Budapest University of Technology and Economics
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LÁSZLÓ CZÖVEK

APPLICATION OF FLIGHT DATA IN THE ANALYSIS OF REAL AERONAUTICAL SITUATIONS

PhD Dissertation
Theses

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Budapest, 2005

During preparatory works of this Thesis the following research activities were fulfilled and published:

1) *Computerized Integrated Objective Measurement Unit for recording on-board flight data (SZIROM – Hungarian abbreviation)*, that was developed to replace the original Russian electro-optical data recording unit of MiG-21 fighter planes. The development was performed between 1989 and 1993 in Taszár, at the 31th Tactical Flying Corps. The system – after modifications – was also applied on Mi-24 combat helicopters, and L-39, JAK-52 training planes of the Hungarian Air Force.

2) *Autopilot Data-recording and Evaluation System (ROBAR)* that is a special equipment to record the input and output signals of the on-board automatic control unit during flight and also on ground. The development was performed between 1991 and 1994 in Taszár, and the system was designed for MiG-21 type planes to facilitate the optimization process of their autopilots. (1994, Dr. Univ. at BME)

3) *Integrated Computerized Analysis of flight data recorded by TESZTER (TISZA).* This system was developed in order to replace the original data processing units of SZU-22 battle planes, to improve the speed and precision of flight data analysis. The development was performed between 1990 and 1993 in Taszár.

4) *Instrumental Presentation and Analysis of flight data recorded by TESZTER (TEMES).* A whole new kind of visual presentation system was developed using the database of TISZA. The program is able to graphically present (with physical annotations) the flight trajectories in space-time, using on-board flight data. The pilot or the trainer had the possibility to simulate in 3D and to evaluate the pilot's performance after executing the mission. The development was performed between 1991 and 1993 in Taszár.

5) *Receiving and Analyzing TESZTER data (TAVASZ-22)* is a system that can read on-board data of SZU-22 planes, can evaluate technological status, and archive flight information. The development was performed between 1993 and 1996 in Taszár.

6) *On-board medico-biological data recording unit (MEDICINA)* is measuring, recording, and storing the psycho-physical parameters of the pilot during flight. The data proved to be useful for medical examinations of pilots, and the development was internationally inquired.

7) The development of *TAVASZ-29* and the *Flight Data Analysis System (RAR)* was performed between 1997 and 2001 in Kecskemét, and this research work is covered in this Dissertation.

Thesis I. Based on simulation data I have developed the specification of solid-memory data recording unit used to store flight data (Chapter II.3, and Appendix 1).

1. I have determined the number of parameters to be measured, evaluated the available recording channels (116 out of 256 proved to be applicable for the new unit), and finally, defined the frequency of measurement based on the physical meaning of signals.
2. I have transformed the general equations of flight dynamics into a more application oriented form, in order to simplify simulation tests.
3. I have bounded the scope of flight parameters to be measured for
   - examination of flight affairs;
   - analysis for diagnostic purposes;
   - qualification of the flight-dynamics, maneuverability, and technological state of planes;
   - optimization of operational process, and evaluation and prediction of parameter value deviances.
4. I have performed simulation experiences to evaluate the usability of information contained in different characteristic parameter sets. I have concluded that the characteristic parameters have modest variances, not only for the different types of aircrafts (fighter, interceptor, combat etc.), but also for individual planes of the same type.
5. I have determined the scope of characteristic parameter that should be used for fast evaluation of flight-dynamics and technological state of planes. Based on these the unit MAKI can perform on-site evaluation directly connected to the aircraft.

Thesis II. I have finalized the structure of the proto-type using simulation results an experimental flights (107 hours), and developed the necessary test-flight procedure.

