.9 meter (m)
1 mile (mi) = 1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in²) = 6.5 square centimeters (cm²)
1 square foot (sq ft, ft²) = 0.09 square meter (m²)
1 square yard (sq yd, yd²) = 0.8 square meter (m²)
1 square mile (sq mi, mi²) = 2.6 square kilometers (km²)
1 acre = 0.4 hectares (he) = 4,000 square meters (m²)

MASS - WEIGHT (APPROXIMATE)

1 ounce (oz) = 28 grams (gr)
1 pound (lb) = .45 kilogram (kg)
1 short ton = 2,000 pounds (lb) = 0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp) = 5 milliliters (ml)
1 tablespoon (tbsp) = 15 milliliters (ml)
1 fluid ounce (fl oz) = 30 milliliters (ml)
1 cup (c) = 0.24 liter (l)
1 pint (pt) = 0.47 liter (l)
1 quart (qt) = 0.96 liter (l)
1 gallon (gal) = 3.8 liters (l)
1 cubic foot (cu ft, ft³) = 0.03 cubic meter (m³)
1 cubic yard (cu yd, yd³) = 0.76 cubic meter (m³)

TEMPERATURE (EXACT)

[(x - 32) (5/9)] °F = y°C

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm) = 0.04 inch (in)
1 centimeter (cm) = 0.4 inch (in)
1 meter (m) = 3.3 feet (ft)
1 meter (m) = 1.1 yards (yd)
1 kilometer (km) = 0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm²) = 0.16 square inch (sq in, in²)
1 square meter (m²) = 1.2 square yards (sq yd, yd²)
1 square kilometer (kn²) = 0.4 square mile (sq mi, mi²)
1 hectare (he) = 10,000 square meters (m²) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gr) = 0.036 ounce (oz)
1 kilogram (kg) = 2.2 pounds (lb)
1 tonne (t) = 1,000 kilograms (kg) = 1.1 short tons

VOLUME (APPROXIMATE)

1 milliliter (ml) = 0.03 fluid ounce (fl oz)
1 liter (l) = 2.1 pints (pt)
1 liter (l) = 1.06 quarts (qt)
1 liter (l) = 0.26 gallon (gal)
1 cubic meter (m³) = 36 cubic feet (cu ft, ft³)
1 cubic meter (m³) = 1.3 cubic yards (cu yd, yd³)

TEMPERATURE (EXACT)

[(9/5) y + 32] °C = x °F

QUICK INCH-CENTIMETER LENGTH CONVERSION

INCHES	0			1			2			3		4			5		6			7		8		9	10
CENTIMETERS	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24 25

25.40

QUICK FAHRENHEIT-CELSIUS TEMPERATURE CONVERSION

°F	-40°	-22°	-4°	14°	32°	50°	68°	86°	104°	122°	140°	158°	176°	194°	212°
°C	-40°	-30°	-20°	-10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°

For more exact and or other conversion factors, see NBS Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50. SD Catalog No. C13 10286.

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EXECUTIVE SUMMARY

This report covers the activities related to the description, classification and analysis of the types and kinds of flight crew errors, incidents and actions, as reported to the Aviation Safety Reporting System (ASRS) database. These actions can occur as a result of the use of Flight Management Systems (FMSs) to fly within the National Airspace System (NAS).

The Analysis of the ASRS FMS-related database reports was conducted for the purpose of determining the types and kinds of design-induced problems that flight crews are having with FMSs that can result in the occurrence of errors, incidents and other operational problems. It was believed that review of these reports would provide a useful background and understanding of the FMS *use domain* (i.e., the flight environment) and offer a window into the cockpit setting. This would enable the identification of categories of difficulties that flight crews appear to have with the FMS and its subsystems. Those elements of the FMS operational logic that are identified as potentially problematic will then be investigated in more detail in the Description and Characterization Study that is also ongoing. The Description and Characterization Study is intended to provide a conceptual framework and methodology for the analysis of the human-computer interface and operational logic embodied in current FMSs. The product of that study will be a series of reports describing the results of comparisons between current FMSs with respect to procedures for performing common tasks, screen and keyboard layout and information presentation, and the logic used to integrate individual FMS subsystems into a coherent system. These comparisons will serve as an important basis for attempting to assess relationships between the design of FMS procedures and logic, and ease of use from the crew's perspective. Together, these two documents will result in a clearer understanding of the design-related FMS contributors to pilot error.

The review and analysis of the ASRS database reports indicates that there does exist a significant number of operational and design-induced problems with these systems that have resulted in human/system performance errors. In most cases these errors resulted in violations of airspace, either laterally or vertically. The most frequently reported result was the inability to meet altitude restrictions. This was due to either not recognizing or understanding the current status of the automation, or not being able to program/re-program the FMS in a timely and correct manner. This indicates that FMSs are not optimally designed from a human-computer interface perspective because the procedures required to program the FMS, [the screen information presented on the Flight Management Computer Control/Display Unit (FMC/CDU), and the organization of information], are provided by other feedback sources. As currently designed, the FMS does not "lead" the pilot in terms of the expected series of steps that must be performed to accomplish the expected goal or end result. Furthermore, the placement of the various information sources that provide feedback to the pilot, has not been optimized, and requires significant visual and cognitive workload to obtain and understand the necessary information.

The data and crew observations, analyzed and presented in this report, have served to point out the existence of certain design/system weaknesses associated with the use of this equipment by the flight crews. These weaknesses result in programming errors, airspace violations, and not being able to effectively comply with ATC requested flight path changes. The primary areas of concern are related to the pilot's interface with the equipment itself, as well as the interface to the ATC system. The implementing of the short-term ATC clearance requirements require the flight crew to program/re-program (or activate the automation control algorithms) the FMS in a timely manner to accomplish the intended objective.

The implications from these findings are that FMS designers, implementors, and integrators need to consider restructuring their FMS user-machine interface software routines (including individual screens, screen linkage, navigation logic, and automation selection/implementation logic). This will ensure that the flight crew's ability to respond to short-term ATC clearances is not overly impacted by FMS-induced cognitive demands at points of high workload.

A variety of tools and methodologies, currently available in the user-interface and cognitive engineering domains, offer potentially valuable means for assessing the usability of various aspects of the FMS. Tools such as the GOMS Model Methodology, Modified Petri Nets, and Operational Sequence Diagrams, when applied to the FMS logic and structure, can provide a useful framework for analyzing the common features and procedures across the various FMSs. These analysis can result in the development of recommendations for the design/re-design of standardized interfaces, procedures, and placement of critical information. In addition, the use of such tools may also point out the need for specific training materials and curriculum that will ensure the proper usage of the FMS equipment by the flight crews.

The material in this report was developed using data from NASA's Aviation Safety Reporting System database. The reports in the database have been voluntarily submitted, primarily by flight crew members or other participants in the Aviation System and, as such, they reflect certain reporting biases. These data and materials may not be entirely representative of types and number of occurrences that actually occur, consequently, the application of statistical tools to these data should be treated with care. However, the reports provide an excellent source of qualitative information and, as such, offer a useful picture of the nature and types of problems that are occurring as a result of using FMSs in the flight environment.

1. SUMMARY

This report documents a portion of the work accomplished under DOT/VNTSC contract DTRS-57-89-D00086 (RA 0008), Work Order #2, entitled "Flight Management System Description/Characterization," during the period October, 1990 to July, 1991.

1.1 Scope

This report covers the activities related to the description, classification and analysis of the types and kinds of flight crew errors, incidents and actions, as reported to the Aviation Safety Reporting System (ASRS) database. These actions can occur as a result of the use of Flight Management Systems (FMSs) to fly within the National Airspace System (NAS).

1.2 Purpose

The analysis of the ASRS FMS-related database reports was conducted for the purpose of determining the types and kinds of design-induced problems that flight crews are having with FMSs that can result in the occurrence of errors, incidents and other operational problems. It was believed that review of these reports would provide a useful background and understanding of the FMS *use domain* (i.e., the flight environment) and offer a window into the cockpit setting. This would enable the identification of categories of difficulties that flight crews appear to have with the FMS and its subsystems. Those elements of the FMS operational logic that are identified as potentially problematic will then be investigated in more detail in the Description and Characterization Study that is also ongoing. The Description and Characterization Study is intended to provide a conceptual framework and methodology for the analysis of the human-computer interface and operational logic embodied in current FMSs. The product of that study will be a series of reports describing the results of comparisons between current FMSs with respect to procedures for performing common tasks, screen and keyboard layout and information presentation, and the logic used to integrate individual FMS subsystems into a coherent system. These comparisons will serve as an important basis for attempting to assess relationships between the design of FMS procedures and logic, and ease of use from the crew's perspective. Together, the products from the ASRS Database Study and the Description and Characterization Study will contribute to a clearer understanding of the design-related FMS contributors to pilot error.

1.3 Results

The review and analysis of the ASRS database reports indicates that there does exist a significant number of operational and design-induced problems with these systems that have resulted in human/system performance errors. In most cases, these errors resulted in violations of airspace, either laterally or vertically. The most frequently reported result was the inability to meet altitude restrictions. This was due to either not recognizing or understanding the current status of the automation, or not being able to program/re-program the FMS in a timely and correct manner. This indicates that FMSs are not optimally designed from a human-computer interface perspective because the procedures required to program the FMS, [the screen information presented on the Flight Management Computer Control/Display Unit (FMC/CDU), and the organization of information], are provided by other feedback sources. As currently designed, the FMS does not "lead" the pilot in terms of the expected series of steps that must be performed to accomplish the expected goal or end result. Furthermore, the placement of the various information sources that provide feedback to the pilot, has not been optimized, and requires significant visual and cognitive workload to obtain and understand the necessary information.

1.4 Work In Progress

The material presented in this report is based on 63 reports selected from the 1989 ASRS database and 36 reports selected from the 1988 ASRS database. An additional 30 reports from the 1988 database have been selected, however, they have not been completely analyzed as of this report. It is intended that they will be added as an addendum to this report. In addition, a selected number of 1990 and 1991 ASRS reports may also be included in the addendum.

1.5 Conclusions

The reports contained in the ASRS database provide an excellent source for ascertaining the nature and scope of the problems that flight crews are currently experiencing in using the FMS to control their flight path (both laterally and vertically) under normal flight conditions. The information contained in this database is unique in that it provides a "snapshot," from the pilot's perspective, of the types and kinds of problems/errors that are being experienced in attempting to use the high levels of automation that characterize today's modern transport aircraft cockpit.

The data and crew observations, analyzed and presented in this report, have served to point out the existence of certain design/system weaknesses associated with the use of this equipment by the flight crews. These weaknesses result in programming errors, airspace violations, and not being able to effectively comply with ATC requested flight path changes. The primary areas of concern are related to the pilot's interface with the equipment itself, as well as the interface to the ATC system. The implementing of the short-term ATC clearance requirements require the flight crew to program/re-program (or activate the automation control algorithms) the FMS in a timely manner to accomplish the intended objective.

The implications from these findings are that FMS designers, implementors, and integrators need to consider restructuring their FMS user-machine interface software routines (including individual screens, screen linkage, navigation logic, and automation selection/implementation logic). This will ensure that the flight crew's ability to respond to short-term ATC clearances is not overly impacted by FMS-induced cognitive demands at points of high workload.

The issues raised in this study suggest the need to conduct further studies that will result in the critical description and characterization of the current pilot/automation interface, in order to:

- Ensure that the both the retrofit and next generation of FMS equipment rectify the current design problems that are contributing to the occurrence of pilot error;

- Ensure that information presentation is accurate and understandable in terms of what the automation is doing, or is expected to do; and

- Satisfy the flight crew's needs to be able to implement short-term modifications to the flight plan in an efficient, safe, and predictable way, through the introduction of improved V NAV algorithms and more exact control of the automation parameters.

In order to accomplish the objectives of the overall description and characterization task, the problems identified above, as well as other less critical (but perhaps contributing) factors, need to be examined and evaluated in terms of the usage of common features shared by all FMSs, including:

- Navigational tools such as mode select and line select keys;
- The mode control panel interface logic as it is used to control level of automation (flight director, autopilot, V NAV/L NAV);
- Screen information content and placement;
- Information feedback display content and placement;
- Potential alternative keying logics.

A variety of tools and methodologies, currently available in the user-interface and cognitive engineering domains, offer potentially valuable means for assessing the usability of various aspects of the FMS. Tools such as the GOMS Model Methodology, Modified Petri Nets, and Operational Sequence Diagrams, when applied to the FMS logic and structure, can provide a useful framework for analyzing the common features and procedures across the various FMSs. These analysis can result in the development of recommendations for the design/re-design of standardized interfaces, procedures, and placement of critical information. In addition, the use of such tools may also point out the need for specific training materials and curriculum that will ensure the proper usage of the FMS equipment by the flight crews.

1.6 Limitations

The material in this report was developed using data from NASA's Aviation Safety Reporting System database. The reports in the database have been voluntarily submitted, primarily by flight crew members or other participants in the Aviation System and, as such, they reflect certain reporting biases. These data and materials may not be entirely representative of types and number of occurrences that actually occur. Consequently, the application of statistical tools to these data should be treated with care. However, the reports provide an excellent source of qualitative information and, as such, offer a useful picture of the nature and types of problems that are occurring as a result of using FMSs in the flight environment.

2. INTRODUCTION

Flight Management Systems (FMSs) play a critical role in the performance of a number of flight tasks, including navigation and maintenance of desired aircraft position, attitude, and orientation; and aircraft performance optimization. FMSs are highly integrated systems, consisting of a number of subsystems including Flight Management Computers (FMC's), the FMC Control/Display Unit (CDU), the mode control panel (MCP), the Autothrottle System, the Attitude Director Indicator, and the Software Database. Because they are currently being designed and built by a host of manufacturers, it is likely that FMSs differ with regard to the automation philosophy driving the operation of their functions, the architecture and logic of their software, and the rules and procedures required to operate the system.

From the perspective of the flight crew, differences in the rules and procedures for using the system, together with variations in system responses to crew actions, are, of course, the primary concern. Under normal conditions, such differences are simply a nuisance. Under time critical conditions, these differences can impact the flight crew's ability to respond effectively, especially when they increase the complexity of the task, inhibit the flight crew's ability to utilize the capabilities of the FMS, and consequently, increase the flight crew's workload.

At the present time, feedback concerning operational complexities and problems associated with the use of FMSs is not generally reported, except when an incident occurs that results in the submission of a report to the ASRS. The purpose of this report is to extract basic FMS-related knowledge from the ASRS reports, and then to make assessments concerning the underlying causes of the reported problems. This knowledge can then be used as critical guidance for identifying those aspects of FMS use that appear to cause the greatest difficulty for the flight crew. Problem areas can then be analyzed in greater detail, by means of a description/characterization analysis of current FMSs, in order to better identify the underlying design or procedural issues that may have contributed to the occurrence of reported incidents. In addition, by comparing the logic and procedures of current FMSs, it may be possible to specify those approaches, actually in use, that are more likely to encourage the occurrence of flight crew problems.

3. APPROACH

A total of 282 FMS-related reports, describing incidents reported to ASRS that occurred during 1988 and 1989, were retrieved from the ASRS database using FMS-related search terms. From these 282 reports, 129 reports were selected on the basis of the reported incident having arisen, at least in part, because of crew problems with the FMS. To this point, 99 of these reports have been reviewed in detail, and this report represents the analysis of those reports.

Certain statistical qualifications must be remembered when ASRS data are used. All ASRS data, including those used in this study, are submitted voluntarily by the reporter and may reflect reporting biases; as such, they constitute a non-random sample population of aviation incidents and events. Further, the reports used in this study have been selected because the reporter clearly described some type of connection to FMS use. It is possible that some reported incidents that were excluded from study did, in fact, include a contributing role of the FMS but failed to be included in the analyzed sample. Consequently, the reports cited in this study should not be considered a random sample of all FMS-related incident reports in the ASRS database.

The reports in this sample were reviewed and evaluated using 12 incident descriptive categories associated with FMS-related incidents that were developed through the initial evaluation of over 300 ASRS reports gathered from the years 1986 through 1989. These categories were identified based upon an extensive review of the ASRS reports and other FMS-related technical literature, and are considered to be descriptive of the types of problems that are encountered by the flight crews as they interface with the various elements of the FMS. These categories are listed in Table 3-1.

Table 3-1. FMS Incident Descriptive Categories

1) Keyboard errors made by flight crew in inputting data
2) Logic errors made by flight crew in inputting data
3) System performance errors - attributed to hardware errors/failures
4) System performance errors - attributed to software mistakes/design problems
5) Errors of expectation/interpretation by the flight crew - ATC logic related
6) Errors of expectation/interpretation by the flight crew - FMS logic related
7) Errors due to ATC/crew high workload – above 10,000 ft.
8) Errors due to ATC/crew high workload – below 10,000 ft.
9) Mode control panel (MCP)/automation control selection errors made by flight crew
10) FMS/MCP interaction errors
11) Errors related to pre-stored database/company routes
12) Training/flight crew proficiency related errors/performance problems

These incident descriptive categories are not mutually exclusive in that the same incident can fit into more than one category. Also, they reflect a first attempt at a classification scheme and are clearly operational in nature. The decision was made to use an operational classification scheme in the preliminary phase of the analysis in order to avoid bias that can arise through inferring beyond what is said in the report itself. Because incident reporters rarely base their explanations of what happened on human factors/cognitive causes (two exceptions being "high workload" and "distraction"), a categorization scheme organized around human factors/cognitive factors would necessarily involve inference on the part of the report analysts. Because of the preliminary stage in which these analyses have been performed, it was felt that analyses based on inference are premature. However, it was quickly discovered that an operational categorization scheme failed to encompass what the authors came to believe was "really going on." Consequently, the operational categorization scheme has been supplemented by a set of more general "problems" categories that attempt to describe causes of errors that go beyond the purely operational. These categories begin to get at the more human factors/cognitive types of error causes but are probably best described as operating at the level of pilot explanations of problems.

[Note: Technically, the terms "FMS" and "FMC" can both be used to refer to that part of the FMS used to control V NAV and L NAV. For the purposes of this paper, however, the term "FMS" is used to refer to the Flight Management System as a whole, including the autopilot, flight director, and Flight Management Computer. "FMC" is used specifically to refer to the subsystem that controls V NAV and L NAV, that is, the coupling of the FMC with the autopilot, with the FMC/CDU as the crew's interface to this subsystem.]

4. FINDINGS

In this section, the findings based on the review of the 99 selected reports are described. Incidents fall into two main categories: Those that arose because of crew error and those that appear to be due to hardware or software malfunctioning. Flight crew-related errors are discussed in Section 4.1 with hardware/software errors presented in Section 4.2.

4.1 Crew-Related Errors

In this section, crew-related errors are addressed from two perspectives. Section 4.1.1 summarizes the data concerning types of crew errors and the conditions under which these errors tend to occur. Section 4.1.2 offers a more qualitative approach to the ASRS reports and describes some possible contributing causes for the occurrence of these incidents.

4.1.1 Descriptive Summaries

This section of the report presents summaries of the data that pertain to three analyses:

- Number of incidents for each type of crew error;
- Number of incidents thought to be caused, at least in part, by either high workload or insufficient training;
- Number of incidents as a function of phase of flight.

4.1.1.1 Types and Frequency of Crew Action-Based Errors

Table 4-1 presents a descriptive summary of the number of incidents that were based, at least in part, on actions (or lack of action) on the part of the crew. These errors often arose because of the flight crews' expectation that the FMS would perform in a particular way, for a given set of commands or selected operations. When it did not perform as expected, the crew often expressed surprise at the end result.

The Incident Description Categories, used in Table 4-1, are defined as follows:

- Keyboard errors made while inputting data usually involved a straightforward error of inputting information that was wrong, such as an incorrect navigation fix or mis-keying the data during entry and not catching it before execution.

- Logic errors usually involved the flight crew entering data in a format or form that the FMC would not recognize, or the pilot not understanding the underlying limitations of the system when he or she tried to enter the data.

