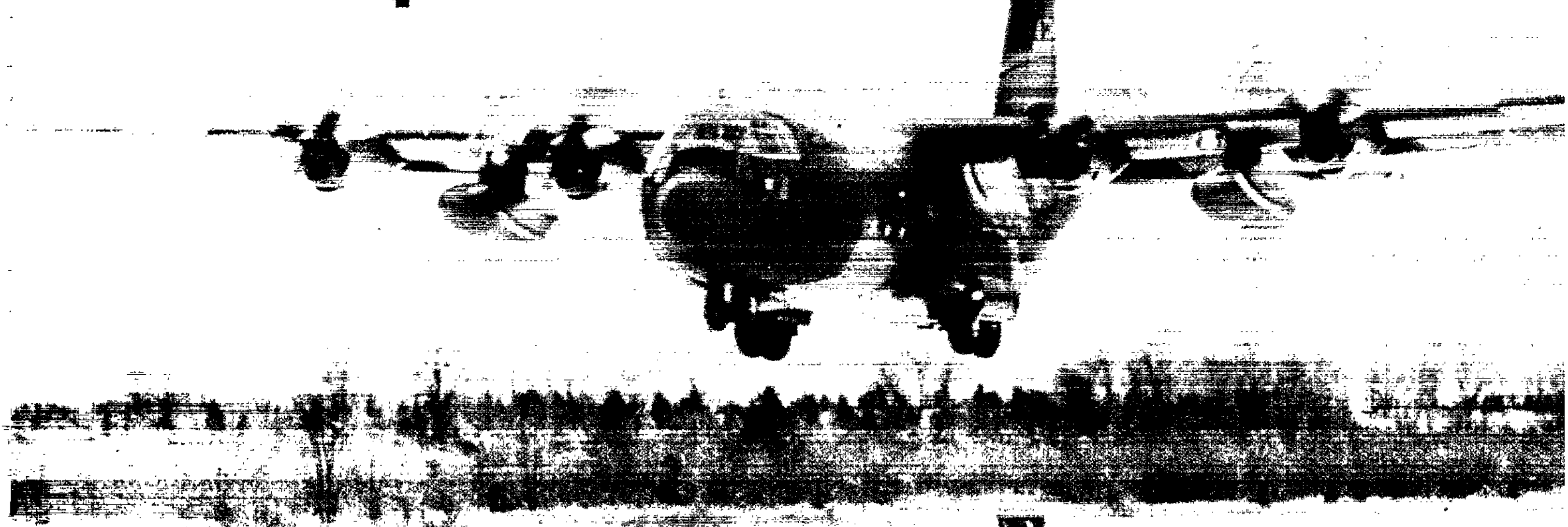
National Défense
Defence nationale

DCIEM Report No. 98-R-16

Human Factors of CC-130 Operations

Volume 3: Future aircraft performance measures



W.D. Fraser

Defence and Civil
INSTITUTE OF ENVIRONMENTAL MEDICINE

Canada

February 1998

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HUMAN FACTORS OF CC-130 OPERATIONS

VOLUME 3: FUTURE AIRCRAFT PERFORMANCE MEASURES

W.D. Fraser
T. Gee

Defence and Civil Institute of Environmental Medicine
1133 Sheppard Avenue West, P.O. Box 2000
Toronto, Ontario
Canada M3M 3B9

DEPARTMENT OF NATIONAL DEFENCE – CANADA

EXECUTIVE SUMMARY

This report outlines a proposed two year program for the investigation and implementation of a low cost Automated Operational Flight Performance Monitoring System (AOFPMS) for CC130 operartions. This work follows on from Phase I of the study, that developed a performance scoring system for CC130 flight operations. The system will utilize automated data collection and transmission technologies, a knowledge-based, flight-performance scoring system, and advanced artificial intelligence and data fusion technologies for the automated tracking of long-term trends in aircrew performance and operational flight safety during changes in training, doctrine, operations, and experience levels.

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INTRODUCTION

This Volume is the third in a six volume series describing a human factors study of Canadian Forces (CF) CC-130 aircraft operation (see References [1-5] for details of the remaining documents in this series). This Volume deals with the issue of crew performance measurement.