1. I have collated the simulation and measurement processes, and developed a new calibration technology. In designing MAKI-H I have considered the physical characteristics of measured data, the types of sensors, the form and method of recording and presentation, and also the special modifications of individual plane types.
2. Based on the above I have introduced an individual calibration process that is described in Chapter IV. I have
   - processed the information of test-flights and ground measurements;
   - optimized the measurement technology for different channels;
   - suggested the multi-channel recording of given parameters (sampling time, measurement range, sensitivity).
3. Based on the results obtained in the course of experimental flights I proposed an improvement of both of terrestrial and airborne flight operation systems.

- According to my proposition, a new airplane service, maintenance and repair technology have been introduced at the organizations operating the MIG-29 fighters dated back to 2001.
- After successful system integration of the prototype system I prepared the operating and maintenance documents of the new information system.

Thesis III. In order to ensure portability of recorded data I made a computer program for performing the necessary data conversion (see CD attachment / Converter).

1. I processed and converted the flight data (.RAW is the data read-out from the board computer in raw format which is then converted to .TXT format by the converter, which in turn, is the input of the unka.exe producing the more tractable .DAT file format.)

   - As a result, the precision of the system was increased of one order of magnitude; moreover, the time of investigation required for analyzing flight event situations and accidents was decreased significantly.
   - Based on the above achievements the 3D reconstruction of flight trajectories, the construction of flight simulation models and motion equations can be made easily based on the recorded data.
2. I elaborated the system of conditions of frequent deployment of flight troops, as well as the conditions of air force operations initiated from alien air bases.

   - The equipment checks and visualizes the result from various viewpoints besides the airplane, immediately after reading out the data from the board computer. Evaluation of data is based on 59 selected parameters.
   - The equipment is capable to store significant amount of flight information related to various flight programs. It helps immediate application of the data evaluation method for fast military actions possible. See details in CD attachment No.2.
   - I performed the investigation of flight parameters for the proper selection of features best characterizing the flight mission. Parameters related to flight operation, control of the airplane and the jet engine were analyzed as the function of the error ranges of recording and visualization.
   - I made simulation experiments in MATLAB for selecting aircraft type specific features to be recorded in different airplane environments.

Thesis IV. With the utilization of in-flight recorded data I investigated the applicability of mathematical models and transfer functions for diagnostic purposes.

1. I performed examination of the control rules of the automatic control system and the deviation of the transfer rate.

   - I determined the adaptation of the automatic control system regarding the aircraft type and individual flight range (according to "wing-number", military terminology).
   - I made the analysis of the mathematical model of the controller regarding the set of fixed parameters (this can be found in the third chapter of the thesis).

- I established the rule of the improvement of the conditioning number of the diagnostic matrix assuming the input and output parameters of the matrix are recorded objectively.
- I performed investigation of operational methods applied in Hungarian Air Force troops. I made the conclusion that status-specific operation strategies can only be realized with the simultaneous use of advanced diagnostic methods. The information provided by the developed equipment could be satisfactory for the continuous sustenance of the mentioned operational procedure, providing the proper expertise of the operational personnel.

2. I refined existing and developed new mathematical models and simulation methods necessary for the utilization of task specific flight information data.

   - I proved that the mathematical model of aircraft dynamics relates parameters describing the position and movement of the plane, moreover, this model makes the analysis and design of controllers possible too.

3. The new board recorder stores parameters of the diagnostic matrix and the deflections of flaps.

   - Representing the system of linearized differential equations of the longitudinal and transversal movements in a matrix form one obtains the vector differential equations in their general forms [94] which are usually referred to state equations. Neglecting external disturbances the state-space representation of the airplane is obtained as [96,112,113,142]:

     $$\dot{\mathbf{x}} = \mathbf{Ax} + \mathbf{Bu}$$
     $$\mathbf{y} = \mathbf{Cx} + \mathbf{Du}$$

     where $\mathbf{A} = \mathbf{A0} + \Delta\mathbf{A}$, $\mathbf{B} = \mathbf{B0} + \Delta\mathbf{B}$ etc. are the deviation originated from specificity of the aircraft.

4. I identified the entries of the matrix according to the applied flight coding system.

Literatures referenced in the thesis book can be found in the CD attachments / Thesis summary.