- Errors of expectation/interpretation that were ATC-related dealt primarily with errors in the crew's understanding of how the FMS would respond to modifications that affect the aircraft's vertical or lateral path. This class of errors is referred to as ATC-related because these modifications are typically made in response to ATC clearances.

- Errors of expectation/interpretation that were related to the FMS logic involve crew misunderstanding of the FMS itself, that is, how the various subsystems that comprise the FMS can be used and modified.
- Mode control panel/automation control selection errors involved incorrect selection or modification of an automation level by means of the mode control panel.

The data presented in Table 4-1 suggest the same underlying problem: The crew fails to operate the FMS properly and, at the same time, fails to catch the error before an incident occurs. The following example demonstrates this pattern in a case where the flight crew received a multiple clearance from ATC and became confused when they tried to re-program the FMC/CDU.

> (130700)[1] "We were assigned a heading, altitude and airspeed change (by ATC) all at once. The first officer was flying, the aircraft was on autopilot and the FMS was controlling the autopilot. We were assigned 250 knots at 7,000 feet. They slowed us to 210 knots and the first officer entered the command in the FMS. A couple of minutes later, ATC slowed us again to 170 knots. The confusion occurred when we saw the aircraft was still doing nearly 250 knots! It had not slowed down. We entered the altitude change, began descending, and were playing 'What's it doing now?' game to determine why it hadn't slowed as commanded. ...Time lost trying to decide what it's up to put us behind the aircraft."

These data appear to argue for the need for the crew to continuously monitor and pay attention to the FMS, even when the FMS is in a fully automated mode and has apparently accepted the flight crew command inputs. The simplicity of this statement, however, is questionable and will be reviewed in the Section 4.1.2.

Table 4-1. Flight Crew FMS Actions/Errors

Category	Incident Description	Citations
1	Keyboard errors made by flight crew in inputting data	15
2	Logic errors made by flight crew in inputting data	3
5	Errors of expectation/interpretation by the flight crew – ATC related	12
6	Errors of expectation/interpretation by the flight crew – FMS logic related	27
9	Mode control panel (MCP)/automation control selection errors made by flight crew	18

4.1.1.2 Temporal Contributors to Crew-Based Errors

Two major factors, of a temporal nature, that contribute to success in using the FMS are:

- preparedness of the flight crew to interface with the FMS and make the necessary actions required to use the system, (i.e. training)
- conditions during the flight that contribute to the crew's ability to use the FMS (i.e. workload)

The data in Table 4-2 summarize the information from the ASRS reports in which the flight crew indicated that a high workload element or flight crew training element contributed to, or was involved in, the incident. Workload was only included in this table if it was directly cited by the reporter, or it was clear that the pilots or ATC were unusually busy. Those citations for workload above 10,000 feet usually occurred in the middle altitudes below the flight level altitudes. The pilots' inability to deal with the FMS was often attributed to a high workload level, either from ATC or weather, which did not allow them time to concentrate on FMS programming or trouble shooting.

High workload errors for ATC and flight crews relating to FMS errors were stratified - above and below 10,000 feet - to gain some insight on workload patterns. 10,000 feet was selected as a cut-off since, technically, the highest level of automation, which involves using the FMC) is not supposed to be modified below 10,000 feet. If modifications are required, the crew are supposed to use a different automation level, such as flight director or autopilot. It is interesting to note that at least six crews chose to ignore this policy and attempted to use the FMC automation.

Of greater interest is the comparison between workload above 10,000 feet and insufficient training as a contributing factor to the occurrence of the incident. Training and flight crew proficiency related error were only cited if it was clear, from the reports, that they could be considered contributing factors to the event occurrence.

Based upon the data in this table, insufficient training and workload are equally likely to be cited as a contributor. This suggests that crews find that the automation does not help in

Table 4-2. Associated Incident Events and Precursors

Category	Incident Description	Citations
7	Errors due to ATC/crew high workload-above 10,000 ft.	11
8	Errors due to ATC/crew high workload-below 10,000 ft.	6
12	Training/flight crew proficiency related errors/performance problems.	12

Table 4-3. Phase of Flight

Phase of Flight	Citations
Climb	21
SID	6
Enroute	14
Transition	2
Crossing Restriction	40
Descent	10
STAR	4
Approach	2
Holding Pattern	6

reducing workload and the system itself requires considerable experience to be effectively used.

4.1.1.3 Phase of Flight

The data in Table 4-3 describe the reported point, in the progress of a flight, that the FMS error was discovered and/or the incident occurred. It does not necessarily represent the point where the initial error occurred. For example, an erroneous holding pattern being included in the navigation database provided with the FMS, is an error which likely occurred before the airplane was first flown, by this crew, and on this route. The error may only be discovered some time later when the flight crew performs the operations necessary to implement the ATC instructions and fly that particular holding pattern.

This table, however, does provide some insight as to where these flight crews experienced their difficulties. Of particular note is the significant percentage (72%)[2] of the reports involving altitude changes (climb, descent, and crossing restrictions). The vertical navigation operation of the FMSs, and/or the flight crew's understanding of this capability, is certainly an area that deserves closer attention in terms of potential re-design.

4.1.2 "Problems" Categories

Reading the actual incident reports suggests that the types of statistics just described do not give a complete picture of contributors to, and causes, of crew errors. There appear to be difficulties faced by the crew that are not reflected in these statistics. Based on the reports, these problems appear to fall into eight basic categories:

1. Raw Data and FMS/Aircraft Status Verification
2. FMS Algorithmic "Behavior"

3. Improper Use of the FMC Automation Level
4. FMC Programming Demands
5. Multiple FMC Page Monitoring Requirements
6. Complex ATC Clearances
7. Complex FMC/CDU Tasks
8. Lack of Adequate Pilot Training

These problem areas are described below.

4.1.2.1 Raw Data and FMS/Aircraft Status Verification

A common observation by the majority of the pilots submitting these reports was the belief that they did not have enough information about what the FMS was doing to be able to effectively monitor the system. This was particularly problematic when the pilots were very busy and could not spend the extra time needed to focus on the FMS and/or the aircraft. Essentially, once they enter data or commands into the system, they must assume any or all of the following:

- That the data entered is correct;
- That the intended operation will be executed correctly; and,
- That it will be executed at the proper time.

There is usually no easy method for pilots to monitor the system's progress or to know if the data/commands they entered will work as planned until the action or error occurs. The ASRS reports appear to indicate that this is particularly troublesome when the flight crew get busy and lose their ability to focus on what the FMS is doing. This reported lack of situational awareness or "being in the loop" is particularly difficult for most pilots since their basic flight training has usually emphasized maintaining an awareness of what the airplane is doing, and what it is likely to do next. This is sometimes described as "staying ahead of the airplane." One pilot described the experience as follows:

> (123705) "We were instructed to cross Holey intersection at 11,000 feet. I was flying the aircraft coupled on the autopilot. I programmed the correct data into the FMC and selected 11,000 on the mode control panel. The aircraft indicated a top of descent point in 17 miles. Having confidence in the system, I switched attention to creating waypoints for approach and appropriate runway. I thought to myself 'We should have started down by now'; we were 10 miles from the intersection and 13,000 feet. Immediately, I started a rapid descent and we crossed Holey at 12,500 feet. My point is that I have almost 3,000 hours in the airplane and I am very knowledgeable in its operation, but pilots cannot rely on the computers to fly the aircraft."

The reported lack of trust in the FMS that arose from this incident was mirrored in many of the other reports reviewed for this study. Although not cited specifically, it was clear that many of the pilots submitting these reports were, and still are, receptive to the additional sophistication and efficiency represented by the FMS, but have quickly become mistrustful when they experienced errors, irrespective of the cause. The concluding statement in many of the reports is "use raw data backup to verify the performance of the FMS." For example:

> (88652) "Took off from JFK runway 31L on a 'Kennedy 1 Departure, Breezy Point Climb.' At 400 feet we turned left to proceed to CRI VOR. When turn towards CRI was initiated, I selected a Direct to CRI in the flight FMC. Captain followed the command bars on the HSI which showed a course straight ahead. Controller asked where we were heading. He advised that CRI was in our 9 o'clock position and gave us a left turn to 220 degrees. The map on our HSI shifted and CRI VOR showed correctly... In the future, I intend to have one pilot in VOR mode on HSI with VOR manually selected to absolutely verify the accuracy of the departure routing."

However, monitoring the "raw data" is not as simple as it would appear. To adequately monitor all of the relevant data can mean scanning a number of different flight instruments (FMC/CDU, the mode control panel, the Attitude Director Indicator, etc.) and then correctly integrating this information so as to construct an accurate picture of the FMS/aircraft's status.

> (86946) "The first officer was flying this leg. Initially we were cleared to cross Kubbs intersection at 10,000 feet. First officer was inserting data into the Performance Management System to let the aircraft do it... I was expecting Kubbs at 10,000 feet because other flights on the frequency had been assigned it... I announced to the first officer the miles to the crossing point and the number of thousand feet we had to lose. He then went to Vertical Speed Mode, closed the throttles and fully extended speed brakes. The controller then gave us descent to 11,000 feet... The MLG (medium large transport) was descending quite rapidly. Because of the high sink rate and close crossing restriction, I was watching my flight instruments quite closely. My Flight Mode Annunciator was showing Altitude Capture as being armed until we approached 10,000 feet. At that point, it dropped off. We went through 10,000 feet at a fairly high rate of sink. At 9,900 feet I pulled back on the yoke, the first officer rearmed the Altitude Preselect. The airplane continued to descend. I disengaged the autopilot and stopped the descent at 9,800 with an abrupt jerk back on the yoke. I got the airplane back to 10,000 feet, trimmed and at the correct speed, looked up and saw 11,000 feet in the Altitude Preselect window. Since the first officer had been flying with the autopilot ON, he had been resetting the ALTs. I got everything set up, re-engaged the autopilot and gave the airplane back to the first officer... The Altitude Preselect window is far away from viewing range especially from the left seat. It would be nice to have an Altitude Preselect repeater in the Flight Mode Annunciator or somewhere close to the flight instruments. Also, it seems difficult sometimes to know how far to let the automatic equipment go or when to step in and take command of the situation..."

Not surprisingly, monitoring the raw data can be especially difficult for the more inexperienced pilot:

> (108752) "Descent from FL200 to 12,000 feet using the FMC nav and autopilot. At approximately 15,000 feet enter the tops (of the clouds) and encountered moderate

to severe turbulence, heavy rain. Almost simultaneously, ATC cleared us to cross 40 southwest LRP at 12,000 feet. LRP not available immediately due to not being on auto-select on the VOR, and (fix) off screen on the CRT. Captain (pilot not flying) scrambled to find the airway chart to get the VOR frequency while I got engine anti-ice and ignition turned on. The captain began adjusting radar to find out why we were getting heavy rain and turbulence. When DME finally locked on LRP, it read 31 miles (southwest of LRP). I deployed spoilers and turned off the auto thrust. Rain and turbulence worsened in descent. As we approached 12,000, I observed airspeed decreasing. Not immediately realizing, due to concern about the extreme turbulence, that the autopilot was leveling the aircraft at 12,000. Without auto thrust being available, I turned off the autopilot. The aircraft was trimmed nose down and continued descent below 12,000. The captain realized the problem and immediately called out altitude. Flew the aircraft back to 12,000 and reengaged the autopilot... Contributing factors: Proficiency – I am junior on (this aircraft), have been mostly assigned for the last six months as relief pilot or with restricted captain. Consequently, I flew one leg in October, two in November, one in December, none in January, one in February and none in March. This was my sixth leg in six months... ATC procedure – assignment of a crossing restriction only 10 miles from the crossing fix, using a navaid which is behind an aircraft using FMC equipment imposed an excessive workload on the crew with too little time to set it up... ATC should avoid short range crossing restrictions. Controllers should be trained on the operational characteristics of FMC (equipped) aircraft."

Clearly, the issue of knowing what the FMS is going to do is a critical issue. Consequently, an important part of the FMS Description/Characterization analysis will involve looking at what data are available to the crew for monitoring FMS/aircraft status, how easy it is to access this data, and how informative the data are for accurately assessing future FMS "behavior."

4.1.2.2 FMS Algorithmic "Behavior"

The verification process is compounded by the fact that, in many cases, by the time the crew is able to detect that the FMS is not going to respond correctly, it may be too late to compensate. FMS response is determined not only by crew inputs but also by software algorithms that define when to initiate the inputs made by the crew. These algorithms are designed in accordance with a variety of criteria, one of which is to optimize aircraft performance so as to minimize fuel usage. However, these algorithms can create problems for the crew, as is shown by the substantial number of ASRS reports that involved vertical navigation. The referenced reports often dealt with problems such as altitudes not being captured, crossing restrictions not being met, and climb and descent rates being excessive. As Table 4-3 showed, crossing restrictions not met represent 40% of all flight phase categories in these 99 reports.

In many of the reports, an altitude excursion was the result of the FMS not performing as expected, or the flight crew not recognizing that the FMS was not working properly or was mis-programmed. It is likely that many of these incidents occur because the FMS algorithms are designed to level off the aircraft at the last minute. If the flight crew missed the 900-foot and 300-foot cues that signal approaching the selected altitude, this leveling off is the major cue to the crew that the desired altitude will be acquired. The last-minute nature of the leveling-off process, coupled with missing the altitude alert cues, means that the crew knows a problem has occurred only when the airplane does *not* level off, at which time it is probably too late to perform any actions that can prevent the altitude deviation. One pilot described the experience this way:

> (125410) "On departure, we were cleared to climb to 12,000 feet, but we had an altitude deviation and climbed to 12,450 before returning to our assigned altitude of 12,000. At 11,000, I called 1,000 to go and then looked back outside to clear for traffic in the turn. I looked back inside and saw that we were at 11,800 climbing at 4,000 feet per minute (fpm). I pushed forward on the yoke the same time I said '12,000'... This aircraft is a popular modern transport with an excellent thrust to weight ratio, glass cockpit, auto throttles, FMC's, the works. With this aircraft's power it has quite a good climb rate and the automated systems fly the aircraft exceptionally well, but they do not climb or descend the aircraft according to the Airman's Information Manual (AIM). It is not at all unusual to approach within 300-400 feet of an altitude at 4,000 fpm. The computer will capture the altitude with about a 1.25 G pull or a .75 G pushover so that the passengers don't really feel it... I feel that if the AIM descent and climb rates were programmed into the computer that would be a better system. That way, high vertical speed in the last 1,000 feet would be the exception and not the rule and much more likely to result in a timely level off instead of an altitude bust. After all, it would take more that 30 seconds to overfly/underfly an altitude by the magic 300 feet at 500 fpm as opposed to only slightly more that 4 seconds it would take at 4,000 fpm."

This type of algorithm can encourage the occurrence of altitude excursions since it does not leave much room for error compensation. The pilot's recommendation for a modification to the altitude capture logic of the autoflight system to slow the climb rate for the last 1,000 feet appears reasonable when the performance of this particular aircraft is considered.

4.1.2.3 Improper Use of the FMC Automation Level

The FMS is a complex system supporting several levels of automation that can be used for controlling the aircraft. Reading the ASRS reports, however, suggests that the crew do not always take best advantage of these automation levels. Several ASRS reports show that the crew tend to rely only on the FMC to control the aircraft. The FMC, however, is intended for long-term control of the aircraft. In cases requiring more immediate response from the aircraft, better automation choices are the flight director, the autopilot, or even manual control if the temporal response is critical. The following report describes the problem:

> (112925) "...Center cleared us to cross Lendy at FL230. The Captain programmed the FMC for this crossing just as the #1 flight attendant came into the

cockpit to complain about something. Neither one of us noticed the FMC reverted to speed mode from V NAV path mode. About 15 mile from Lendy, I noticed we were much too high to make the restriction... Center then cleared us to cross LGA at FL190 at 250 knots. The Captain began programming the FMC when we should have started right down. As a result, we had to make a high speed descent to FL190 to make altitude and we could not slow down to 250 knots. The Captain commented that he always tells new co-pilots to begin the descent before programming the FMC if there is any doubt about making the restriction... We did not fly the airplane first and program the FMC second. We relied too much on the FMC in a situation where they require too much input and monitoring and increase the workload."

Based on this report, it would appear that pilots who went to a manual reversion early, either by hand flying the airplane using raw data or by obtaining raw navigation data for back-up purposes, did the best in minimizing the FMS-related incident. Those pilots who reported that they continued to try and program the FMC/CDU and/or "troubleshoot" the system, while trying to fly the aircraft and meet the clearance objectives, appeared to be the ones who quickly found that the incident had progressed to an uncomfortable stage. Fortunately or unfortunately, it would appear that experience (i.e., time with the system) is the only way to compensate for the difficulties associated with using the FMS automation features to perform "short-term" ATC clearance procedures or maneuvers.

The question arises as to why crews are reluctant to use automation levels other than the FMC. In at least one case, the reason was obvious. The captain insisted that the first officer use the FMC because the company's policy was always to use it. In other cases, however, the reason is not obvious. One possible reason may be the flight crew's difficulty in moving between automation levels, especially in moving from flight-director or autopilot control to FMC control. This hypothesis needs to be addressed in greater detail in the description/characterization study.

Improper use of the FMC automation level can also include nonstandard procedures, as in the following example:

(122778) "We were cleared to cross 40 NM west of Linden VOR to maintain FL270. The captain and I began discussing the best method to program the CDU to allow the performance management system to descend the aircraft. We had a difference of opinion on how to best accomplish this task (since we are trained to use all possible on-board performance systems). We wanted to use the aircraft's capabilities to its fullest. As a result, a late descent was started using conventional autopilot capabilities (vertical speed, maximum indicated mach/airspeed and speed brakes). Near the end of descent, the aircraft was descending at 340 KIAS and 6000 feet-per-minute rate of descent. The aircraft crossed the fix approximately 250-500 feet high. Unfortunately, we made no call to ATC to advise them of the possibility of not meeting the required altitude/fix. This possible altitude excursion resulted because: (1) captain and first officer had differences of opinion on how to program the descent. A) Both thought their method was best: the captain's of programming (fooling) the computer to believe anti-ice would be used during descent, which starts the descent earlier; the first officer's of subtracting five miles from the nav fix and programming the computer to cross five miles prior to Linden at FL270. B) A minor personality clash between the captain and first officer brought about by differences of opinion on general flying duties, techniques of flying and checklist discipline. C) Time wasted by both captain and first officer (especially first officer) in incorrectly programming CDU and FMS for descent, which obviously wasted time at level flight, which should have been used for descent. Observation: as a pilot for a large commercial carrier at its largest base, we seldom fly with the same cockpit crew member. This normally does not create a problem. I do, however, feel that with the "new generation" glass cockpits being on the property approximately six years; this can cause a bit more difficult transition than, say month to month cockpit crew change on a 727 or pre-EFIS DC-9. I have flown commercially for 10 years, and have flown two-man crew aircraft for eight of those 10. The toughest transition for me is to determine who shares pilot flying and pilot-not-flying duties. This historically (3 years) has been most difficult when the other crew member has transferred from a 3-man cockpit to a 2-man "glass cockpit." This is especially pertinent when the crew member has been on a 3-man crew aircraft for a number of years. As first officer, when you are the pilot-not-flying, you accomplish your normal duties. However, often times when one is the pilot flying, he also has to do the pilot-not-flying duties to the extent that it is required on 2-man cockpits, whether they be conventional or EFIS. This obviously can lead to a myriad of problems. Add weather problems or an airport such as Washington National, Laguardia or Orange County, and problems can accelerate with alarming rapidity."

Appropriate response to an ATC instruction involves two elements: selecting the most appropriate automation level in order to produce a timely response to that instruction, and using that automation level correctly. In the example just described, the flight crew did not even consider the issue of appropriate automation level but chose to focus on how to fool the FMC into producing a timely response. As a result, they found themselves in the position of not being able to use the FMC at all, and had to push the aircraft to its performance limits in order to try to accomplish the objective.