In a recent AGARD publication [6], it was projected that both aircrew flight performance and aircrew psycho-physiological state would be routinely monitored by the year 2020, both to track the efficacy of the crew and to provide input into the artificial intelligence of the 'electronic crew-member'. At the present time such systems have been tested both in simulators and on commercial transport aircraft.

Aircrew performance monitoring or measurement can be defined as "...the act of ascertaining the dimensions, quantity, quality, of the performance of the aircrews by comparison against a standard..." [7]. Performance monitoring can be done during aircrew section, aircrew training, recurring qualification, and role qualification [7], as well as during ongoing day-to-day operations. The current extent of operational flight performance monitoring in most military transport operations, including the CF CC-130 fleet, consists of satisfactory/unsatisfactory ratings by 'check' pilots. With respect to evaluations by check pilots, errors are largely catalogued with respect to procedural or technical mistakes, with the quantity of errors as the primary concern and with little focus on the magnitude of the error or its impact on the safety of the flight [8]. Statistics on major incidents generally come from pilot-based narrative reporting systems similar to the US Aviation Safety Reporting System used by the commercial airline sector. Due to its rarity, accident data is of limited value for tracking trends in composite performance, nor does it quantify the number of significant and/or dangerous deviations which did not result in an accident. None of these data sources provide sufficient information on performance to correlate with changes in procedures, training, or experience, nor does the data collected quantify the extent of performance degradation which increases the risk of accidents.

In many cases, the subjective information from check pilots or self-reports by aircrew is of less value than objectively measured data, such as that obtained from flight-data recorders [8]. As an example, flight crews involved in controlled-flight-into-terrain (CFIT) accidents generally know where they are laterally, but not vertically [9], but almost no reliable data are available as to the frequency at which flight crews deviate from the correct vertical or lateral position. Expert observer evaluations undertaken during research programs have provided valuable insight into crew behaviour, cockpit resource management (or lack of), and how flight crews resolve the consequences of their own errors. However, for routine monitoring and the quantification of incidence rates, cost would prevent such an approach.

A number of barriers to the development of crew performance monitoring systems based on data collected from flight data recorders remain. The tools for objectively measuring and quantifying flight performance are not yet mature, cost is a major issue, as is pilot acceptance. However, there are a number of programs in use by commercial operators in Europe, including British Airways (BA), Scandinavian Airline Systems (SAS), Royal Dutch Airlines (KLM), and Air Portugal (TAP) which track flight performance on a continuous basis, providing feedback to specific crews in some circumstances. However, they are primarily concerned with identifying unwanted events, i.e., exceedences or incidents. Little attempt is made to track overall trends in group performance, and the impact of training and procedural changes [10].

The National Aeronautics and Space Administration (NASA) and the United States Federal Aviation Administration (FAA) have undertaken the multi-year joint development of an Automated Performance Measurement System (APMS) to generate a set of tools and methodologies for the commercial airline sector in the United States to collect and process the large quantities of flight data which would be generated on an ongoing basis [10]. The conceptual design of the APMS was used as a basis for tailoring an approach to the development of an Automated Operational Flight Performance Monitoring System (AOFPMS) for CC-130 operations.

The NASA/FAA system is designed to analyse the extent of deviations from nominal flight parameters in a commercial airline industry. As part of the desire to develop a flight-performance scoring system in Phase I of this study [11, 12], that was both relevant to CC-130 operations and focused on the safety of operations, a flight-performance scoring algorithm was developed using a knowledge engineering approach. Twenty-nine standards officers in the CF Air Transport Group (ATG) completed a survey in which they were asked to:

(i) rank the importance of each flight parameter (i.e., altitude, heading, glide-slope angle, etc.) in each phase of a flight,
(ii) assign a score of 0% to the absolute deviation from each nominal flight parameter, which in their opinion, would result in a *significant probability of an accident*, and
(iii) generate a function which could calculate a score ranging from 100% to 0% for a given deviation from the optimal flight parameter.