4.1.2.4 FMC Programming Demands

Many of the ASRS reports included the complaint that the FMC/CDU is difficult and time-consuming to program. This complaint is magnified in the case where, for whatever reason, the FMC rejects the programmer's (pilot not flying) initial attempt. Under these conditions, it is not uncommon for the pilot flying to then get involved as well, at which point no one is flying the airplane. The frequency of these comments gives rise to the impression that the design of the current FMC/CDU does not appear to be optimal for the pilot's needs in the operational environment.

(107738) "On descent into MSP on the Bunker 6 arrival, we were given a clearance to cross Cedar intersection at or below 15,000 feet and to maintain 10,000 feet. At the time we were southwest of RWF. (Cedar is 26 DME southwest MSP Vortac).

I was the PNF (pilot not flying), so I put the clearance into the FMS CDU. The captain had programmed the arrival for runway 11R but upon getting ATIS, the approaches were to runway 29, so he started changing the arrival. He also was on vertical speed for descent instead of V NAV. After reprogramming the Cedar crossing, the altitude was erased and never re-entered. I was also spending too much time with other duties like calling gate radio and watching captain (conduct) the descent check to notice flight path. At one point, I noticed a recalculation of 14,400 at Cedar and assumed all was well. Somehow I had mistaken Caase (MSP 8 DME) for Cedar and thought we still had plenty of distance to descend. Center called us as we passed Cedar, reminded us of the clearance and asked our altitude. We were at FL230 instead of below 15,000. After a short vector, MSP center said 'MSP approach will accept you, call them ...' In summary, we missed our crossing restriction due to pilot flying doing pilot not flying duties, that is, extensive CDU reprogramming and not monitoring the flight path. I also didn't monitor the flight path close enough while involved in other duties. We received the clearance from MSP center, but failed to comply. Only one person should be doing heads down FMS work while the other monitors the flight path. Very busy time in two person cockpit requires extreme discipline."

(87750) I was operating the aircraft on autopilot at the time. The Captain was making the required in-range call to Washington National Operations at the time. I had just completed a V NAV descent to FL270 when we were given a vector heading followed shortly by a clearance to descent to FL240. Since the Captain was on the other radio, I acknowledged the clearance and reset the Altitude Alert on the Mode Select Panel (MCP) to 24,000. I then pulled up the cruise page on the Flight Management Computer (FMC) and entered FL240 into it and executed. In my mind the Autopilot/Flight Director was still in the V NAV Mode and in that Mode, executing the cruise altitude of 240 should have started a descent to that altitude. The aircraft had, however, leveled off at 270 and transferred into the Altitude Hold Mode, which would not automatically respond to the setting and executing of a new, lower altitude in the FMC. Meanwhile, the Captain had tuned the ATIS and I heard from his cockpit speaker that Washington National had switched from the north operation we had expected and had set in the FMC to a south operation. I pulled up the Arrival Page on the FMC and reset the computer to the new arrival while the Capt was copying the ATIS. In the meantime, the aircraft continued to cruise at FL270. Shortly thereafter, Washington Center called and asked to verify our altitude, at which time I realized what had happened and started an immediate descent. There was no indication from Center that the failure to descend had jeopardized safety... In training they emphasized that one pilot should fly and the other should program the FMC. I understood and believe that, however, most of the experience pilots I had been flying with since training seemed to do most of their own FMC Management while flying, especially if I was otherwise occupied on the other radio. Following that example, which may work for an experienced large transport pilot but certainly not for one at my level, I fell into the trap they had warned me about! I pushed the buttons, but I did not check the response to the input before going on to something else. No one was flying the aircraft. In the future I will initiate all altitude changes on the MCP (using flight level change) when the other pilot is unable to enter data in the FMC, and will check the basic aircraft instruments for a response to the inputs I make to the complex, multi-faceted auto Flight Control system."

The substantial amount of programming that can be required to modify the flight plan while in the air can, in effect, negate the workload advantages of the FMS automation. In addition, this programming is likely to be required during periods that have a high workload nature to begin with, that is, transitions, altitude changes, etc. Periods of high workload are to be expected in the cockpit of modern air transport aircraft. The important issue to note is not that high workload periods exist but that the crew interface to the FMC/CDU often exacerbates an already busy time. The worst case situation arises when both pilots become so focused on dealing with the FMC/CDU that they diminish their attention to flying the airplane. This last point gave rise to a common observation in many of the reports. Many pilots stated that in the future they will focus on flying the airplane first and dealing with the FMS second.

The awareness of those pilots who stated they reduced their reliance on the automation when the situation started to become confusing or the system appeared to be malfunctioning is commendable. This knowledge, however, only seems to have been developed after gaining sufficient operational experience with the FMS. The operational demands of the two-pilot high performance aircraft in the dynamic environment of terminal operations and air traffic control appear to be an ongoing problem and should be considered in the design/re-design of the next generation FMS user interface and feedback system.

Another issue cited in some of the reports was the difficulty that the flight crew had in recognizing programming errors once the data were entered into the FMC/CDU. These pilots maintained that the FMC should be more capable in reviewing and alerting the pilots to entries that appear to be in error or do not logically fit with the rest of the data entered. This "logic parameter check" might include such elements as the ability to recognize that a navigation fix was entered in error, even though it is in the database, is in a different region of the country than the filed route of flight, or was an airport identifier, not a waypoint. In this case, the FMC/CDU might highlight and ask for verification from the crew before accepting the fix. (Note: It would appear that the A320 FMGS system checks for duplicate names and requires the pilot to select the appropriate fix, which is a step in the right direction).

4.1.2.5 Multiple FMC Page Monitoring Requirements

The organization of information within the FMC/CDU appears to be an issue for some pilots. Monitoring the overall status and performance of the aircraft includes being aware of fuel status, lateral path, position, vertical path, and so on. To adequately monitor aircraft status by means of the FMC, the crew must review the information that is presented on a number of different pages which are accessed by means of a number of mode and/or line select keys. Extensive monitoring of the FMC/CDU diminishes the crew's ability to monitor the data in the mode control panel at the same time, thus creating the possibility for missing important information about the status of the aircraft.

> (119836) "Approach DEN from the east on J80 the captain (pilot flying) asked copilot (pilot not flying) to request FL390 due to building thunderstorms over the Rocky Mountains. I (copilot) put FL390 in the right FMS computer to check aircraft capability for FL390. After entering and executing FL390 in 1 L on FMS, I verified that the altitude window on the mode control panel was at 35,000 feet and that the autothrottles did not add power for the climb. At this point, the mode control panel altitude window was holding the aircraft at current cruise altitude of 35,000 feet. This has been an accepted procedure in this situation. After checking altitude capability in the FMC, I mentioned to the captain that we could make FL390 and would save approximately one percent of fuel with the climb. This whole check took probably less than 20-30 seconds. I then called DEN ATC and was advised to expect FL390 in approximately two minutes due to traffic. Anticipating the higher altitude, I left FL390 in the FMC active cruise page, once again checking to make sure the window read 35,000 feet. I continued to prepare the ACARS position report to be transmitted over DEN. We were approximately three minutes east of DEN. I remember checking the ETA for SLC and entering the fuel over DEN as 22.5. Since I was preparing the position report I changed from the Cruise page on the FMC to the Progress page, but the captain still had the Cruise page in view with the FL390 Cruise active page on it. During the minute or minute and a half of preparing the ACARS position report and waiting for the ATC clearance to FL390 the captain (pilot flying) changed the mode control panel altitude window to 39,000 feet, anticipating the climb. Of course, the FMC not being constrained at 35,000 feet any longer started a slow climb to FL390. The captain also began a passenger announcement to the passengers about DEN and the turbulence, and that we expected a climb to a higher altitude shortly. The center called, 'Maintain FL350.' Without even hesitating, I responded 'Roger, maintain 350.' By this time the captain (pilot flying) had already started a push-over. The aircraft had reached an altitude of approximately FL357. After the aircraft was returned to FL350, I checked the mode control panel altitude window and was surprised to see 39,000 feet. We returned it to 35,000 feet, our cleared altitude. Within a few minutes, Center cleared to FL390. Crew coordination and lack of communication may have contributed to the altitude excursion and conflict. The mode control panel altitude window is, in my judgment, the last step in the altitude change process, to be changed after clearance has been received. The autoflight system will not depart the mode control panel altitude, even if the FMC is programmed for a different altitude."

This example provides a feel for the number of information sources the crew must monitor. From the description, it appears that the first officer looked at, as a minimum, the following information sources:

- The altitude window on the Mode Control Panel
- Autothrottle status

- The Climb page to assess aircraft capability for FL390
- The active Cruise page
- The Progress page to determine position, ETA, and to enter remaining fuel

while, at the same time, preparing a company progress report. Monitoring a number of pages through the FMC/CDU can contribute to substantial cognitive workload in that the pilot must remember what page is appropriate for finding the desired information and how to access that page, either through mode select or line select keys. The overall layout of information in terms of the types of information on a given FMC/CDU page and the navigational tools for accessing these pages needs to be addressed in terms of how effectively the most critical set of information can be found for a given set of tasks.

4.1.2.6 Complex ATC Clearances

Under ideal conditions, the flight plan programmed into the FMC during preflight will be the flight plan that is actually flown. If this were always the case, virtually all of the errors that occur through FMS use would disappear. One reason as to why flight plans have to be changed, in the air, is Air Traffic Control and today's complex airspace. In areas of high traffic density, ATC clearances issued to a particular flight can be numerous, and in some cases contradictory, making effective use of the FMS difficult due to re-programming requirements, and/or the time needed for the FMS to respond to the new commands. It is also likely that ATC's understanding of the capabilities and limitations of FMS-equipped airplanes may not be what pilots anticipate. High traffic levels with correspondingly high ATC workloads and complex airspace result in very dynamic situations which often require timely and flexible responses from the flight crew.

The issue of high pilot workload in high traffic areas can be a problem for all flight crews, not just those flying advanced cockpit airplanes. Advanced cockpit airplanes, however, often engender workload difficulties that are unique as portrayed in the following report.

> (114409) "During climbout from DFW the controller issued a clearance to turn to a heading of 300 degrees, intercept the DFW 274 degree radial, climb to and maintain 16,000 feet, and maintain 250 knots until advised. As the first officer, and pilot not flying, I proceeded to read back the clearance and program the FMS computer for route, speed and altitude. The Captain selected speed intervention of 250 knots and heading to the assigned intercept heading. He also attempted to couple the vertical navigation of the autopilot but this was not accepted so he used flight level change and speed of 250 knots to climb to the assigned altitude of 16,000 feet at 250 knots... Unfortunately, the autopilot entered an altitude capture mode approaching 10,000 feet instead of continuing to climb to 16,000. In addition, the auto throttle disregarded the 250 kt restriction and continued to accelerate. The controller called to ask our speed and as I looked up from the FMS, I noticed approximately 330 knots... At the time of the incident, the two of us were given an intercept heading, an altitude change, and a speed restriction. In the process of attempting to accomplish the programming for

the FMS, listen for ATC, and watch for traffic, the airspeed capture of the auto throttles was overlooked until the speed approached 330 knots."

In this case, the flight crew was busy dealing with a relatively complex clearance from ATC which included a speed restriction. The problem leading to the incident arose when they tried to program the FMC/CDU to handle the clearance and it did not work as planned. The pilots depended on the FMS to help them comply with the ATC restriction of 250 knots but its subsequent malfunction, or mis-programming on their part (not clear in the report), led to their exceeding the speed limitation. It is likely that the flight crew would have recognized the problem soon due to an over speed warning if ATC had not brought it their attention.

When ATC and the flight crew are both busy, problems can become even more complicated since neither may have the time to point out errors or ask questions. The following ASRS report addresses this issue.

> (121873) "We were approximately 100 west of FNT when we were given a descent restriction of FL240, 64 miles northwest of FNT. FNT was not on our route of flight, therefore, in order to enter the restriction into the 'legs' page of our FMC it was necessary to build it into our route at the appropriate place... It was necessary to subtract the appropriate amount of distance from the closest point to the east of the 65 mile point. I accomplished this and made the restriction as requested. Then while talking to DTW approach control, we were given holding instructions. The instructions were to hold northwest of the SVM 322/25 fix with right turns, 10 mile legs at FL200, EFC at 2010. Again SVM was not on our route. Therefore, it had to be programmed into the 'legs' page of the FMC at the appropriate point then the holding info had to be put into the holding page. I entered the info correctly except that I entered SVM 322 degree radial and left out the 25 DME fix... The controller changed our assigned altitude approximately five times to eventually 12,000 feet. The controller was very busy and called us flight 'ABCD' instead of 'ABEF.' There was another aircraft with the same numbers as the first two digits of its four number call sign (as ours) and it appeared he was combining our call sign with his. While I was off the ATC frequency talking to the company about our delay, ATC called and told us we were past our holding fix, make an immediate left turn and level at 13,000 feet... I realized my mistake and began to immediately rebuild the route we were filed and establish the correct holding fix. After this was accomplished, we discovered the holding fix that we were assigned was two miles west of Pinto intersection. Pinto was on our original route of flight. DTW approach control had been giving other aircraft hold instructions for Pinto, my question is why weren't we given the same instructions?... The error was mine (in this situation), however, I feel that controllers need to understand the increase in workload that is placed on a two-man crew using an FMC when given restrictions and holding instructions off of a fix not on their route."

This situation encompasses a busy flight crew, a busy controller and navigation fixes not in the original flight plan. The flight crew's observation that the controllers should be aware of the increased workload caused by using fixes not in the flight plan is understandable but may be unreasonable. In this case, it was clear that the controller was also busy and was trying to keep the overall situation from getting worse. The relationship between ATC and the pilots is symbiotic in that each often depends on the other to assume additional responsibility when one becomes overburdened. The desire of this flight crew for ATC to remain aware of appropriate fixes (i.e., those in the FMS database) may be outside the realm of what is practical for ATC. The real question underlying the flight crew's desire is how do FMSs best fit within the ATC operational environment today and in the future? Do you change the ATC system to accommodate FMS-equipped airplanes or do you design/re-design FMSs to work within the constraints of the next generation automated ATC system? The solution probably lies in a positive answer to both questions, but identifying the specific types of change will take time and, as such, will not address the problems experienced by flight crews today.

The issue of ATC sensitivity to FMS-related workload does need to be addressed. Under high traffic conditions, this may not always be possible. However, including some type of familiarization with the FMS as a standard part of controller training may have some value.

> (114392) "New copilot flying, having a lot of difficulty with the FMC. We had been cleared to cross a point 100 miles out of Boiler at FL260 which we did. We were then given a delaying vector for spacing. We were then cleared direct to Boiler and told to descend to FL240. Copilot was having a difficult time trying to get the right page and right line to program the computer to descend. We did delay our descent to the point where ATC asked us if we had left FL260 yet. I feel training methods need to be improved. As I will be faced with a lot of new copilots I plan to change my method of operations to ensure this sort of thing does not happen. I do not believe that ATC controllers understand the operation of computer driven aircraft. We are plagued with late clearances and frequent changes. That is, I am told to expect a crossing 20 west of PMM at FL 200 and at 320 knots. Computer plans a last point of descent. Controller then says cross 15 west at FL200 and 320 knots. It's too late to change the program. Use speed brakes and a high dive (rate). Also it would be nice if the center used the enroute waypoints instead of mileage points... These simple changes to procedures would help cut our workload so we could keep our heads out of the cockpit and still use the computer."

The use of the FMS in busy airspace in which multiple clearances from ATC are likely, along with multiple aircraft configuration and speed changes, appear to make effective use of the FMS difficult, especially for short-term navigation activities. This difficulty is due to the need for pilots to remain flexible and respond quickly to the needs of ATC. The FMC/CDU, however, apparently is not that easy to re-program and is not designed to support short-term changes. Although this study did not look at ATC-related problems relative to altitude specifically, many of the ATC related incidents occurred in the middle altitudes between 10,000 feet and FL240. The complexity of this airspace, and ATC overall, seems to be involving larger portions of a given flight's overall trip. Clearly, the role of ATC should be a major consideration in how the next generation automated systems are designed and operated. With the advent of the ATC Advanced Automation System, it may be necessary to re-think the way in which automated aircraft will interface with the ground-based automation systems. Automated time-based "metering and spacing" algorithms may become the dominant mode of air traffic control from Top of Descent to Touchdown, and will require a very sophisticated interface to the airplanes' automation systems, which will impact the flight crews' use of the FMS.

4.1.2.7 Complex FMC/CDU Tasks

A small subset of tasks which are being performed either just before or during the occurrence of an incident appear repeatedly in the ASRS reports reviewed. This suggests that some tasks performed by means of the FMC/CDU may be more difficult than others. To address this possibility, the approximately 300 reports, including the 99 that were specifically analyzed for this report, were reviewed in order to identify these complex tasks. Not all tasks are equally difficult nor does task difficulty appear to be simply a matter of the number of key presses involved. Numerous page selections, key presses made in conjunction with the mode control panel in order to couple the FMC guidance to the automation, and cognitive demands for determining how to input the relevant information appear to affect overall task difficulty.

Tasks identified as potentially more complex than others include:

- Developing and entering a crossing restriction at a distance from a fix along a radial
- Entering a route not in the flight plan
- Cruise to climb or descent clearances
- Direct intercept clearances
- Verification of planned versus "as-filed" flight plans/route structures
- Intercepting routes away from VORs

The following ASRS reports provide examples of each of these tasks, and serve to suggest the complexities involved in performing that task.

Developing and Entering a Crossing Restriction at a Distance From a Fix Along a Radial

> (126707) "Cleared to cross 80 miles south of RIC VOR at FL270. We were leveled at FL330. The aircraft has been adapted with a new FMC. This particular restriction was difficult to get accepted into the FMC. It continuously showed down in the scratch pad (invalid entry). Nevertheless, the procedure for the entry was correct. ATC called and queried us about it and we initiated the descent with idle power and full speed brakes and 330 knots. ATC asked if we were going to make it. We (I) acknowledge with an 'affirmative' and continued with the steep descent. As I was doing so, the winds were showing higher than usual on the FMC Progress page. Upon realizing that the restriction was not going to be met, just when we were going to advise ATC and request vectors so as to meet the crossing restriction, DCA ATC informed us not to make a steep descent because there was no conflicting traffic involved. I understood what he meant by that statement that everything was okay and

> we did not request vectors, but continued the descent, crossing 80 DME about 1,000 feet high."

Entering a crossing restriction at a distance from a fix is one of the most common types of clearances received. Nonetheless, pilots do appear to have trouble implementing this clearance, as is shown in this example. What is especially interesting about the example is the response of the FMC to the pilot's entered data. When the entered data do not meet the requirements of the FMC, the only feedback received is "Invalid Entry." No clues are provided as to the nature of the problem. One would expect that this lack of informative feedback can only contribute to the programmer's frustration. This example also demonstrates a second common occurrence: The programmer's conviction that what he/she programmed in was correct. This conviction is common to many of the ASRS reports, as was shown in Table 4-1.

Entering a Route not in the Flight Plan

> (121873) "We were approximately 100 miles west of FNT when we were given a descent restriction of FL240, 65 miles northwest of FNT. FNT was not on our route of flight, therefore, in order to enter the restriction into the Legs page of our FMC it was necessary to build it into our route at the appropriate place. The FMC will not accept 65 northwest of FNT because of other points along our route between FNT and the 65 mile point. Therefore, it was necessary to subtract the appropriate amount of distance from the closest point to the east of the 65 mile point. I accomplished this and made the restriction as requested. Then while talking to DTW approach control, we were given holding instructions. The instructions were to hold northwest of the SVM 322/25 fix right turns, 10 mile legs at FL200, EFC at 2010. Again SVM was not on our route. Therefore, it had to be programmed into the Legs page of the FMC at the appropriate point then the holding information had to be put into the Holding page. I entered the information correctly except that I entered SVM 322 degrees radial and left out the 25 DME fix. I backed up the holding fix with the VOR by manually tuning the SVM VOR and 322 degree radial again without checking the 25 DME fix. While we were doing this the controller changed our assigned altitude approximately five times to eventually 12,999. The controller was very busy and called us XX1234 instead of XX234. There was another aircraft with the same numbers as the first two digits of its four number call sign and it appeared he was combining our call sign with his. While I was off the ATC frequency talking to the company about our delay, ATC called and told us we were past our holding fix. Make an immediate left turn and level at 13,000 feet. We accomplished that, as requested. I immediately realized my mistake and began to rebuild the route that we were originally filed (on the FMC) and establish the correct holding fix. After this was accomplished we discovered that the holding fix that we were assigned was two miles west of Pinto intersection. Pinto was on our original route of flight. DTW approach controller had been giving other aircraft instructions to hold at Pinto. My question is why weren't we given the same instructions? It seems unwise to give us holding instructions off of a navaid that wasn't on our route of flight that placed us

two miles west of a point (Pinto) that was on our route of flight. While everything that was given to us was legal, I believe there was a better way of doing it. The error was mine, however, I feel that controllers need to understand the increase in workload that is placed on a two-man crew using an FMC when given restrictions and holding instructions off of a fix not on their route. Not to mention the chance of error. I understand that there are operational requirements to do this from time to time, however, I don't believe this was the case. We were essentially at the same point in the sky but approach controller decided to define it with a navaid not on our route as opposed to a point that was."

Of special interest in this example is the reporter's description of the CDU pages that had to be accessed in order to program the clearance into the FMC. At the same time, the pilot must also remember what the clearance was. After several different clearances in a short period of time, the task of entering clearances into the FMC and remembering the correct clearance can become problematic. This example reinforces the impression that the FMC is difficult to use when quick changes to the flight plan are required.

Cruise to Climb or Descent Clearances

(116871) "Enroute from ATL to CMH. Given late handoff to Columbus Approach from Center. Center had issued a vector for traffic. Upon contact Columbus Approach issued crossing restriction of 11,000 feet MSL 40 NM south of Appleton Vortac. The aircraft was approximately 56 NM southwest of Appleton at 19,000 MSL at 300 KIAS. The crossing restriction included an airspeed restriction of 250 KIAS at 40 NM south of Appleton. Captain attempted to program the FMS to comply with restriction but due to his inexperience with the aircraft FMS (two months total on aircraft) and the fact that the aircraft was on a vector that had taken it off the FMS L NAV course. The captain could not properly program the FMS to cause the aircraft to leave altitude. Aircraft was taken out of V NAV mode and flown via vertical speed mode by first officer to make altitude restriction. Captain informed Columbus Approach that the aircraft would be unable to comply with speed restriction due to late crossing restriction issuance. Columbus Approach responded by saying that they needed the altitude due to crossing traffic but didn't clearly indicate whether or not the speed restriction had been lifted. Aircraft was above descent profile for remainder of vectoring for ILS 10R approach due to speed required to make crossing restriction. Compounding the problem was loss of communication with Approach due to a stuck mike on frequency. Captain switched to Columbus Tower and received approach and landing clearance. Several S-turns were required to achieve stabilized approach by 1000 feet AGL. Multiple factors of unfamiliarity with FMS limitations, late crossing restriction by Approach and fixation on FMS rather than using DME and common sense resulted in a hurried confusing situation. Better FMS training with emphasis on "Gotchas" in the system is badly needed."

There is little to add about the problem of vertical navigation. Clearly, altitude deviations are the most common result of FMS-related crew error and, therefore, require additional study.

Implementing Direct Intercept

> (114409) "During climbout from DFW airport on aircraft flight XX June/ Wednesday/89, the controller issued a clearance to turn to a heading of 300 degrees to intercept the DFW 274 degree radial, climb to and maintain 16,000 feet, and maintain 250 knots until advised. As the first officer and pilot not flying, I proceeded to read back the clearance and program the FMS computer for route, speed, and altitude. The captain selected speed intervention of 250 knots to climb to the assigned altitude of 16,000 feet. (16,000 feet was selected in the altitude window correctly). He then monitored for traffic and my programming of the FMS. Unfortunately, the autopilot entered an altitude capture mode approaching 10,000 feet instead of continuing to climb to the selected 16,000 feet. In addition, the auto throttle disregarded the 250 knot speed intervention and continued to accelerate. The controller called to ask our speed and as I looked up from the FMS I noticed approximately 330 knots. I replied 330 knots slowing to 250 knots assigned. It should be noted that the Climb page on the FMS was programmed for V NAV operation from 1000 feet AGL up but it also malfunctioned when V NAV was selected at 1,000 feet. At the time of the incident, the two of us were given an intercept heading, an altitude change, and a speed restriction. In the process of attempting to accomplish the programming of the FMS, listen for ATC and watch for traffic, the airspeed capture of the auto throttles was overlooked until the speed approached 330 knots. Callback conversation with reporter revealed the following: Reporter states that he had programmed the FMS for departure but was at the time very busy dealing with ATC vectors and the captain had entered the speed restriction manually into the FMS but the system ignored the restriction and limitation was activated. Many things were taking place at this time and it was difficult for the reporter to say for sure what was happening. The entire event was entered into the maintenance log but the outcome was not known to the reporter. Supplemental information from ACN 114194: At no time did the FMC give a warning that it had failed."

Direct intercepts are of special interest because they are a primary means for accessing the specific route of interest. There are two common scenarios in which direct intercepts are used. The first, described in the example above, involves transitioning from climbout to the first leg of the flight. This is an especially busy time for the crew in that the aircraft performance parameters are constantly changing and must be carefully monitored.

A second common use of the direct intercept involves returning to the flight plan programmed in the FMC. In this case, the aircraft has been diverted (because of traffic, weather, etc.) away from the programmed plan. If the crew wants to return to the FMC flight plan, it is not simply a matter of pressing the L NAV switch on the mode control panel. For example, the Boeing 767 requires that the aircraft be within 2.5 miles of the programmed course in order for L NAV to be engaged. If the aircraft is outside of this limit, the crew must either use heading select to guide the aircraft to the course or enter a "Direct To" into the FMC flight plan. The "Direct To" procedure needs to be investigated in some detail in order to assess its ease of use relative to the other demands likely to be imposed on the crew when attempting to implement it.

Verification of Planned Versus "As-filed" Flight Plans/Route Structures

(86874) "Crew late to aircraft due to changing aircraft in PIT and on other side of the terminal. Filed flight plan was different than programmed company route in the FMC. Both pilots encountered difficulty in entering filed route into FMC prior to pushback. Finally got route in FMC during taxi-out. After airborne and at FL370, center clears us direct to Hancock. Shortly afterward, cleared us to FL290 when 40 east of Hancock. Last I knew, FMC was flying direct to Hancock as cleared. Both heads in cockpit trying to get descent information into the FMC when I look up and see aircraft has turned 90 degrees right to about 180 degrees heading. I immediately switch to heading mode and turn back to the east. At about the same time, New York Center calls and asks where we are going. I switch to manual on VOR and dial in Hancock. I see we are 44 miles southeast of Hancock still at FL370! We advise ATC that computer must have had a 'glitch' in it. ATC replies that they get glitches all the time and then ATC clears us direct Bradley and begin descent to FL290. Captain and I discussed what happened and we still don't know! ATC had no further comments and no mention of us not making FL290 restriction. Factors affecting problem: Rushing to get aircraft out on time. Changing stored route to new filed route. Trouble entering descent information/crossing restriction into FMC. Both pilots relatively new to aircraft (four months each). On the next leg, [controller] gave us a new route from PVD to DCA. Again we had trouble entering information. Especially how to intercept a radial off of a 'J' airway. I'm going back to the ground instructors and ask for more information."

Initial entering of the flight plan typically takes place under relatively stress-free conditions prior to leaving the gate. It is not unusual, however, for the flight plan to be modified prior to takeoff. Under these conditions, the crew is busy preparing the aircraft for takeoff and the accuracy of the entered plan may not be assessed. As this report suggests, mistakes in modifying the flight plan while on the ground can cause serious problems when in the air, especially if the errors affect the early part of the flight when the crew is attempting to "clean up" the airplane.

Intercepting Routes Away from VORs

(107421) "First officer was flying the aircraft from TPA to MEM. Departed on runway 18R and in departure climb first officer was manually flying the aircraft using V NAV and heading functions selected on the flight director. Captain was performing the pilot-not-flying duties or copilot duties. Flight XX was handed off to JAX ATC while passing 10,000 feet in the climb. JAX cleared flight XX to climb to 16,000 feet and fly a heading of 360 degrees to intercept the 349 degree radial of PIE and fly this radial outbound. Captain set the PIE frequency and 349 degrees on the flight guidance panel and then selected VOR on the FMC panel to have a course bar on the HSI display. First officer adjusted heading to fly the 340 degree radial outbound as the course bar centered on the HSI. The aircraft is now out of 12,000 feet and climbing at 4,000 feet per minute. Flying a VOR radial is not usually done on this large transport as the usual procedure is point-to-point L NAV for course navigation. First officer requested a PIE 349 degree/150 NM fix entered on the FMC computer, so that a direct course could be flown. This took two settings as the first direct course was not on the PIE 340 degree radial. Setting this direct course caused both pilots to concentrate on course and not watch altitude in the climb. The 2,000 feet to go and the 1,000 feet to go call outs were missed. Captain noticed that the altitude was 15,800 feet and the aircraft was still climbing. He called out cleared to 16,000 feet and the first officer stopped the climb at 16,400 feet and descended to 16,000 feet. JAX called flight XX assigned altitude is 16,000 feet as the aircraft was descending to 16,000 feet. Captain reported leveling at 16,000 feet. Contributing factors: There was too much effort on flying the assigned radial and not enough concentration on the altitude during the climb. The events described above took less than two minutes. First officer was manually flying the aircraft which takes more concentration on course and altitude. The flight director does not have a VOR function. This increases the effort to fly a course. Flying a VOR radial outbound is not a common procedure for line flying in the large transport. The computer only allows flight to a fix, not from a fix. A fix must be established on the outbound radial to fly toward. A possible preventive action: Fly the aircraft using VOR displaced on the HSI and use V NAV and heading on the flight director. Concentrate on course and altitude or use the autopilot to fly the aircraft using V NAV and heading while the L NAV fix is being set into the FMC."

If task difficulty is gauged by the amount of heated emotion conveyed by the reporter, then the task of intercepting a VOR radial and flying the radial *from* the VOR is clearly one of the leaders in complexity. Several reports, including the one just presented, reflect the opinion that the crew simply should *never* be given this type of clearance. It is not clear as to just how frequent this type of clearance is given, but the complexity that is apparently involved in figuring out how to set up the FMS to fly it clearly suggests that this task needs to be investigated in greater detail.

Given the higher than normal frequency with which these tasks appear in the ASRS reports, there may be some value in analyzing them in great detail in order to ascertain potential contributors to complexity, such as possible cognitive difficulties in identifying the required data to be entered into the CDU, problems in recognizing whether the correct information has actually been entered, and workload conflicts between performing this task and other tasks that need to be accomplished at the same time. These types of analyses could also suggest alternative ways for performing the task that could help to reduce their complexity.

It is, of course, possible (and likely) that some tasks appear frequently in the ASRS reports because they are commonly performed tasks and therefore, through the laws of chance, more likely to be the task being performed when an incident occurs, and not because they are more complex than other tasks. However, since they are common tasks, the same type of analysis would also be appropriate in that improvements that simplify the performance of commonly performed tasks could contribute to better use of the FMS.

4.1.2.8 Lack of Adequate Pilot Training

The review of the ASRS reports used in this study raises the question of how well trained are the pilots in the use and limitations of FMS, in particular the FMC/CDU. Although none of the reports dealt with training directly, many cited training as a factor in the incident's occurrence (see Table 4-2). Many of these pilots reported that they did not have a good understanding the of underlying logic and limitations of the FMS, and seemed to become easily confused and overloaded in high workload situations, when they continued to try and program the FMS. From the perspective offered by these reports, it appears that current pilot training does not accurately reflect real world needs in using the FMS relative to ATC requirements and the resulting high workload. The following report addresses this issue.

> (116912) "During IOE training (enroute PHL to CLE) was given clearance to cross 10 miles east of YNG Vortac at 24,000 feet. In discussion with check airman on best method to enter this information into the FMC, I decided to start down and then work on the FMC in the descent. I inadvertently selected 10,000 feet into the flight guidance system. Again, we went heads down to concentrate on the programming FMC for the descent path. Moments later, CLE center requested our altitude. We looked up as we were through 22,000. Leveled out at 21,000. We informed center, Weather was clear and center said to maintain 21,000. Apparently, there was no conflicting traffic. This is not a new problem. Automation has taken over in the cockpit. Computers are not learned overnight and (pilots) need hand on operating experience. It all comes back to fly the airplane first."

While this particular altitude excursion did not cause a serious problem, the reporter's observation that computers are not learned overnight indicates that he or she was uncomfortable with the training they had received. Another reporter described the experience this way:

> (110413) "This was my first trip on this aircraft without training people on board. This is still a brand new aircraft and none of the pilots have much exposure or experience flying people in it. We were on the Civet profile descent to runway 25L at LAX. Our crossing restriction was 14,000 feet to Civet. We misinterpreted our instruments and began descent to 10,000, believing we were inside Civet. At about 13,000 the LAX controller told us we had started down early and needed to maintain 14,000 to Civet. After rechecking our instruments, we realized that our DME reading was based on Fueler intersection instead of the LAX localizer DME. I feel this was an easy mistake to make based on our limited exposure to this aircraft. I find the glass cockpit a very difficult system to master and a frightfully easy way to make critical mistakes—at least when the pilot is new to it... A fix for this problem, I believe, is more training for the crews. Checkouts have become extremely costly forcing airlines to make them in the shortest time possible, which is understandable.

However, I think more training would help pilots with this extremely complex new flight system."

The reporter was contacted by ASRS to discuss the situation further and the reporter offered the following observations.

(110413) "The flight crew was very low on combined experience as the Captain only had 30 hours of experience including the 25 hours of IOE time. The reporter stated that his 15 hours he had as operating experience was three take offs and landings and the rest of the time was logged from the jump seat. The reporter feels this is too little exposure to the real world of operating a $125 million dollar aircraft and that he was overworked in the arrival and got confused as the Captain started the descent prematurely. He was of no assistance in preventing the deviation... The economics as practiced in this low training hours approach cannot be justified considering the possible results from the mix of low in type pilots in an ever changing and ever increasing complex environment. Providing the best in hands-on experience and training should be the goal and... first officers should obtain their operating experience in the seat they would normally function. Jump seat riding should not be considered for operating experience in this complex aircraft."

The training these pilots received seemed to focus on operating the system without considering the difficulties imposed by air traffic control and the associated workload. This is compounded further by the mixing of flight crews where both pilots are relatively inexperienced. This was an often cited occurrence in these reports.

(124912) "Finished (aircraft) checkout on 6/89. No position was available until 10/89. Flew the simulator in 9/89 for 90-day landing currency. You could say the fine points of working the FMC has escaped my memory. We were cruising at FL390 and received clearance to FL410. Captain loaded in mode control panel glareshield altitude at which point asked how he inputted the data for the climb. Neither of us were monitoring to confirm the climb to FL410. Several minutes later, center asked if we had climbed. "No, still at 290". The altitude had not been put in the FMC, and we were navigating with V NAV and L NAV. Both crew members low experience in type contributing to the altitude oversight. Factors affecting performance: 1) supervision management practice of putting two inexperienced crew members together; 2) just not monitoring/keeping track of crew's level of experience; and 3) after training crew member on advanced/automated cockpit, waiting an extended period before assignment to aircraft. Fly the aircraft."

In some of the selected ASRS reports, the reporter stated that the training on the FMS was clearly inadequate. Other reporters cited the combination of being new to the airplane, along with less than adequate training, as being particularly troublesome. The following report is descriptive of the problem of pilots being relatively new to the airplane.

(86894) "After (we got) airborne and at FL370, center clears us to FL290 when 40 miles (east) of Hancock. Last I knew, FMC was flying direct to Hancock as cleared. Both heads (of pilots) in cockpit trying to get descent into FMC when I look up and see aircraft has turned 90 degrees right to about a 180 heading… I switch to manual on VOR and dial in Hancock. I see we are 44 miles southeast of Hancock still at FL 370!… Captain and I discussed what happened and we still don't know. Factors affecting the problem: Rushing to get aircraft out on time, changing stored route to new filed route, trouble entering descent info/crossing restriction into the FMC, and both pilots relatively new to the aircraft (4 months each)… I'm going back to the ground instructors and ask for more information."

Pilots seem to be concerned with the fact that their training is not representative of how the FMS will have to be used operationally. The constraints of traffic congestion and multiple ATC clearances often appeared to make effective use of the FMS difficult. The use of FMSs requires a somewhat different approach to flying in that the pilot must know and understand what the system is capable of, and what its limitations are since once he or she enters a command, the FMS will theoretically do the rest. For example, one limitation may be that it is not productive to try and use the full capabilities of the FMS once the number of ATC instructions start to increase past a certain level. Other limitations may be due to the V NAV algorithms themselves: Since they were designed to optimize descent and climb profiles (in terms of being cost effective), they may not be suitable for all situations.

When a pilot is flying without a FMS, they are more likely to be aware that they are, or are not, meeting an ATC restriction or clearance since they are constantly managing the airplane to meet that goal; that is they are actively "in the control loop." The FMS, on the other hand, strives to meet that goal in the most efficient and economical manner without the same level of pilot involvement. The pilot's primary interface with the FMS is when data is entered or commands issued. In this situation it is easy for the pilots to rely on the FMS while they take care of other duties, but it is clear from these reports that use of the FMS does not appear to be suitable for every activity within every phase of flight. The training need for pilots would seem to be centered on how these systems should best be used under the operational circumstances that the pilots are most likely to encounter. As part of an overall training approach, controllers would also benefit from an increased awareness of the capabilities and limitations of FMS-equipped airplanes.

4.2 Hardware/Software-Related Errors

The data in Table 4-4 summarize the findings from a number of ASRS reports in which the flight crew believed (stated) that the FMS itself either failed or had a design flaw which influenced the incident's occurrence. Reported system performance errors involving FMS hardware were usually directly related to the failure of some component of the FMS. System performance errors attributed to software mistakes or design problems were more difficult to discover but usually involved reference to algorithms that either did not work as intended or were judged to be not well designed.

Table 4-4. Hardware/Software-Related Errors

Category	Incident Description	Citations
3	System performance errors (SPE)-attributed to hardware errors/failures.	15
4	System performance errors (SPE)-attributed to software mistakes/design problems.	17
10	Flight management system/mode control panel interaction errors.	3
11	Errors related to pre-stored databases/company routes.	15

Two types of reported errors that appear to create the greatest difficulties for the crew are:

- FMC/MCP interaction errors involving commands that were input into the FMC but were not properly executed.
- Errors relating to pre-stored databases that involved either the wrong information, or lack of specific information, being in the database.

4.2.1 FMC/MCP Interaction Errors

Several of the reports appear to indicate that the FMS can be programmed correctly, provide feedback to indicate this, yet still not perform as intended. In the example below, appropriate status information appeared to have been provided (e.g. top of descent circle) yet the FMS did not initiate the descent.

> (119740) "On August/Thursday/89, I was the captain on a large transport aircraft flight XX, LGA-DTW. Our routing was the LGA 3 SID out of LGA to Neon intersection J95 to Kooper direct Aylmer V-2 Rhyme direct DTW airport. We were enroute from Kooper to Aylmer at FL350 and were cleared to cross 15 east of Aylmer at FL310. We programmed 15 east of Aylmer at 310 in the FMC and set 310 in the mode control panel. A "top of descent" circle showed up on the screen depicting where the descent would begin. However, at the top of descent point, the aircraft did not descend and due to distracting conversation between us, neither I nor the first officer noticed it until we were about 20 miles east of Aylmer. I immediately started a fairly rapid descent of about 4000 feet per minute with speed brakes and saw we were not going to make 15 east Aylmer at FL310. I called CLE and said we started down too late and were not going to make 15 east Aylmer at 310. In fact, we were crossing 15 east Aylmer at 330. CLE said that's okay and gave us a frequency change. I don't know why, with everything apparently set in properly, the aircraft did not descend at the proper time. I feel the cause of this mistake is too much reliance

on automated systems and a lack of vigilance on my part as to the altitude and position of my aircraft."