Composite scoring functions, based on all the survey results, were used to rank the performance of 15 crews flying a simulated 'medivac' mission. The performance rankings of the crews were compared to the proficiency rankings assigned by a civilian pilot and experienced human factors engineer who reviewed the cockpit videos of the simulated flights. The flight path analysis based on the scoring functions provided a ranking of the crews on the most important flight parameters in each phase of the flight Scores ranged from 98% to 51% in maintaining assigned altitude, from 66% to 26% in maintaining heading, and from 32% to 15% in maintaining glide slope. There was a significant correlation between the rankings generated from the glide slope scores and the proficiency rankings generated by the check pilot ($r = 0.55$, $p < 0.04$). Crew rankings derived from altitude and heading scores correlated with the proficiency ratings at $p < 0.1$.

It was apparent that application of knowledge engineered scoring system (KESS) to an experimental study, with a small number of crews, flying identical missions, in a simulator setting, is not the appropriate use of such a technology. Such a technique would more appropriately address the needs of the CC-130 community where it can be used to track the kind and quantity of errors which aircrew make and provide better feedback with respect to training, doctrine, mission scheduling, and duty-rest cycles on the overall group performance.

AUTOMATED OPERATIONAL FLIGHT PERFORMANCE MONITORING SYSTEM

An Automated Operational Flight Performance Monitoring System is one component of the Flight Operations Quality Assurance Program (FOQA) under consideration for commercial operations in the United States. The goal of an AOFPMS, in the context of CF CC-130 operations, is to provide the CF with a tool to track the safety and efficacy of flight operations.

Data collected from AOFPMS could be used at a number of levels; such as

- evaluating performance of individual crews on specific flights, i.e., providing an automated check ride capability;
- composite data could be be collected and analysed during various training and operational exercises, or used to identify particular operations, procedures, aerodromes, or flight conditions where safety is highly compromised; or
- the system could be used to track long term trends in flight performance and safety on a squadron or fleet-wide level (considered to be the most important, and statistically valid, use of the system).

The results of the Phase I study indicated that a flight performance monitoring system based on performance criteria provided by standards and training pilots from the CC-130 community is possible. This Volume outlines an approach to the development of an AOFPMS which will:

- allow the quantification of flight performance with respect to flight safety; and
- track changes and trends in flying performance as a result of changes in doctrine, strategy, tactics, training, and experience levels.

It is necessary that such a system be designed and implemented specific to the requirements of CC-130 operations and within the current financial restraints imposed on the Canadian Forces. A number of design goals have been used to devise an approach to the development of an AOFPMS. A primary focus has been to use:

(i) existing hardware and software development tools currently available at DCIEM, and
(ii) utilise inexpensive commercial hardware and software tools to design and implement the system.

Specific design goals are listed in the following section.

DESIGN GOALS

- The system should provide an objective measure of aircrew flight performance.
- Flight performance measures should be based on the expertise and experience of standards and training officers.

- The scoring and analysis of flight performance measures should focus on the safety of flight operations.
- The design should minimise the personnel and financial resources of the operators required to implement and run the system.
- The system should be applicable to the complex CC-130 operational requirements and missions.
- The system should be readily affordable in terms of the initial capital costs and long-term operating costs.
- The data collection, data analysis, and report generation should be automated.
- A high degree of data security should be inherent in the system in order to insure the confidentiality of the data.

DEVELOPMENTAL APPROACH

An extensive literature review and trade study has been undertaken into the hardware and software technologies that would allow these design goals to be met. A two-year development effort is proposed building on the technical expertise developed in Phase I of the CC-130 study as well as DCIEM resources developed in support of other research and development programs.

Year I efforts will focus on the following areas:

Knowledge Engineered Scoring System (KESS). In Phase I of this study, the Knowledge Engineering Scoring System was developed using a written questionnaire which was distributed to 29 standards and training pilots in the ATG community. Based on the feedback received, a revised computer-based questionnaire would be prepared and distributed. Follow-up interviews would also be undertaken in order to develop a consensus as to the appropriate level of risk that would be assigned to a given flight deviation. This modified KESS would be incorporated into the AOFPMS.

Statistical Analysis/Artificial Intelligence Technologies. Techniques for tracking and analysing trends in various performance metrics will be further investigated. Prototype versions of the software will be implemented and tested using flight data collected from commercial aircraft operations. Techniques for developing a composite performance score based on multiple attributes of flight performance [13] will be implemented and tested using the data from Phase I of the study as well as flight data records from commercial operations and published research.