If this is, in fact, what happened, there is little the crew can do to prevent the occurrence of an incident if the FMS fails to "behave" as programmed. By the time the crew detects a problem (e.g. failure to begin a descent or level off), it may be too late to compensate.

4.2.2 Inaccurate Pre-Stored Databases

A number of reports describe errors stemming from the use of pre-stored databases that contained incorrect information. Holding patterns and crossing fixes based on DME values often were depicted differently from what was shown on the charts or what was expected by ATC. For example, one report stated:

> (104874) "(We were) Cleared to hold at Colax intersection on the Scurry Arrival into Dallas Fort Worth (DFW). (We) Entered the hold into the FMC/CDU. The FMC/CDU displayed the holding pattern automatically and (we) entered the hold as displayed. However, the pattern displayed on the control display unit (CDU) was for a standard hold while the actual pattern at Colax is a non-standard pattern (left turns)... We entered holding for a standard pattern rather than the depicted non standard pattern... It was a mistake that was prompted probably by two reasons: 1) believing that the computer generated pattern was correct and 2) not catching the difference when checking the arrival plate."

This report is typical of the types of reported errors relating to pre-programmed navigational data contained in the FMS. Incidents related to pre-stored navigation routings and fixes were associated with 15% of the 99 reports. These types of errors are particularly difficult to recognize. The only practical way for a pilot to discover the existence of this type of fault, before an event occurs, is to compare the computer generated navigational image (on both the Navigation Display and the CDU) against the information contained in the paper navigational charts. Once the problem has been discovered, the flight crew often still had difficulty responding to the ATC clearance correctly or in a timely manner because typically they would do one or all of the following:

- Try to find the fix in the computer;
- Start looking for the fix on their charts once they discovered that it was not in the FMS database, or was wrong;
- Try to program the correct information into the FMC/CDU.

Performing these additional procedures results in an increase in the pilot's workload at a time when workload is likely to be already increasing. Some pilots also pointed out that the need to verify every fix and holding pattern eliminated some of the advantage of having these data stored in an onboard database.

Coping with an incorrect or missing fix or holding pattern can be particularly difficult if it occurs during a high workload situation, as demonstrated in the following case where a navigation fix being used as a holding point was not included in the FMS database.

> (117306) "...Among scattered cumulus and thunderstorms, on autopilot, FMS lateral and vertical navigation engaged, and level at 11,000 feet... Approach control issued us holding instructions for the Krena Intersection, as published, 11,000. The Captain requested right turns in the pattern due to a thunderstorm cell and the request was granted. As the Captain entering the hold into the FMS, the aircraft ahead of us requested holding at Popps Intersection due to the thunderstorm at Krena... The controller then assigned us holding at Popps. We glanced at our charts, located Popps, and the Captain tried to enter it as a waypoint in the FMS. The FMS rejected it as not in the database. By the time we determined the distance for the Northbrook VOR to Popps, and had switched to VOR mode, we were two to three miles past Popps... The problem arose from, I feel, three factors; 1) late issuance of holding instructions for Popps, 2) Popps not programmed in the database of our FMS, and 3) our dependence on FMS navigation and slow changeover to the NAV-VOR mode."

In this incident, the crew reported having a difficult time keeping abreast of the situation due to changing weather considerations, other traffic entering the hold, and the resulting ATC instructions. As in other reports, the pilots assumed responsibility for the incident because they felt they did not respond quickly enough by returning to basic VOR navigation once they were aware that the fix was not in the computer.

The data in Table 4-5 provide insight as to where the pre-stored database routes and navigation fixes caused problems in the course of a flight.

Table 4-5. Errors Related to Pre-Stored Databases/Company Routes

Phase of Flight	Citations
SID	3
Transition	1
Enroute	4
Crossing Restrictions	3
Holding	5
Descent	2
STAR	1
Approach	1

Of particular interest is the fact that five of the six holding pattern problems included in Table 4-3 (Phase of Flight) were caused by erroneous information being stored in the database. As pointed out earlier, the ATC clearance would direct the flight to hold at a fix as depicted. Based on the ATC clearance, the flight crew would program the FMS/CDU to call up and initiate the hold. Subsequently, ATC would then inform them they were conducting the hold with turns opposite that charted. The main concern expressed by the pilots who experienced the problem of not having the fix correctly entered into the pre-stored database was twofold:

- First, they typically reported that they found themselves surprised and had to rush to find the appropriate paper charts to verify where they should be going or what fix they should be using.
- Secondly, this problem, once experienced, often led the pilots to be highly skeptical of the comprehensiveness of the FMS database and/or the systems ability to readily access these data.

4.2.3 Distribution of Incidents Across Aircraft Type

A final question that needs to be addressed concerns the issue of whether one type of aircraft/ FMS configuration is responsible for the majority of FMS-related incidents. A good deal of discussion, in previous ASRS studies and other sources, has been devoted to the problems with altitude busts in medium large transport aircraft. If this is the case, the conclusion could be made that FMS-related problems are specific to that aircraft/FMS combination. To evaluate this belief, the distribution of incidents across aircraft type, by weight class, was compiled. The data in Table 4-6 show the results. As the table suggests, there appears to be an even distribution of incidents between the MLG and the LRG/WDB classes of aircraft.

Table 4-6. Aircraft Type

Aircraft Type	Citations
LTT - Light Transport Aircraft (14.5 to 30 k.lbs.)	2
MLG - Medium Large Transport (60 - 150 k.lbs.)	50
LRG - Large Transport Aircraft (150 - 300 k.lbs.)	23
WDB - Wide Body Transport.	24

The light transport airplanes (LTT) in this data set most likely represent corporate turbojet aircraft with advanced automation cockpit features. They were included because the advanced automation technology features are not limited to only air carrier airplanes, and the reported equipment problems are similar to those experienced in the larger commercial transport aircraft. Medium large transports (MLG) include aircraft such as DC-9/MD-80's and Boeing 737s. The large transport category (LRG) includes aircraft such as the Boeing

757 and the Airbus A-300, while the wide body transport (WDB) category includes the Boeing 767, Boeing 747, and Airbus A-320.

Table 4-7 shows that these data appear to indicate that the problems with FMSs are generic in terms of both phase of flight and specific FMS.

Table 4-7. Number of Citations by Aircraft Type

	Aircraft Activity		
Aircraft Type	Climb	Crossing Restriction	Descent
MLG	10	15	7
LRG/WDB	11	15	7

5. CONCLUSIONS

While the sample of ASRS reports, reviewed in this study, cannot be said to be statistically representative of all FMS-related incidents, it does offer a useful perspective as to what types of problems are occurring as a result of the use of FMSs in the National Airspace System. These reports provide insight into problems that air carrier (and/or corporate) pilots are having with FMSs that would not be available from any other perspective or source. The advantage of evaluating ASRS reports such as these is that the insight gained can be used to determine where, and what type of, operational problems exist with these systems "on the line" along with an estimate of developing trends.

The major issues associated with the FMS-related incidents, addressed in this analysis, include:

- Raw Data and FMS/Aircraft Status Verification
- FMS Algorithmic "Behavior"
- Improper Use of the FMC Automation Level
- FMC Programming Demands
- Multiple FMC Page Monitoring Requirements
- Complex ATC Clearances
- Complex FMC/CDU Tasks
- Lack of Adequate Pilot Training
- FMC/MCP Interaction Errors
- Inaccurate Pre-Stored Databases

All of these factors, singly or together, can combine to increase the pilots' workload to the point that they lose their situational awareness and "get behind the airplane." In this situation, the pilot who continues to focus on trying to understand what the FMC/CDU is doing is no longer truly involved in flying the airplane, but trying to troubleshoot a computer that happens to be installed in an airplane. The pilots that did best with FMS-related problems, in high workload situations, were those that elected to reduce the level of automation (by turning OFF the selected function) and appeared to recognize that they needed to become actively involved in flying the airplane.

From these reports, it is clear that the current FMSs have not been designed for optimal use under all circumstances, by the flight crew, in the environment where ATC is heavily burdened and expects pilots to remain flexible and responsive to their changing needs of moving traffic. Based on this analysis, it would appear that pilots should not try to use the full features of the FMS under all conditions. Many of the pilots submitting these reports learned that fact, but only after they experienced the incident that initiated the ASRS report. This lends credence to those pilots who argued that the training they received was not adequate to prepare them for using these systems operationally.

Problems attributed to the FMS design/user interface were also found in many of the reports. The most commonly reported problem area was the vertical navigation capability of these systems. The algorithms for climb and descent seem to be predicated on the most efficient, hence most rapid, climb to and descent from altitude. Thus it would appear that these algorithms have been developed in such a manner that they leave little margin for error if the system does not initiate actions as expected. In terms of utility, it might be wise to relax the stringent rules and criteria that were used for developing the software implemented algorithms, and provide a wider bandwidth for operational application.

Other system/operational related problems include the FMS database not including fixes used by ATC or having the wrong fixes or flight routings. While the majority of these deficiencies are likely to be identified by the pilots through initial checklists and verification procedures, the difficulty arises when ATC changes clearances when the aircraft is in the air and the flight crew tries to enter the new fix, then finds that it is not in the database. Many times the crew will continue to try and find the fix in the database rather than locate the fix on the charts. This wasted valuable time which sometimes caused the clearance to not be achievable by the flight crew. The point was also made that ATC should be encouraged to use fixes for clearances that are contained within the FMS database, or should specify fixes along the current flight path, instead of fixes that have already been passed (and therefore dropped from the current route/path).

Recognition and understanding of the nature of the existing problems, such as those identified and described in this report, is the first step in finding solutions and making recommendations for design changes that will make FMSs work better, and be less prone to flight crew error.

6. RECOMMENDATIONS

Two types of recommendations are provided. The first type offers suggestions for how the results of this study should be used to guide the Description and Characterization study that is currently in progress. The second set of recommendations are more global in nature, suggesting changes in the overall FMS "use environment," including suggested additions to crew training and modifications to ATC procedures.

6.1 Design-Related Recommendations

This analysis of the FMS-related incident reports from the ASRS database has provided a valuable look at the problems crews are having with current FMSs. On the basis of this review, the following recommendations suggest how the Description and Characterization study can be focused to concentrate on those issues that appear to have special importance.

1) A common problem involves selection of the appropriate level of automation to be used for a given task. As Section 4.1.2.3 clearly points out, flight crews appear reluctant to use a mode other than the V NAV and L NAV provided by the FMC. Consequently, it would be of value to analyze the FMS *as a system* which is comprised of multiple automation levels (flight director, autopilot, FMC). Each of these levels needs to be clearly understood in terms of the procedures required to utilize that automation level, steps used to move from one automation level to another, and any constraints imposed by one automation level onto another. As a specific example, the relationship of the autothrottle to vertical and lateral path control needs to be examined. Several reports suggested that the crew did not understand the logic of the autothrottle as it is influenced by the automation levels controlling the lateral and vertical performance modes. It appears that many flight crew simply do not understand how the various subsystems contribute to the overall functioning of the FMS.

2) As a supplement to the first recommendation, a task-oriented analysis should be performed that would involve identifying alternative ways of performing the same task, and the conditions under which each alternative is preferred. Many of the incidents in the ASRS reports occurred because the crew chose a poor alternative over one that would have been more effective. This analysis might aid in understanding the decision making process that must be performed in order to correctly choose how to perform a given task.

3) Feedback sources for each automation level, and for each task, need to be specified. A major concern for many flight crews is the inability to effectively predict and understand what the FMS is doing. Issues of adequate and meaningful feedback need to be addressed.

4) As a supplement to the third recommendation, the role of the algorithms as they affect the "behavior" of the aircraft also needs to be examined. A number of problems with

vertical navigation appear to be the result of the crew's inability to adequately take into account the temporal contributions of the algorithms in predicting the short-term and long-term responses of the aircraft.

5) Section 4.1.2.7 argued that some tasks appear to be more difficult to perform than others. An analysis of the procedures required to perform these apparently complex tasks may enable a better understanding of the sources of the complexity to be achieved. The vast literature on user-computer interaction should be applied to the FMC/CDU in order to determine what elements of screen design and system logic appear to be problematic.

6) The number of screens that have to be reviewed in performing some tasks also is an important issue. There is an obvious need to review the overall organization and layout of information across pages, and the means for navigating from one screen to another, in order to determine the contributions of these factors to the complexity of the task.

7) The evaluation of feedback sources needs to be addressed within the context of problems that can arise as a result of incorrect or missing data in the database. Clearly, the obvious solution to this problem is to ensure that all of the data is there and that it is correct. This, however, may not be a totally achievable solution. Consequently, the question arises as to how the crew can be helped to more quickly recognize the existence of the problem in order to give them additional time to cope.

8) Finally, a tool (or tools) that would allow an overall assessment of how easy a specific FMS is to use would have great value, especially as a means for evaluating new FMSs when they are presented for certification. This recommendation may be an ideal that is not achievable at this time but, at the very least, attempts to develop such a tool that would support the identification of factors that contribute to complexity. This secondary goal would support attempts to design FMSs that are easier to use on the basis of established principles that define complexity and the conditions that contribute to it.

6.2 Global Recommendations

1) Training of pilots flying FMS-equipped airplanes needs to be representative of the problems that are likely to be encountered operationally, especially those actions and activities related to working with ATC. This might include such approaches as numerous LOFT scenarios based on real world clearances and problems that impact FMS utilization, programming/re-programming, automation management and overall situation awareness, as part of the overall training curriculum.

   The need for this intensive training could potentially be reduced by re-design of the FMC/CDU mode/screen logic to incorporate a better human-computer interface. This could be possible through the use of prompts that "lead" the pilot through the sequential steps necessary to program or implement the desired clearance or action.

2) Based on the pilots' comments in the ASRS reports, it would appear that it is not a good practice to assign two pilots with low experience in FMS-equipped airplanes to the same flight crew. Because of the complexities associated with using the current FMSs, experience (in terms of hands-on operational use) with the FMS appears to be the best measure of how well the flight crew can use the FMS to accomplish the assigned tasks.

3) The current V NAV climb/descent algorithms need to be re-programmed to "soften" the climb or descent during the last 1,000 feet. These algorithmic changes will give the pilots a little more flexibility in recognizing potential problems without compromising the efficiency (i.e., cost) of the flight to a great degree. Changes in the way that the algorithms are structured and the way that they are executed should also eliminate the need to use excessive vertical speed to accomplish the climb or descent.

4) The operational demands (from both cognitive and visual workload perspectives) on the two-pilot crew, both in the enroute environment and the high workload terminal environment, need to be considered in the design and certification of FMSs. This is especially necessary with regard to the user interface (in terms of screen layout and navigation), the automation selection algorithms, and the placement of the feedback information. The location and manner of presentation of critical information is an important design issue that needs to be looked at. This will determine the appropriate place to put pilot feedback information with respect to the mode that the aircraft/FMS is actually in at any point.

5) There is a need to investigate the feasibility of providing a "preferred fix" list to the ATC facilities. This list would be provided by the same commercial firms that currently provide the database and database updates for the air carriers' FMSs. The resultant improvement in the flight crews' ability to program/re-program the FMS to accomplish the requested clearance based on the use of common well-defined fixes will positively impact the efficiency of ATC operations involving FMS-equipped airplanes.

7) The Enroute/Terminal air traffic controllers should receive some training on the strengths and limitations of FMS-equipped airplanes. How best to plan for these considerations when controlling FMS-equipped aircraft in their airspace should also be stressed.

8) The feasibility of improving the error checking/notification logic of the FMS should be evaluated. One particular concern is the pilot's ability to make erroneous fix entries which are accepted simply because they are contained in the database, but are not valid for that particular flight.

There is little question that the inclusion of FMS technology in modern air carrier aircraft has been extremely advantageous and has provided improvements in both efficiency and safety of operation. However, since the FMS design-related issues raised in this report are considered representative of the types of problems that currently exist, it is important that a thorough description/characterization analysis of the existing FMSs be performed. This will ensure that the potential user interface and logic problems that appear to exist in the current systems are understood. Furthermore, it is recognized that some of the potential sources of pilot error, in the newer systems, are difficult to recognize until a significant amount of experience has been gained in the use of the FMS technology. For example, as of this report, there are only a few entries in the ASRS database concerning the use of the highly controlled, highly automated Flight Management Guidance System on the A320 aircraft. It is assumed that as more experience is gained with the A320 FMGS system in the NAS, there will be an increased number of reported issues and incidents in the ASRS database. For these reasons, the ASRS database, as well as other sources, should be reviewed periodically in order to identify trends in FMS-related incidents. For example, there appear to be well over 200 entries in this category for the year, 1990, as compared to approximately 170 reports for 1989.

The primary goal should be the continued improvement of FMSs in such a manner that the flight crews should not have to interpret "what" the system is going to do, or "how" to implement a specific time-critical, short-term task. Instead, the FMS should be designed so that programming logics and procedures are easy to implement and appropriate feedback is available to keep the pilot/flight crew constantly aware of what the system is doing.

APPENDIX A

ASRS REPORT ANALYSIS SUMMARY

	A	B	C	D	E	F	G	H	I	J	K
1	Report	Accession numbi	Date	Aircraft type	Total	1] kb	2] logic	3] spe hdwr	4] spe sftwr	5] ATC expt	6] FMC expt
2	88:2	80388	8801	WDB	1	1				1	
3	88:3	80463	8801	LRG	1					1	
4	88:5	80652	8801	LRG	1						
5	88:9	81597	8802	LRG	1						
6	88:10	81969	8802	MLG	1			1			
7	88:11	82259	8802	LRG	1	1					
8	88:13	82622	8802	WDB	1				1		
9	88:15	82921	8803	LTT	1			1			
10	88:20	83690	8803	MLG	1					1	
11	88:22	83932	8803	MLG	1					1	
12	88:23	83994	8803	LTT	1			1			
13	88:26	84576	8803	WDB	1						
14	88:28	85126	8804	WDB	1			1			
15	88:29	85157	8804	MLG	1				1		1
16	88:32	86152	8804	MLG	1					1	
17	88:34	86734	8804	MLG	1			1			
18	88:35	86759	8804	LRG	1			1			
19	88:36	86894	8805	MLG	1		1				
20	88:37	86946	8805	MLG	1			1			
21	88:38	87045	8805	MLG	1						
22	88:41	87184	8805	MLG	1			1			
23	88:43	87268	8805	MLG	1				1		
24	88:44	87569	8805	WDB	1			1			
25	88:45	87750	8805	LRG	1						
26	88:46	88210	8805	LRG	1				1		
27	88:47	88652	8806	WDB	1				1		1
28	88:48	88713	8806	WDB	1			1			
29	88:49	89101	8806	MLG	1						
30	88:51	89620	8806	MLG	1			1			
31	88:53	89995	8806	MLG	1			1			
32	88:54	90069	8806	MLG	1						
33	88:55	90211	8807	LRG	1					1	
34	88:56	90246	8807	MLG	1						1
35	88:57	90386	8807	WDB	1						1
36	88:58	90740	8807	MLG	1					1	
37	88:60	91422	8807	MLG	1						

	A	B	C	D	E	F	G	H	I	J	K
38	89:12	104874	8902	WDB	1						
39	89:23	107421	8903	LRG	1				1		
40	89:25	107738	8904	WDB	1	1				1	
41	89:27	107916	8904	MLG	1					1	
42	89:28	107922	8904	LRG	1	1				1	
43	89:30	108107	8904	WDB	1					1	1
44	89:32	108361	8904	WDB	1						1
45	89:34	108752	8904	WDB	1					1	
46	89:35	108763	8904	WDB	1			1			
47	89:47	110142	8905	MLG	1	1		1			
48	89:48	110413	8905	WDB	1						1
49	89:50	110571	8905	MLG	1						
50	89:51	110778	8905	MLG	1				1	1	
51	89:55	111415	8905	MLG	1						
52	89:58	112283	8905	MLG	1	1	1				
53	89:59	112881	8906	MLG	1	1					
54	89:60	112925	8905	WDB	1						1
55	89:61	112939	8906	MLG	1				1		
56	89:62	112968	8906	LRG	1				1		1
57	89:63	113210	8906	MLG	1						1
58	89:65	113594	8906	MLG	1	1					
59	89:66	113722	8906	MLG	1				1		1
60	89:71	114289	8906	MLG	1						
61	89:72	114392	8906	MLG	1						
62	89:73	114409	8906	LRG	1				1		1
63	89:77	116429	8907	LRG	1			1			
64	89:78	116474	8907	LRG	1			1			
65	89:79	116871	8907	MLG	1						1
66	89:80	116912	8907	MLG	1	1					
67	89:81	117306	8907	WDB	1						1
68	89:83	117395	8907	MLG	1						
69	89:87	118257	8907	WDB	1						
70	89:93	119740	8908	LRG	1				1		
71	89:96	119836	8908	LRG	1						
72	89:98	120121	8908	MLG	1				1		
73	89:100	120705	8908	MLG	1	1					
74	89:103	121365	8908	MLG	1						

	A	B	C	D	E	F	G	H	I	J	K
75	89:104	121873	8909	LRG	1	1					
76	89:105	122020	8909	LRG	1						
77	89:106	122307	8909	MLG	1						
78	89:114	122778	8909	LRG	1						1
79	89:116	123182	8909	WDB	1						1
80	89:118	123705	8909	MLG	1						1
81	89:125	124225	8910	MLG	1						
82	89:126	124540	8910	MLG	1						1
83	89:127	124641	8910	WDB	1		1				
84	89:129	124912	8910	LRG	1						
85	89:132	125379	8910	MLG	1						1
86	89:134	125410	8910	MLG	1						1
87	89:139	126140	8910	LRG	1				1		
88	89:140	126180	8910	WDB	1	1				1	
89	89:141	126262	8910	MLG	1	1				1	
90	89:144	126707	8910	MLG	1				1		1
91	89:145	126842	8910	MLG	1						1
92	89:150	128009	8911	WDB	1						
93	89:152	128632	8911	MLG	1	1					
94	89:155	128735	8911	LRG	1	1					
95	89:163	129915	8912	MLG	1	1					1
96	89:164	130037	8911	MLG	1						1
97	89:166	130487	8912	WDB	1						
98	89:169	130630	8912	LRG	1						
99	89:170	130700	8912	MLG	1						
100	89:172	130858	8912	WDB	1				1		

	L	M	N	O	P	Q	R	S
1	7] wkld>10	8] wkld<10	9] mcp	10] fms/mcp	11] datbas	12] phase	13] trng	14] hold
2	1					crossing		
3						climb		
4					1	SID		
5					1	descent		1
6						crossing		
7						enroute		
8						crossing		
9						climb		
10						enroute		
11						descent		
12						approach		
13			1			crossing		
14						climb		
15						crossing		
16		1				SID		
17		1				SID		
18						climb		
19		1				enroute	1	
20						crossing		
21			1			climb		
22						enroute		
23						approach		
24			1			climb		
25			1			descent	1	
26						descent		
27					1	SID		
28		1				SID		
29			1			climb		
30						descent	1	
31						climb		
32						climb	1	
33						descent		
34	1					enroute		
35					1	SID		
36						approach		
37			1			STAR		

	L	M	N	O	P	Q	R	S
38					1	descent		1
39	1			1		climb		
40	1					crossing		
41						crossing		
42						enroute		
43						crossing		
44						enroute		
45	1					crossing		
46	1					enroute		
47				1		climb		
48						descent	1	
49						crossing		
50						crossing		
51					1	crossing		
52	1					crossing		
53						enroute		
54	1			1		crossing		
55		1				SID		
56						climb	1	
57						crossing	1	
58						transition	1	
59						climb		
60					1	transition		
61			1			descent	1	
62						climb		
63				1		climb		
64						crossing		
65						descent	1	
66						descent	1	
67					1	approach		1
68			1			crossing		
69					1	enroute		
70						crossing		
71			1			climb		
72						crossing		
73						enroute		
74			1			climb		

	L	M	N	O	P	Q	R	S
75	1				1	descent		1
76			1			descent		
77			1			STAR		
78			1			crossing		
79		1				SID		
80						crossing		
81					1	enroute		
82						enroute		
83						crossing		
84			1			climb	1	
85			1			crossing		
86						climb		
87						enroute		1
88						enroute		
89						enroute		
90						crossing		
91			1			climb		
92					1	enroute		
93						climb		
94					1	crossing		
95	1					crossing		
96					1	crossing		
97					1	enroute		1
98	1		1			crossing		
99			1			descent		
100						crossing		

APPENDIX B

II-1 1988 ASRS REPORT DATABASE
II-2 1989 ASRS REPORT DATABASE

	A	B	C	D	E
1	Report	Accession Number	Date	Aircraft Type	Oprtnl Err Type
2	:2	:80388	:8801	:WDB	
3	:3	:80463	:8801	:LRG	
4	:5	:80652	:8801	:LRG	
5	:9	:81597	:8802	:LRG	
6	:10	:81969	:8802	:MLG	
7	:11	:82259	:8802	:LRG	
8	:13	:82622	:8802	:WDB	
9	:15	:82921	:8803	:LTT	
10	:20	:83690	:8803	:MLG	
11	:22	:83932	:8803	:MLG	
12	:23	:83994	:8803	:LTT	
13	:26	:84576	:8803	:WDB	
14	:28	:85126	:8804	:WDB	
15	:29	:85157	:8804	:MLG	
16	:32	:86152	:8804	:MLG	
17	:34	:86734	:8804	:MLG	
18	:35	:86759	:8804	:LRG	
19	:36	:86894	:8805	:MLG	
20	:37	:86946	:8805	:MLG	
21	:38	:87045	:8805	:MLG	
22	:41	:87184	:8805	:MLG	
23	:43	:87268	:8805	:MLG	
24	:44	:87569	:8805	:WDB	
25	:45	:87750	:8805	:LRG	
26	:46	:88210	:8805	:LRG	
27	:47	:88652	:8806	:WDB	
28	:48	:88713	:8806	:WDB	
29	:49	:89101	:8806	:MLG	
30	:51	:89620	:8806	:MLG	
31	:53	:89995	:8806	:MLG	
32	:54	:90069	:8806	:MLG	
33	:55	:90211	:8807	:LRG	
34	:56	:90246	:8807	:MLG	
35	:57	:90386	:8807	:WDB	
36	:58	:90740	:8807	:MLG	
37	:60	:91422	:8807	:MLG	

	F
1	Synopsis
2	Clrnc Interpretation of Alt. crossing rstrctn resulted in missing crossing point 25 DME
3	LGT given a clb to higher alt with time limit for exec.\Cntrlr had to give hdg vector for seperatn
4	Aircraft LRG track deviation on departure
5	Acft deviated frm pblshd Hold pttrn - crew used FMS pttrn NOT pblshd Aero Chart Enrte High Alt
6	Acft MLG alt deviation undershot Alt Crossing Restriction during descent
7	Crew prgrmd FMC in Error\Instead of plotting Airways FMC plotted direct rte to KLAX airport
8	Failed to make Crossing Restriction
9	Acft LTT Alt Deviation overshot during climb
10	Crew prgrmd FMC using strd rte\clrnc was for different rte\Cntrlr advsd on wrng rte\60 NM off Crse
11	Alt overshot on descent when change in maintain Alt missed by the PF
12	Corp. LTT Overshot Alt in Descent
13	Missed crossing rstrctn account FMS rvrtd to VNAV and was not noticed by flt crew
14	WDB in Cruise set FMS to climb from FL330 to FL350. Began descent to 3500' instead
15	ACR MLG Alt Deviation overshot during descent into DFW
16	Acft failed to comply with Altitude crossing restriction
17	ACR MLG overshot crossing rstrctn Alt causing less than std Sep with preceding MLG
18	AdvancedTechnology LGT overshot Alt in Automatic Mode
19	Failed to comply with clrnc crossing rstrctn while attempting to program to FMC
20	During Descent MLG overshot assignedAlt by 200'
21	Alt overshot on climb when FMC not properly programmed
22	FMS problem causes acft to turn 8 miles off course
23	Failed to make crossing restriction when FMC dropped the DME distance
24	ACR LGT in Auto Mode failed to capture and overshot Alt.
25	ACR LGT non adherence to ATC Clrnc. Flt crew failed to start descent after clrnc readback
26	Advanced Technology ACR MLG undershot crossing restriction on descent
27	Due to faulty MAP alignment of FMC display ACR WDB incurred trk deviation on Departure
28	ACR WDB with equipment prblm distractd Plt and resulted in trk deviation
29	ACR MLG ovrshot Alt resulting in less than standard seperation
30	ACR MLG Alt deviation crossing restriction not met
31	MLG overshoots assigned Alt causing less than standard seperation
32	Alt overshot on climbout
33	ACR LGT Alt Deviation-late starting descent then overshot amended clrnc Alt.
34	Autothrottles disconnected resulting in autoplt changing modes andalt excursion of 400'
35	ACR WDB overshot Turn on SID
36	MLG unsure crssng Alt at Menlo INTXN on TIP TOE vis apprch, made Alt OK but 2 fst w spd dev
37	ACR MLG Alt deviation heading deviation from STAR into DFW

	G
1	Clearance
2	Crossing restriction: 50 S of PVD at FL250\vector 30 deg turn-turn to 110 deg Hdg\PVD at 11000
3	Crew rqstd FL410 from ABQ ARTCC\Given FL410 in 4 minutes
4	6 NM S SEA-TAC clrd to trn left to 130 to intrcpt SUMMA 2 Dep as filed\Rght vctr for terrain clrnc
5	inbnd to BOS from S clrnc to Hold at SCUPP (pblshd Hold = E of SCUPP with left turns)
6	Crossing Restriction of 35 SW of BLD VORTAC at 15000
7	Enroute SFO to LAX As filed
8	Ten NM N of Dayton VOR clrd to Cross 50 NM N of Dayton VOR at FL240
9	Given HDG vctrs, a 250 Kt spdrstrctn and a clb to 12000
10	Cancun Clrnc differnt thn cmpny rte:CUN A26E PARRA UA26 SWORD A26 GNI MEI LGCG ATL
11	10000 dsndng\clrnc to LGA VOR-clrd to 6000\4000 chngd to 6000
12	25 NM SE of SJC Rwy 30L LOC-Dscndng to maintain 10000
13	Assngd Alt FL350\ATC clrd to FL270 to cross FL290 in 2 mins or less
14	In Cruise at FL330 using FMS and Autopilot\MEM Cntr clrd to FL350
15	Appchng DFW on BOIDS 9 Arr\Clrnc to cross PIVOT INTXN at 11000 and 250 kts
16	SJC 4 Dep, AVENAL Trans. clb/maintain FL230\Crs 005 deg R of SJC VOR at or blw 5000
17	SJC 4 Dep, AVENAL Trans, clb/maintain FL230\Crs 005 deg R of SJC VOR at or blw 5000
18	Clrd from FL310 to FL350
19	At FL370 clrd direct to Hancock\then clrd to FL290 when 40 NM E of Hancock
20	Initially clrd to cross KUBBS INTXN at 10000\cntrlr chngd clrnc to 11000
21	climb and maintain FL220
22	Dprtd Gordonsville VOR on J75 Rte\Approx 20 NM SW of G VOR acft strtd slo L turn - Draik Intxn
23	clrd to cross 25 NM NE SAX VOR at 7000
24	Climb to FL310
25	Cmpltd VNAVdscnt to FL270-Given a vector hdg & clrnc to dscnd to FL240
26	Enrte MIA-DCA-using offset LNAV for TSTMS Dev-clrnc to cross 40 NM S of CVI at FL330
27	JFK Rwy 31L-Kennedy 1 dep, Breezy Point clb
28	Clrd via Prado Dep frm Rwy 26R-clb to 2000-L clb trn to PDZ VOR\Acft had cptr/ectrcl prblms
29	during clbout from CVG approx 13-14000-clbng to FL230\clrnc direct HMV rstrctn to 19000
30	clrnc: 20 NM W of AML VOR at 11000
31	Clbng enrte TUS-LAS out of FL230 assigned FL290 for crossing traffic at FL310-Filed at FL350
32	Dep from CLE-LAX-clrd to clb to 6000 on vctrs\at 5000 clbng 2800 fpmclrd fly hdg intrcpt alrwy
33	FL 410, about 110 NM S of RIC clrnc: dscnd to cross 80 NM S of RIC at FL270\ltr expdt thru FL350
34	Enrte SAT-ATL at FL330
35	SJC 4 rwy 30L dep using FMS/moving MAP dsply for LNAV-1st turn at 4 NM
36	Big Sur Profile dscnt SFO rwy 28-apprchng Menlo-clrd to crs Menlo at/abv 4000 & 170 kts
37	Apprchng DFW from SW assigned 11000 & delete SPDS on STAR

	H
1	Crew Action
2	Prgrmd FL250 25 S of PVD-began Des\Crew distracted by F/A-Meals\Acft slowed-leveled off
3	FL410 entrd MCP\FL410 entrd CRS page & Exec.\Hdg vctr left to 340 at FL406\Clrd drct Meinz
4	As fild expctd inrcpt of 143 SEA radial frm 130 hdg then to SUMMA & dep as filed
5	Calld up Hold on FMS\ Hold dpctd S of fix w stndrd right trns\drct entry to Hold frm S w 20 NM lgs
6	Prgrmd FMC for crsng rstrctn/verified on FMC CDU
7	Flight plan was After AVE-J1-LX\FMS accepted routing was AVE-J1-KLAX (airport)
8	PF cmptd dstnc frm KLINE VOR since acft had pssd Dayton VOR\PNF reclcltd frm Dayton VOR
9	Autopilot cpld\MCP prgmd fr Alt Cptr & HDG Trk\Anti-Ice slctd\4000'rate of clb to mntn 250 kts
10	Entered CUN-ATL cmpny rte\dprtd & trnd on crse 011 deg R towards ROBIN INTXN
11	PF dscndng thru 5000 to 4000 assgnd\PF did not hear Alt rstrctn when clrd to VOR
12	Drng dscnt crew reviewng App Plt for ILS Appch-acft dscndd thru 8600\Alt crrctd-ATC advsd
13	Capt init dscnt w 1700 fpm then 3000 fpm\then prgrmd FMS-chngd dsnt mode frm vert spd to other
14	Slctd FL350 on FMS-engagd VNAV\F/O chngd Alt Alrt Slctr to 35000\Acft bgn dscnt 1000 fpm
15	In dsnt with autoplt-IAS mode &11000 armd\at 12500 ATC rqst to xpdt dsnt\incrs 1500 to 2500 fpm
16	Slctd FIX page of FMC\entrd SJC VOR for cont brng/dist\Passing 6000 & clbng fast\ATC cmplnt
17	5000 set and armed in DFGS #2\Alt Alrt at 5400-clbng at 4000-5000fpm\A/P dscnct-lvl off at 6300
18	FMC in FL CH Mode\new Alt slctd on MCP & FMC\Alt Arm Annunc - system didn't chng to Alt. Cptr
19	Both crew attmpt prgrm FMC w dscnt info\acft trnd 90 R to 180 hdg\swtchd to hdg mode & turn E.
20	PF usd v/s-clsd Thrtls- extndd spdbrks fr rpd dscnt to mke alt rstrctn\entrd new rstrctn in Alt wndw
21	PNF set 220 in MCP\PNF ack FL220\PNF left ATC Freq to get ATIS info\acft lvld at FL230
22	Plts saw crs error as acft 8 NM off crs\Turn to 270 Deg init-acftrtrnd to J75 cntrlne
23	Inserted downtrack fix in cptr-checked by crew for accuarcy
24	Acft climbed through assigned altitude (31000) stopped clb manually at 31400
25	Ack clrnc-reset Alt Alrtr on MCP to 24000-Pulled up Crz page on FMC-entrd FL240 & Exec
26	Fix created/entered into VNAV on a crossing rstrctn-Top of descent (T/D) pnt creatd by cmptr
27	trnd L to CRI-PNF slctd Drct To CRI in CDU-PF fllwd cmd bars to CRI whch shwd strt ahd on HSI's
28	acft clbd strt ahead to 4000-forgot 2000 L clbng turn\dstrctd by cptr/elec prblm-ATC clld
29	Nav cptr prgmd Direct HMV\chngd to 29.92 at 18000\did not reset trgt Alt on Alt Alrtr to new alt
30	didn't meet rstrctn-12000 at 20 NM W AML VOR due to slo spool up time of cptr to calc time/rate
31	at arnd FL 260 gvn Drct Bldr Cty VOR-PF strtd setup drct (rnav)\PNF chart wrk-1000' Alt wrng hrn
32	PNF new hdg hdg bug-slctd LEGS page-prgrmd intrcpt angle\acft clbd to 6600-Alt wrnng at 6300
33	Dscndng thru 350 to 270\cntrlr gave vctr 40 deg L & rtrn to crs-cntrlr said clrnc was to 350 & mntn
34	FMS Nav & Spd enggd-PF prgm rte intrcpt on FMS-PNF dsengged A/T to cpy nmbr for eng log
35	used VOR/DME to chk dstnc-at 5 NM-missed 4 NM turn\MAP dsply didn't shw crrct
36	Capt thght clrnc at/blw 4000-discussion with f/o-used spoilrs/gear to get to 4000 but at 235 kts
37	PF selected Pitch mode on FGS-A/P thru pitch cntl seeks to maintain spd at time of slct