In the initial implementation of the system, performance tracking will focus on the take-off and landing phases or other phases of flight, such as search patterns, which provide appropriate benchmark performance with which to compare actual flight profiles. These segments of flight are also the most critical with respect to flight safety. A major part of this study will be to determine which flight data can be automatically compared to an objective standard.

Database and Data Warehouse. Implementation of an AOFPMS will result in the collection of tera-byte quantities of data. Costs for the physical storage of such quantities have been dramatically reduced with advances in optical storage technologies. However, the organisation and tracking of such large quantities of data is problematic. Commercial database systems, designed primarily for financial and personnel data are generally inappropriate for the type of data that would be collected from an aircraft flight data recorders. DCIEM has investigated a number of database approaches developed in support of remote sensing systems and interplanetary space missions. This has resulted in several prototype database systems for the storage and archiving of large amounts of physiological research data. A prototype database and data warehouse system utilising object-orientated database management technologies will be designed to handle the large amount of data from CC-130 operations. As in the case of the physiological data, the data storage system will be integrated into the data analysis architecture of the AOFPMS for efficient analysis and report generation.

FLIGHT DATA RECORDER

A major barrier to implementing an AOFPMS in the CC-130 operational system may be the cost of retrofitting and maintaining a dedicated AOFPMS flight data recording system in the CC-130 fleet. Additional costs associated with transferring the data to an analysis centre could also be prohibitive. However, advances in data collection and storage technologies have reduced potential costs dramatically. A trade study and preliminary design of an inexpensive flight data collection module to interface with the databus of the upgraded avionics system of the CC-130 aircraft will be undertaken. The system will be based on commercial embedded digital hardware for local signal processing and data storage and modern cellular telephony hardware and software to automate the transfer of flight data to DCIEM for processing and analysis. As much local data processing and analysis would be performed in the aircraft-based system as possible to reduce the quantity of data transferred and the associated costs.

At the end of the first year, technical reports will be prepared on the feasibility and progress in each of the key technical areas, described above, required for the implementation of the system. Given sufficient progress in addressing all of the implementation problems, the second year of the program will involve the development and testing of a prototype AOFPMS system.

Flight data recorder. A prototype flight data collection and transmission unit would be installed in one of the CC-130 aircraft. The automated data collection, security systems, and transfer of flight data to DCIEM would be tested.

Statistical Analysis/AI Technologies. Software for the automated processing of flight data would be tested, evaluated, and refined. The overall efficacy of the data analysis technologies and report generation will be evaluated. The operators will be asked for input on the usefulness of the analysis and the design of the automated reports.

Data Base and Data Warehouse. The design of database and data warehouse system will be finalised. A prototype version of the software will be implemented and tested on the DCIEM file server.

At the end of the second year of the study, a second series of reports will be prepared. These will include recommendations as to whether to proceed with implementation of the AOFPMS in the CC-130 fleet based on feedback from the operators. This report will include estimates of the cost of hardware installation in the CC-130 aircraft, monetary and manpower costs associated with the ongoing maintenance of the hardware, and the ongoing costs associated with maintaining the analysis systems and data warehouse at DCIEM.

CONCLUSIONS

An Automated Operational Flight Performance Monitoring System (AOFPMS) could be a valuable tool for the quantification of flight performance with respect to flight safety; and for the tracking of changes and trends in flying performance as a result of modifications to doctrine, strategy, tactics, training, and experience levels of CC130 personnel. It is necessary that such a system be designed and implemented specific to the requirements of CC-130 operations and within the current financial restraints imposed on the Canadian Forces.

A two-year development effort is proposed building on the technical expertise developed in Phase I of the CC-130 study as well as DCIEM resources developed in support of other research and development programs. This approach is designed to minimise the risks and costs associated with the development of an AOFPMS.

REFERENCES

1. Hendy, K.C., Thompson, M.M., Fraser, W.D., Jamieson, D.W., Comeau, P., Mack, C.I., Paul, M.A., and Brooks, C.J. (1998). Human factors of CC-130 operations — Volume 1: Final report of the DCIEM/ATG study team (DCIEM 98-R-14). Toronto, Ontario, Canada: Defence and Civil Institute of Environmental Medicine.