	I
1	Narrative 1
2	PNF busy with long ATIS/snow Rpt\PF prgrmd wrong clrnc info\Crew distracted by F/A-meals
3	Acft strtd clb 22 sec. aftr data entry\Cntrlr issued hdg vctr for seperation at FL406-approx 4 mins
4	HSI showd that acft would intcpt dep btwn SUMMA &Pendelton\FMS database shld be chngd
5	Cntrlr said Hold was E of fix\Cntlr gave left trn to 080 for vctrs to re-enter Hold at SCUPP INTXN
6	35.5 NM SW BLD LAX Cntr rqstd DME\FMC indctd 42 Nm SW\crew vrfy w raw data frm nav rcvr
7	Crew mistakenly entrd J1 to KLAX instd of J1 to LAX\J1 doesn't go to KLAX\Cmptr prgrmd Drct rte
8	Rclcltn from Dayton VOR shwd 47 NM N and passing FL260\infrmd cntrlr could not make rstrctn
9	Acft passed 12500\Alt Select did not capture\dscnct autopilot & dscndd to 12000
10	Crew failed to verify clrnc with CUN twr befre Dep\didn't crosscheck with paprwrk frm filed flt pln
11	For this airline PNF suppsd to set Alt Atrtr on FMC\70% PF sets in Alt ChngsPNF dstrctd by F/A
12	VNAV cptr/cltr failed to provide Alt Alrt\Autopilot failed to cptr
13	Acft lvld off at FL320\Cpt slctd vert spd-then flt lvl chng\dployd spoilers-dsndd thru FL240
14	In chkng FMS it shwd 3500 not 35000\The FMS didn't take last0 or drpppd last 0
15	When V/S slctd on FGP drppd out of A/P annunc\dscndd to 10600 at 2500 fpm\clb bck to 11000
16	Crew set Dep clrnc Alt-FL230 in Alt Alrt Wndw\Crew thght tht rstrctn at/abv 5000-misled by FL230
17	Complicated SID with lower Alt rstrctn than issued by ATC clrnc & High init clb rate
18	At approx 34800 Alt Cptr not annunc\A/P & A/T dscnnct\acft lvld off 2-300 abv 35000
19	Swtchd to manual VOR and see at 44 NM SE of Hancock at FL370\ATC cldr drct Bradley-FL290
20	acft dscnd thru 10000 w high v/s rate\A/P dscnct-rcvrd at 9800 & rtrnd to 10000\11000 in Alt wndw
21	PNF indicated prblms in setting Alt in MCP-if set too fast you can miss the shallow detent w knob
22	Flt continued using raw VOR data\Maint at destination found no fault
23	Busy w apch oprtn & did not notice cptr fix chng frm 25 NM to 16 NM\Mssd crssng rstrctn by 3000
24	Suspect FMC cptr malfnctn-chkd L: C: R; IRS's-L; C; & R; autopilots\Continued to BWI manually
25	Plt thght A/PFD in VNAV-expctd strt dscnt aftr exec-Acft lvld off at FL270 & trnsfrd to Alt Hold mde
26	Approx 70 NM out, offset cncld & acft strtd bck to orgnl crs\Approx 3NM S of 40 NM fix cntr clld
27	Cntrlr issued vector L trn to 220 Deg-as acft trnd, MAP on HSI's shfted and CRI VOR shwd crrct
28	Prado Dep rqrs turn drct to PDZ-sign on txwy rqrs 2000 bfr turn-not on SID-not in acft nav datbse
29	crew noticed at 18800 & clbng at 3500 fpm-rounded off at about 20000-clbg back to 19000
30	Given 2cd clrnc 5 DME W of AML at 8000 - Met rstrctn
31	acft clbng thru FL290-FL300 set in MCP-stppd clb at FL297-sepr loss at FL295 & dscndng
32	crrctd back to 6000 10-15 secs\cont. flt to LAX-Plt flying manual-no A/T; no FD; cmd bars stwd
33	Capt thght that rstrctn to cross 80 S at FL270 still valid\plt/cntrlr misunderstanding
34	FMS A/P into Mach arspd mode-maintains Mach regardless of Alt.-acft clbd thru FL334
35	problem may have been due to improper use of automation & lack of crew planning & coord
36	cntrlr gave hdg bhnd WDB for spcng\acft then trnd back and completed apprch
37	acft strtd to dscnd-PF discnnctd A/P after 300' dscnt-PF overcrrcted by +300'\cntrlr gave new Alt

	J
1	Narrative 2
2	Acft slowed/lvld off- probably due to crew action MCP or CDU\Vectors-wrong dir turn-not attntv.
3	Crew argued that they met time rstrctn even with turn\Questnd when does clrnc time start
4	Crew felt 130 deg hdg short of the 11 DME is a hdg to Pendleton Trnstn\chng to intrcpt 143 deg
5	Crew rechckd charts\Hold was E of SCUPP w left turns\Cntrlr gave other acft spcfc Hold instrctns
6	FMC 6.5 NM dscrpncy due to prblms w IRS prior to T.O.\At 35 SW BLD missed Alt rstrctn-18000
7	Cmptr gave direct rte to LAX arpt from the AVE VOR instead of going over Fillmore VOR on J1
8	FMS cmptr inpt mre accrte for VOR dwnstrm thn for alrdy pssd VOR\xtra entry rqrd for pssd VOR
9	The Alt Select captured and then dscnctd on 2 more level-offs during descent\Eqpmnt problem
10	crew complacency caused flt on wrong airway
11	Prcdr chngd so that PNF set in all Alt chngs
12	Multiple failures of Alt Preselect Unit on acft\6 failures svc life 10-67 hrs\rqrs cnstnt supervision
13	Dsnt rstrctn cld have been made with V/S slct on MCP-incrprtng FMS caused prblm-not needed
14	Since Alt Alrtr Slctr was set for 35000-there was no 250' wrnng of lvng Alt
15	MLG A/P drops Armed Alt frequently\Often missed by crew
16	with FL230 set wld not rcv Alt Alrt until 1000 blw 23000\no Alrt for at/blw 5000\need 5000 set wndw
17	crew blamed A/P malfunction & ATC dstrctn for problem
18	appears to be a problem with acft in fleet\Alt busts rprtd in VNAV mode also-same prblm
19	Trbl entrng as filed rte\trbl entrng dscnt info & crsng rstrctn & Rad intrcpt\both pilots new to acft
20	when F/O prgrmd PMS he also set 11000 in Alt. Preslct window which causedAlt Cptr to drop off
21	when misset the Alt can go to either side of selected Alt.
22	recommend that all FMS generated data be backed up by VOR data
23	Apprch contrlr called to ask for notice when crssng rstrctn cannot be met
24	Plt thought he inadvertently actvtd something that was not intended-Deactvtd Capture mode
25	Plt pshd buttons-did not chk rspns aftr input bfr prcdng to smthng else-will use FL CH on MCP nxt
26	IRU RNAV pos shwd 2.5-3.1 NM to go\Cntr shwd 40 NM out of CVI\plts had no vor crschk tuned
27	Error thght due to IRS prblm due to delay on Grnd-solution-tune 1 set of flt instrmnts in VOR mode
28	crew claims 2 man cockpit on short leg too busy with cptr/elec prblms
29	acft on overshoot lost sep with other acft\returned to assgnd alt w/o abrupt action
30	crew rcgnzd that timely use/data from automation is necessary to avoid prblms-after the fact
31	MCP chngd from 290 to 300\crew awareManufacturer's bulletin on nonslctd MCP dsply chngs
32	comment on crew style\crew coord.
33	different understanding reslted in conflict/resolved by vctrs from cntrlr
34	PF disengaged A/P & A/T and flew acft back to FL330
35	Ater rewiew plt thght MAP dsply programmed in error-may not understand system
36	If 6000 set in FMC for Menlo this would satisfy rstrctn & would allow spd reduction at Menlo
37	PF missed turn on STAR because busy pushing buttons on FMS-not flying acft

	A	B	C	D	E
1	Report	Accession Number	Date	Aircraft Type	Oprtnl Err Type
2	:12	:104874	:8902	:WDB	
3	:23	:107421	:8903	:LRG	
4	:25	:107738	:8904	:WDB	
5	:27	:107916	:8904	:MLG	
6	:28	:107922	:8904	:LRG	
7	:30	:108107	:8904	:WDB	
8	:32	:108361	:8904	:WDB	
9	:34	:108752	:8904	:WDB	
10	:35	:108763	:8904	:WDB	
11	:47	:110142	:8905	:MLG	
12	:48	:110413	:8905	:WDB	
13	:50	:110571	:8905	:MLG	
14	:51	:110778	:8905	:MLG	
15	:55	:111415	:8905	:MLG	
16	:58	:112283	:8905	:MLG	
17	:59	:112881	:8906	:MLG	
18	:60	:112925	:8905	:WDB	
19	:61	:112939	:8906	:MLG	
20	:62	:112968	:8906	:LRG	
21	:63	:113210	:8906	:MLG	
22	:65	:113594	:8906	:MLG	
23	:66	:113722	:8906	:MLG	
24	:71	:114289	:8906	:MLG	
25	:72	:114392	:8906	:MLG	
26	:73	:114409	:8906	:LRG	
27	:77	:116429	:8907	:LRG	
28	:78	:116474	:8907	:LRG	
29	:79	:116871	:8907	:MLG	
30	:80	:116912	:8907	:MLG	
31	:81	:117306	:8907	:WDB	
32	:83	:117395	:8907	:MLG	
33	:87	:118257	:8907	:WDB	
34	:93	:119740	:8908	:LRG	
35	:96	:119836	:8908	:LRG	
36	:98	:120121	:8908	:MLG	
37	:100	:120705	:8908	:MLG	

	F
1	Synopsis
2	Wrong turn at holding pattern entry.\Track or Heading Deviation\Unathorized penetration of airspace
3	Fl Crew failed to level off at assigned altitude\Alt overshoot on Clb\non-understanding of FD Functions
4	Alt Crossing Restriction not met on dscnt\At FL230 not 15000 when passing INTXN\CDU prgrm error
5	Failed to descend and comply with assigned atltitude restriction\At FL330 not FL290 at CAP
6	Flight deviated from cleared route while dprtng foreign ARPT
7	Crossing Restriction not met-500' high at restriction point
8	After Receiving Clrnc, Cpt failed to initiate descent in a timely manner\ATC issued radar vector for Sep
9	Altitude overshot during descent in turbulent conditions\
10	Altitude overshot on descent using Performance Command Auto System\Manual recovery by F/O
11	Advanced Technology Alt Selector spontaneously changed 1000' causing Alt deviation
12	Altitude deviation on STAR Approach\Failed to maintain 14000 \Msintrprtd Position
13	Flt failed to comply with crossing Altitude restriction while flying Arr STAR
14	Crew dpnd on AutoNav/FMC to Accomplish Crsng Alt\Eqpmt slow to start Dscnt\Crsng Rstrct not met
15	ACFT's cmptrzd prgrmd autopilot attempted to fly to intrsctn improperly depicted on STAR chart
16	Mssd Crsng Rstrctn\Cpt unable to prgm IRS correctly\high wkld due to new clrnc\F/o out of ckpt
17	Crew prgrmd wrong Rte in cmptr\ARTCC cntrlr intrvnd when ACFT turned off Cleared Rte
18	During Dscnt crew did not comply with assigned crossing Alt or Spd restrictions
19	On Departure Flt failed to follow assigned SID routing
20	ACFT climbed through cleared Altitude\Autopilot did not capture level off
21	ACFT faileed to make alt rstrctn at PLSTN INTXN\FMC proceeded to Nav to next WPT
22	Track and Heading deviation on SID as ACFT's FMC computer was misprogrammed
23	Alt Deviation overshot during climb due to improper use of Autoflight system
24	Deviation from route of SID Transition\Heading and track deviation
25	Start of Descent delayed after receipt of descent clearance from ATC (260 to 240)
26	Airspeed deviation from assigned during climb
27	Altitude Deviation. Altitude overshoot in climb
28	LGT in Auto descent into DEN overshot Crossing Altitude\Cntr intervened due to terrain
29	Arr Acft has problem adhering to Apch Cntrl clrnc for dscnt and Airspeed restrictions
30	Altitude deviation. Altitude overshot in descent
31	Aftr rcvng Holding Clrnc, Acft overflew Holding Fix while trying to locate same on NAV chart
32	Flt crew of MLG on dscnt made ALT crossing rstrctn but unable to comply with Spd rstrctn
33	Acft deviation from clrnc route. Track heading deviation
34	Alt deviation undershoot in descent - crossed at FL330 not FL310
35	Altitude deviation due to misuse of FMC
36	Flt crew of advanced technology acft fails to meet crossing restriction
37	Flt crew of MLG deviated from heading assigned direct MGW

	G
1	Clearance
2	Cleared to hold at COLAX INTXN on SCURRY ARR into DFW.
3	Cleared to clb to 16000;fly hdg of 360 to intrcpt 349 deg rad of PIE & fly rad outbound\above 10000
4	On dsnt-Clrnc to crosss CEDAR INTXN at/or blw 15000 to mntn 10000
5	Cleared to cross CAP at FL290
6	DEP CNTL gave heading to intercept J5
7	At top of Dscnt new clrnc to cross 70 E of CGT at FL240
8	At FL390 vicinity of CIE VOR, ZAB clrd to FL240, Plt's Discretion leaving FL370
9	Dscnt from FL200 to 12000\Approx 15000 encountered Wx/Clrd to cross 40 SW LRP at 12000
10	Dscndng into PHL using Auto Throttle and PMS were Cleared to 12000
11	Clrd after TKOF to clb on S course of ILS (164 degrees) to 15000
12	CIVET Profile Descent to RWY 25 LAX\Crossing restriction was 14000 to CIVET
13	Clrd to crs CEDES at11000\at 26000\Dscnd to 23000 now, dscretn to crs CEDES at11000/250
14	ACFT at FL370 on Flt Pln KESSEL 2 Arr\Clrd to cross 25 nm W of KESSEL at/and mntn 25000
15	Rerouted from AVE to FLW with TANDY Arr
16	Clrnc to cross 55DME S of KENTON at/or blw 270 to maintain 240
17	BORDER 3 Dep from SAN enrt PIT\Made turn at IPL drct to LVS\Crrct Rte J18-IPL to LVS
18	While flying LENDY TWO Arr into JFK -Clrd to crs LENDY at FL230\Later Ctr clrd to crs LGA Fl190/250 Kts
19	Clrd TKOF RWY 31L & KENNEDY TWO Dep-JFK\Left turn to CRI VOR-then out 176 R-Vctrs to COATE INTXN
20	Departed DCA on Radar Vectors from ZDC-Clrd to 17000
21	Clrd the KARLO1 Arr with Crossing rstrctn of 12000 and 280 Kts at PLSNT INTXN\clrd to 11000 later
22	Flt Pln: OVETO 8 Direct DVC\Capt read/Prgmd: OVETO 8 DOVE CREEK transition to DVC
23	On Clb to 270/leaving 26.5, ZME gave Pilot discretion to 240
24	Cmptr gnrtd Flt Pln: AVETO 8. DIRECT DVC\Real Flt Pln: AVETO 8. DVC Transition
25	Clrd to crs a point 100 S of BOILER at 260\Delaying vector for spacing\Clrd Direct to BOILER-dscnd to 240
26	Clrnc: turn hdg 300 Deg to intrcpt DFW 274 Deg R clmb to/and mntn 16000/250 Kts until advised
27	On clmbout clrd to 10000\At 8000 clrd Direct POTTSTOWN VOR
28	At CRS Alt. clrd crs DRAKO INTXN blw FL230/abv FL170 at 250 Kts\At Fl260 Clrd Prfl Dscnt DEN
29	Clrnc: Crossing Restriction of 11000, 40 nm S APPLETON VOR at 250 Kts\56 nm SW, 19000, 300
30	Enrte PHL to CLE, Clrnc to cross 10 nm E YNG VOR at 24000
31	Clrnc: Hldng-KRENA INTXN, as pblshd-11000\Rqstd/grntd rt trns\new clrnc Hldng POPPS INTXN
32	Clrnc to cross MAJIC INTXN at 12000 and 250 Kts.
33	GENDER ATC clrnc different from company filed flt pln entrd into FMS/INS NAV
34	At FL350 clrnc to cross 15 E of ALYMER at FL310
35	At FL350, Expctng clrnc to Fl390, PNF put 390 in FMC Cruise Page with 35000 in MCP ALT wndw
36	At Fl250, clrd to cross PLSNT INTXN at 12000 MSL and 250 Kts.
37	ZOB Clrd: DIRECT MGW ESL BUCKO 2 ARR

	H
1	Crew Action
2	Entered Holding Pos into FMC/Pattern displayed was standard hold
3	CPT Set PIE freq/349 deg on Flt Gdnc Pnl/Slctd VOR on FMC pnl\F/O setPIE 349/150NM drct crs
4	PNF put Clrnc into FMS\ATIS chngd runway from 11R to 29\Cpt reprgmd new Arr & Dltd Crsng rstrctn
5	F/O put CAP at FL290 in DSNT page of cmptr & ALT window of MCP\
6	COPLT entered TEXAPAN 1 DEp into FMS\COPLT entered VOR/Radial for V5 not J5
7	Cpt entrd new Alt\High on Vert Path\Rcvd "Drag Rqrd" Msg\Cpt incrsd SPD/Rate Of Dscnt
8	Cpt programmed the FMC for Descent - Cpt did not begin descent at requested time
9	LRP not immediately available\PNF scrambled to find ARWY chrt to get VOR Freq\PF handled Wx
10	Cpt busy prgmng INS for Rte chng\ACFT dscndng on Auto\Known problems with Baro/Elect Altimeter
11	Alt on MCP was set to 15000 using manual drum knob - somewhere in flt 15000 changed to 16000
12	Started descent to 10000, at 13000 told to return to 14000, climbed to 14400
13	At 18000 dscnctd FMS-attempted to manually reach alt and spd \high/fast at CEDES
14	FMC prgrmd crs DRUZZ INTXN at11000/250 kts\FMC shwd Dist TOP of DSNT/Dist to Fix-2nm apart
15	Prgrmd FLW, FLW123/AVE148, SADDE, TANDY\prgrmd SADDE usng148 Deg R off FILLMORE
16	Cpt difficulty entering the fix into the CDU of the IRS-Kept refusing fix\unable to meet clrnc rstrctn
17	F/O put wrng Rte in FMCS: Direct LVS from IPL should have been J18\90 deg turn to intrcpt J18
18	Cpt prgmd FMC for Crsng\FMC rvrtd to Spd Mode frm VNAV Path Mode\15 nm frm LENDY too high for Crsng
19	F/O prgmd FMCS\Prblm wtih Comm/Freq\F/O steered to Track line (up)-306 Deg\turn left to 176 R
20	COPLT disconnected autopilot and manually descended to 17000-overshoot was 450'
21	Clrnc prgrmd-FMC\clrd on shortcut DIRECT PLSTN-cmpld usng VMC\Spd rstrctn dltd aftr Hndoff APCH Cntrl
22	DVC Transition omitted during programming of FMC-resulted in early turn DIRECT DVC
23	ACFT had gone to Alt Capture when F/O selected 240 on Alt Reminder\Alt Capture disarmed & Acft cont. clmb
24	Mismatch between filed routing and FMC routing not noticed by Crew-caused track or hdg deviation
25	COPLT had difficult time getting right page & right line for prgrmng the cmptr to descend\late lvng 260
26	F/o prgrmd FMC for Rte/Spd/Alt\Cpt slctd Spd intrvntn 250 Kts & hdg selectto intrcpt hdg
27	Cpt entrd data in FMC\F/O hand flying Acft\both F/D on -clmb at 35-4000 fpm\Clmb rchd 10500
28	Put 13000 in Alt Box MCP\Due to dtrctns did not notice no level off at 17000\Cntr intrvnd\Init. Clmb
29	Cpt unable prgrm FMS for Strt Dscnt\F/O-out of VNAV mode, dscnt with VERT SPD to Alt Rstrctn
30	Started dscnt-prgrmd FMC. Inadvertently put 10000 into Flt. Gdnce System. cont'd prgmng FMC
31	FMS rjctd POPPS-no in dtbs\swtchd to VOR mode\2-3 nm past POPPS-bgn RT trn\given Vctrs
32	PF strtd dscnt, armd FMC to cptr dscnt path\Cpt ntcd acft pstn (Alt/DME) advsd ctlr cldn't mk Spd
33	Crew flew cmpny filed rte\flew outbound rte on 231 deg to VOR, shld have flown 256 deg to intxn
34	Crew prgrmmd 15 E of Alymer at Fl310 in FMC & set 310 in MCP. TopOfDscnt circle apprd on ND
35	Cpt changed MCP ALT wndw to 39000 prior to receipt of clrnc, based on PNF prgmng of FMC
36	Cpt programmed the FMC for the Path Dscnt
37	Not part of preprgrmmd rte-rqrd input of MGW into FMC to go direct\Entered MGM not MGW into FMC

	I
1	Narrative 1
2	Pattern on FMS/CDU did not match Approach Plate/Crew did not check\Believed Computer correct
3	Crew busy trying to enter VOR Radial in Cmptr\Cmptr only allows flt to a fix - not from a fix
4	PNF busy with comm & other duties\PNF mistook CAASE for CEDAR\thought enuf time to dscnd
5	At 9 nm frm CAP, CENTER rqstd intntn\F/O misread DSNT PAGE as 9 nm to start Dscnt-not CAP
6	Confusion between Victor and Jet ARWYS on High/Low charts\Comm confusion Dep Cntrlr/Crew
7	Very high rate of descent\1000-2000' prior to rchng FL240 "ALT CPTR" mode startd to level A/C
8	Cruise spd was .83 M\selected Dsnt spd was .80 M\Spd had to bleed off before Dscnt cld bgn
9	LRP data shwd 31 nm SW\PF dployd spoilrs/trned off Auto thrust/autopilot lvld off w/o auto thrust
10	Apparent problem with accuracy of PMS/Altimeter system - approx 300' discrepency
11	Crew relied on automatics (Alt Warning and Auto LevelOff) to give indication of approaching Altitude
12	Strt Dscnt based on DME readng to FUELER INTXN not LAX LOC DME \Small FONT Image PFD blamed
13	When Intrmdte Alt selctd, FMS not actvt restriction until new alt rchd\slow1000 fpm rate dscnt
14	ACFT crossed VOR at 26100/could not meet Alt restriction\ACFT started Dscnt late
15	ACFT flyng 123 Deg off FELLOWS when Autopilot realzd ACFT passing SADDE tried to Cptr
16	ACFT failed to leave FL370 due to difficulty entrng fix\tuned ENO VOR manually to dtrmn dist to fix
17	Capt failed to catch mistake\Capt felt that "manual" VOR Nav with refrnce to hard copy flt pln wld hlp
18	Cpt called Ctr for relief\Stop at FL290\New Clrnc\Cpt began prgrm FMC prior to start Dscnt
19	Comm confusion/wkld & Following Track w/o checking Hdg\5-6 nm N of CRI VOR\Locked into going to COATE
20	Expctd autopilot to level off-did not react\LGT FMC clmbs at 2000 fpm the last 1000'\nose over last 200'
21	Passing PLSTN INTXN alt=15100\FMC began Nav to Next WPT\Crew failed to notice acft not dscndng fast enuf
22	FMC misprogrammed BUT looked exactly right
23	Due to high wkld crew failed to notice clmb (300 fpm)\Cntr Cntrlr intervened at 28.5\Acft put in Dscnt
24	Narrative does not give details of deviation or correction or Cntrlr intervention
25	Late frqnt clrnc changes cause high wkld\cmptr plans a last chance point of Dscnt \crew/acft cannot comply
26	Autopilot entrd Alt Cptr Mode aprchng 10000 not 16000\Autothrottle disregard 250 Kt spd intrvntn-acclrtd to
27	MCP shwd ALT HOLD & CLMB in VERT SPD at same time
28	Autopilot VNAV didn't Cptr 17000\Acft cntnd down to 15700\clb inttd to 17000 at 8.4 W DRAKO
29	Due to unfamiliarity with FMS Cpt unable to prgrm FMS\F/O flew Acft to ALT but not Spd rstrctn
30	Acft continued dscnt thru 22000, leveled off at 21000 after CLE Cntr requested Alt
31	POPPS INTXN not in FMC dtbs & slow chage to VOR mode caused late turn past INTXN
32	PF thought VNAV "kickd-off"\Cpt thought PF did not press VNAV SELECT hard enuf to engage
33	"Non-common" portion of flight plan in FMC different than clrnc-resulted in 10 nm hdg deviation
34	At TopOfDscnt point acft didn't dscnd\crew busy didn't notice prblm until 20 E of ALYMER
35	Acft began clmb to FL390\Cntrlr rqstd "maintain FL350" acft returned from 357 to 350
36	PNF noticed FMC had miscmptd the Dscnt point\at FL250 9 nm frm crsng fix at .77 M notified ATC
37	Since Autopilot coupled to FMC, Acft turned MGM-about 90 deg off course

	J
1	Narrative 2
2	
3	Crew busy with cmptr-not watching altitude-missed altitude callouts\stopped clb at 16400
4	Neither crew monitored flt path\did not comply with clrnc\extnsv CDU reprogram for new approach
5	Cpt forgot to tell F/O he was not monitoring\F/O misread FMC\Cpt busy No backup for sit. awareness
6	Cpt trnd Left to TEXAPAN Dep/Cntrlr wanted turn to intercept J5\Prblm crrctd & flt continued
7	Crew recognized that they should have started descent immediately & then modified FMS Alt.
8	Cpt apparently did not realize autopilot was reducing spd during level flight
9	Assgnmnt of Crsng Rstrctn only 10 nm from fix/using Navaid behind ACFT\excssv wkld to prgm FMC
10	Reliance on Automatics
11	Problem attributed to a maintenance problem - not crew action
12	PFD shwd ILAX ILS/DME Dist frm LAX 25L\ND shwd Dist to WPT in Stord Rte\Autotun blamed
13	FMS Algorithm does not operate as expected
14	Crew lulled into "monitoring complacency" by automatics and/or expectancy
15	Chart should show Direct-To SADDE due to close Prox to FELLOWS/FILLMORE intxn
16	Crossing restriction fix was in wrong sequence in IRS
17	Need to maintain vigilance with automatics/electronic cockpits
18	ACFT made high spd dscnt to make Alt\could not slow down to 250 Kts when crossing LGA
19	Cew did not maintain Situational Awareness\Could have used VOR Mode as back-up
20	Crew stat that alt cnstrnt entrd in VNAV clmb\crew not sure acft wld have stpd clmb\revrt to mnl
21	As soon as FMC bgn Nav to nxt WPT, all info for PLSNT INTXN rstrctn no longer avlabl for rview
22	Plt awareness and backup using conv VOR/HSI Disp to confirm correct FMC execution of SID
23	Problem due to fact that cmptr was prgrmd for lower alt while still clmbng to higher alt
24	
25	Rqst cntrlrs use enrte LNAV waypoints (V84 to OBK cross STORY) not (Cross point 30 E of OBK)
26	Cpt had manually entrd spd rstrctn into FMS\FMS allowed spd to increase to limitation rstrctn
27	F/D continued to malfunction on next 2 intermediate level offs\No addtnl Alt Dev.
28	Numerous static discharges off Acft considered cause
29	At time of clrnc, Acft was on Vectors-off LNAV course\Cpt not able to get Acft to leave ALT
30	
31	Crew tried to enter POPPS into FMC as Wpt\high wkld due to late clrnc for new hold not in dtbs
32	PF started dscnt 5-8 nm ahead of FMC top-of-dscnt\due to high wkld Cpt not monitoring flight
33	Crew/company expectation different than cntrlr clrnc\not cross checked by crew
34	Crew strted dscnt at 4000 fpm with spd brakes-could not make alt rstrctn. Crossed 15 E at FL330
35	crew states FMC will not chng alt even if MCP alt differs from FMC Cruise Page-crew coord prblm
36	
37	PF tuned in MGW VOR to verify hdg\ZOB called to verify hdg\acft turned to correct hdg

	A	B	C	D	E
38	:103	:121365	:8908	:MLG	
39	:104	:121873	:8909	:LRG	
40	:105	:122020	:8909	:LRG	
41	:106	:122307	:8909	:MLG	
42	:114	:122778	:8909	:LRG	
43	:116	:123182	:8909	:WDB	
44	:118	:123705	:8909	:MLG	
45	:125	:124225	:8910	:MLG	
46	:126	:124540	:8910	:MLG	
47	:127	:124641	:8910	:WDB	
48	:129	:124912	:8910	:LRG	
49	:132	:125379	:8910	:MLG	
50	:134	:125410	:8910	:MLG	
51	:139	:126140	:8910	:LRG	
52	:140	:126180	:8910	:WDB	
53	:141	:126262	:8910	:MLG	
54	:144	:126707	:8910	:MLG	
55	:145	:126842	:8910	:MLG	
56	:150	:128009	:8911	:WDB	
57	:152	:128632	:8911	:MLG	
58	:155	:128735	:8911	:LRG	
59	:163	:129915	:8912	:MLG	
60	:164	:130037	:8911	:MLG	
61	:166	:130487	:8912	:WDB	
62	:169	:130630	:8912	:LRG	
63	:170	:130700	:8912	:MLG	
64	:172	:130858	:8912	:WDB	

	F
38	Altitude deviation in climb
39	Aprch Cntrlr gave Holding clrnc not compatible with the FMC prgrm\Result: Holding fix missed
40	Alt Deviation. Overshoot on descent
41	Acft Cpt mistakenly turned Hdg Bug instead of Spd Bugwhile dscndng-result = track deviation
42	Flt crew missed crossing rstrctn due to time spent discussing how to program FMS
43	Flt deviated from DEP procedure and almost entered a prohibite area
44	Alt deviation Alt Undershot. Crossing rstrctn not complied with
45	Acft deviated from clrnc rte. FMC prgrmd incorrectly-not verified by PNF per company procedure
46	Acft track heading deviation
47	Acft Alt Deviation-does not make altitude restriction due to PF involved with prgrmng FMC
48	Acft received amended clrnc Alt. Acft did not climb until reminded by ATC
49	Altitude Deviation. Acft overshoot on descent
50	Acft in high rate of climb overshot assigned altitude
51	Holding clrnc issued to a point 50 nm behind acft current position-SEE NARRATIVE!!
52	Acft flt crew uses computer flt plan in FMS instead of revised clrnc
53	Acft operating on FMC proceeds on wrong Airway. Deviates from flt pln. Multiple Flt plns in FMC
54	Acft Alt deviation, did not make altitude restriction
55	Altitude Deviation. Overshoot in climb
56	Acft descending on autopilot, FMC did not follow dog leg in the airway\Cntr Cntrlr gave vector
57	Flight crew calls up wrong flt plan from Nav computer data bank. Track error results
58	Acft Alt Deviation. Undershot Alt crossing restriction because fix was not in FMC
59	Altitude deviation. Undershoot on descent/crossing restriction not met\Misuse of FMC pages
60	Alt Deviation. Descent crossing restriction not met\
61	CDU Hold Page showed Rt turns for holding pattern\Cntr Cntrlr advised left turns was pattern
62	Aircraft fails to meet crossing restriction in descent
63	Acft assigned hdg, alt, spd changes-same time, failed to turn or slow due to prgrmng Perf Sys
64	Acft fails to meet crossing rstrctn in descent. Cites insufficient lead time for Top-Of Dscnt by FMS

	G
38	Departed SJC on LOUPE Departure with 5000 altitude rstrctn
39	1st Clrnc: Dscnt rstrctn FL240 at 65 nm NW FNT\2cd clrnc: Hold NW SVM 322/25 Fix, Rt turns
40	Cntrlr rqst chng spd 290 to 210\current expctd Alt=10000 prior to dscnt to 8000-On Profile Dscnt
41	On BLUF1 FOUR ARR transitioning from FMC controlled fltbegan to set up Apprch Intrcpt
42	Clrd to cross 40 NM W of LINDEN VOR to maintain FL270
43	Noise Abatement DEP entered into FMGS: (328 Deg Radial/10 DME)
44	Clrnc to cross HOLEY INTXN at 11000
45	Company Rte "DCACLE" entered into FMC-should have been "DCACLE1"
46	At FL350 near BLD, Clrnc DIRECT to HEC flt pln rte
47	At 12000, clrnc: corssing rsstriction 7000 msl, 10 nm DME out of Charlotte
48	Cruising at Fl390 received Clrnc to Fl410
49	Clrd BIG SUR prfl dscnt RWY 28. Rstrctns:Crs ANJEE at/abv 160/Crs SKUNK blw 120/abv 100
50	On departure cleared to climb to 12000
51	At FL260, made left turn bck to 55 nm fix to entr holding\ATC clrd to FL250/made chng/put in MCP
52	F/O loaded company computer flight plan which was different than Clrnc\difference not detected
53	Not Specified!!!
54	At FL330, clrd to cross 80 nm S of RIC VOR at FL270
55	Climbing using FMS with intention of leveling at FL330
56	Clrnc: fly V526 to WAKEM INTXN. V526 has dog leg turn at LPAER INTXN prior to WAKEM
57	On dptr Charleston, clrnc: Turn left and clred on course.
58	Clearance to cross 60 nm W of FNT at FL230. FNT not on Route/not programmed in FMC
59	At FL240 clrd to FL190, then clrd given crossing restrictions PMD - 13000/JANNY INTXN - 8000
60	Clrd Direct to HDF\Clrnc to cross 20 nm NE of HDF at 14000
61	Clrnc FL410 to FL350\Hold W at JENNO INTXN as pblshd\acft chrts shwd no hold ptrn at JENNO
62	Clrnc to cross SW of ABE at 13000
63	Assigned turn from 260 to 220 deg\250 Kts at 7000: then 210 Kts: Then 170 Kts
64	At FL370 clrnc: Alt crossing resriction of 10 W of STILLWATER VOR at FL230

	H
38	Crew placed cleared altitude in the MCP w/o VNAV at 3-3500 fpm
39	SVM not on Rte\prgrmd into LEGS page at apprprt point, then hold into HOLDING page
40	Discnnctd VNAV, used Flt Lvl Chng Mode to slow Acft\Due to actions, FMC uses Alt in Alt wndw
41	Trnd Hdg Selct knob to 250 deg - Meant to chng IAS Bug from 300 to 250 Kts-trnd to 250 deg hdg
42	Crew disagreed on how to program the FMS-Late dsnct strted usng cnvntnl autppilot techniques
43	Strtd Lft turn & called for "managed Hdg" to Intrcpt DEP radial (328 Deg)
44	Prgrmd FMC and selected 11000on MCP-FMC isdicated 17 nm to Top-of-descent
45	Crew did not check to see if correct rte was in FMC. Cmpny has 2 different rtes with same names
46	Entrd HEC in FMC (however eliminated BLD)-entered infor to provide "ABEAM" point for BLD
47	Cpt (PF) spent time programming the FMC/Autopilot to do the descent
48	Capt loaded Alt in MCP - did not enter in FMC
49	FMC: VNAV path dscnt/MCP Alt Atrt 10000. Went to Vert Spd mode to reduce Spd
50	At 11000 called 1000. At 11800 climbing at 4000 fpm. leveled off at 12450
51	Crew attempted to follow numerous clearances while trying to get to holding fix-6 different clrncs
52	Crew busy showing off FMS to Jmp Seat Px\loaded cmpny flt pln\did not pay attn to clrnc
53	Acft Nav on J121 Nbound instead of J165 due to wrong flt pln on FMC
54	Attmptd to put rstrctn in FMC\continuously shwd "Invalid Entry" in scratchpad-correct prcdre fllwd
55	FMS slctd to MachAutothrottle slctd to EPR Limit(CLB EPR LMT)/ALT armed (FL330 in FMS)
56	Error in Computer NAV database shows V526 to be a straight line btwn VWV VOR and WAKEM
57	F/O proceeding DirectTo 1st WPT on CDU\Queried by ZJX about assigned hdg from CHS dep
58	crew forgot to insert INTXN point in the original FMC database\plnnd to figure it out while enroute
59	Entrd FL190 in FMC\entrd 8000 in MCP Alt wndw\VNAV discnnct due unable to meet path dscnt
60	Entrd HDF 010/20 at 14000 into FMS CDU\F/O initiated Rapid dscnt\HDF Wpt no longer avlble
61	Put JENNO INTXN into CDU on Hold Page\Hold ptrn dsplyd right turns\Turned right at JENNO
62	Capt started dscnt with full spd brakes\dscnd over fix at 15300
63	Acft was on autopilot and Changes were entered into Performance System
64	Dscnt was prgrmd into FMC\Problem with engines (1.1 EPR rstrctn) caused late start of dscnt

	I
38	At 4800 lcl cntrlr rqstd level off at 5000-acft leveled off at 5300
39	entrd SVM 322 deg r forgot 25 DME\Manual tune SVM VOR 322 deg R as backup, forgot 25 DME
40	PF forgot mode he was in & expected acft to lvl off at 10000 prior to dscnt to final Alt in alt wndw
41	Aprch Cntrlr questioned hdg-crew turned acft back to 180 deg
42	Crew wasted time in incorrectly prgrmng FMS-each had a differnt apprch to accomplish the clrnc
43	Rlzd FMGS not flying 328 deg R\called for "managed hdg" after already crossed the 328 deg R
44	At 10 nm from INTXN and 13000 high-started rapid dscnt-crossed HOLEY at 12500
45	situation would have been avoided if the crew had checked to see if the proper rte was in FMC
46	Acft turned from approx 215-220 to 280 deg hdg\noticed deviation and turned back to course
47	Cpt busy missed the timely start of descent and missed the alt rstrctn by 700'
48	The Alt had not been put into FMC & since we were using LNAV & VNAV, the acft did not clmb
49	While out of VNAV autopilot will not level off for ANJEE rstrctn w/o 16000 set in MCP Alt
50	Autmtd acft apch within 3-400' of slctd alt at 4000 fpm. slwr rate-500 fpm-by slctng Vert Spd mode
51	F/O cnfrmd that Cntrlr knew he issued clrnc behind the acft\This clrnc =high wkld to reprgrm FMC
52	Crew dprtd PHL using cmpny filed flight plan\after handoff to ZNY, Cntr inquired as to Nav path
53	Crew got busy on ground and did not check route past CHS
54	ATC queried/crew initiated descent with idle pwr/full spd brks-crossed 80 DME 1000' high
55	Cpt manual lvld at Fl330/autopilot in Mach & Autothrottles in EPR LMT\chng. A/T to Mach SLCT
56	Crew did not catch error during preflight-missed difference between database and clearance
57	F/O had loaded Charleston to Charlotte not Charleston to Washington into FMC-wrong route
58	necessary checkpoints were not in theFMC database and had to be figured out prior to entry
59	Crew realized not VNAV coupled - disconnected autopilot & increased rate of dscnt
60	Acft crssd 20 nm fix while passing thru17000\Clrnc fix assoc with non-DME VOR hard to prgrm
61	ZNY gave vector: Left turn hdg 350 Deg\resumed hold
62	Capt inadvertently deleted ALT on the FMC\since acft was on VNAV path error not noticed
63	None of the clearances wer initiated-acft still at 250 kts. Alt change entrd and dscnt initiated
64	Due to engine rstrctn problem crossed 10 W of STILLWATER at FL270

	J
38	VNAV not used due to spd rstrctn at SFO TCA above 6000
39	High wkld in ckpt/Comm with ATC on Alt changes-went past holding fix\near correct fix was in dtbs
40	Dscndd to 9200 before realizing 1 nm to go before cleared out of 10000
41	Crew made turn at a point earlier than they normally did - Inattention to detail
42	F/O argued that the PNF should have the responsibility for prgrmng the FMS to avoid arguments
43	Since we did not have an intercept hdg, the FMGS was just commanding present hdg
44	PF busy enterng other FMS data, not monitoring system, did not understand what went wrong
45	Reliance on automation can be a problem if differences can exist
46	Acft had already passed abeam of BLD when data was entrd\acft strtd rt turn to abeam BLD
47	PNF suggested that in high trffc areas with cnstnt alt and spd adjustments FMC shld not be used
48	Lack of training blamed for the problem
49	Crossed ANJEE below Rstrctn-leson learned: Put current rstrctn Alt in MCP don't rely on FMC
50	at 500 fpm wld take more than 30 sec/at 4000fpm it wld take 4 sec to overshoot more than 300'
51	Navigation is a joint effort between ATC and Crew-each shld know the prblms caused by clrnc
52	
53	
54	Crew infrmd FMC has Flaw-will not accept crsng rstrctn unless within ARR area & X nm from dest
55	Acft started rapid clb to maintain .76 Mach\Cpt clicked off autopilot and recovered to Fl330
56	ATC gave vector to return to course
57	Acft was off the assigned airway by 6 nm when mistake caught
58	
59	Approx 2000' high at PMD, made JANNY 8000'\Cpt entrd data in FMC Cruise pg not DSNT pg
60	Rstrctn was issued too close to the fix to make rstrctn\Clrnc rqrd 15 keystrokes & time to prgrm
61	Acft charts did not show any hold pattern at JENNO-as pblshd should have allowed right turns
62	PNF busy with other activiies not in loop, did not have situation awareness
63	F/O forgot to activate hdg select so the acft didn't turn\other problems not discussed
64	Crew could have started dscnt prior to FMC top of Dscnt\Or Engine rstrctn cld be prt of FMC prog