2. Thompson, M.M. (1998). Human factors of CC-130 operations — Volume 2: Crew performance measures (DCIEM 98-R-15). Toronto, Ontario, Canada: Defence and Civil Institute of Environmental Medicine.

3. Jamieson, D.W. (1998). Human factors of CC-130 operations — Volume 4: Training systems knowledge (DCIEM 98-R-17). Toronto, Ontario, Canada: Defence and Civil Institute of Environmental Medicine.

4. Hendy, K.C. and Ho, G. (1998). Human factors of CC-130 operations — Volume 5: Human factors in decision making (DCIEM 98-R-18). Toronto, Ontario, Canada: Defence and Civil Institute of Environmental Medicine.

5. Paul, M.A., Pigeau, R.A., and Weinberg, H. (1998). Human factors of CC-130 operations — Volume 6: Fatigue in long-haul re-supply missions (DCIEM 98-R-19). Toronto, Ontario, Canada: Defence and Civil Institute of Environmental Medicine.

6. AGARD (1997). Aerospace 2020 (Advisory Report AGARD-AR-360). Neuilly-sur-Seine, France: Advisory Group for Aerospace Research and Development.

7. Hubbard, D.C., Rockway, M.R., and Wang, W.L. (1989). Aircrew performance assessment. In, R.S. Jensen (Eds.), *Aviation Psychology*. Aldershot, United Kingdom: Gower Technology. 342-377.

8. Learmount, D. (1997). Acceptable errors. *Flight International*, 152(November 13), 30-31.

9. Proctor, P. (1996). New statistics on CFIT. *Aviation Week and Space Technology*, 144(April 15), 15.

10. Morrison, R. (1994). Automated performance measuring system: technical summary and workshop synopsis (Techical Report). Moffett Field, CA, USA: National Aeronautics and Space Administration, Ames Research Center.

11. Banks, R.D., Hendy, K.C., Fraser, W.D., Thompson, M.M., Jamieson, D., Wright, H., Gee, T., Mack, C.I., Latulip, J., Davis, B., and Cole, M. (1996). Human factors study of CC-130 operations (DCIEM 96-R-66). North York, Ontario, Canada: Defence and Civil Institute of Environmental Medicine.

12. Fraser, W.D., Gee, T., and Banks, R.D. (1997). Flight performance using a knowledge engineered scoring system. *Aviation Space and Environmental Medicine*, 68(635), 635.

13. Ross, L.E. and Mundt, J.C. (1988). Multiattribute modeling analysis of the effects of a low blood alcohol level on pilot performance. *Human Factors*, 30(3), 293-304.

Unclassified

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(Highest classification of Title, Abstract, Keywords)

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3. DOCUMENT TITLE (the complete document title as indicated on the title page. Its classification should be indicated be the appropriate abbreviation (S,C,R or U) in parentheses after the title.)
Human factors of CC-130 operations: Volume 3. Future aircraft measures (U)

4. DESCRIPTIVE NOTES (the category of the document, e.g., technical report, technical note or memorandum. If appropriate, enter the type of report, e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.)
Technical report

5. AUTHOR(S) (Last name, first name, middle initial. If military, show rank, e.g. Burns, Maj. Frank E.)
W. D. Fraser and T. Gee

6. DOCUMENT DATE (month and year of publication of document)
Feb 1998

7.a. NO. OF PAGES (total containing information. Include Annexes, Appendices, etc.)
11

7.b. NO. OF REFS. (total cited in document)
8

8.a. PROJECT OR GRANT NO. (if appropriate, the applicable research and development project or grant number under which the document was written. Please specify whether project or grant)
Thrust 3fa-11

8.b. CONTRACT NO. (if appropriate, the applicable number under which the document was written)

9.a. ORIGINATOR'S DOCUMENT NUMBER (the official document number by which the document is identified by the originating activity. This number must be unique to this document.)
DCIEM No. 98-R-16

9.b. OTHER DOCUMENT NO.(S) (any other numbers which may be assigned this document either by the originator or by the sponsor.)

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aircrew performance
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#SD8029

98-01221