6th INTERNATIONAL MULTIDISCIPLINARY CONFERENCE

TESTING OF ELECTRO-MECHANICAL ACTUATORS

Paweł Rzucidło, Rzeszów University of Technology, ul. W. Pola 2, 35-959 Rzeszów, Poland

Abstract: *Power-By-Wire (PBW) technology seems to be the next major step in development of the aircraft control. In this solution control power comes directly from the aircraft electrical system to the Electro-Mechanical Actuator (EMA) which assembles the electric motor, controller and gearbox. Testing of servos actuating airplane control surfaces has been presented herein. Testing method and laboratory results have been also described. Then the in-flight testing results of the complete set of servos installed as a part of SPS-1 system on board of an airplane have been presented. SPS-1 is experimental Fly-By-Wire control system for general aviation aircraft designed as a project financed by Polish State Committee for Scientific Research (2004-2006).*

Key words: *electro-mechanical actuator, Fly-By-Wire, aircraft, tests.*

1. INTRODUCTION

The intricate board systems found in large through medium airplanes, are largely featured with hydraulic actuators. Electro-Mechanical Actuators (EMAs) are only applied for quick and accurate control of the boosters. It would be however difficult to install heavy and expensive hydraulic systems on small planes [7]. In most cases it is just impossible. Thus it seems to be rational to use EMA circuits both to control positioning of aerodynamic controls as well as other control system elements, e.g. power control. EMA have the potential to be more efficient, less complicated, inexpensive and more fault tolerant than actuators based on hydraulic systems [1][3].

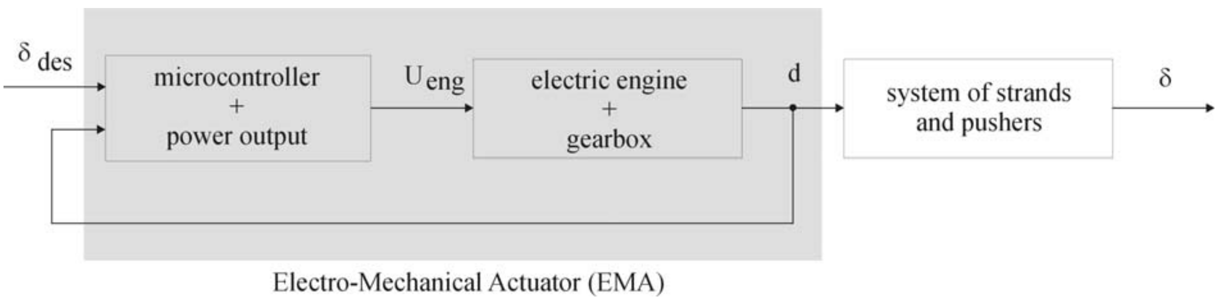

Fig. 1. Simple block scheme of EMA

δ_{des} – desired deflection of control surface [rad],
U_{eng} – engine powering [V],
δ – actual deflection of control surface [rad],
d – displacement of strand [mm].

As actuators are critical elements of Fly-By-Wire (FBW) system, they should be subject to rigorous qualification criteria [2][8]. They have to be reliable, operate stable in any situation. This is a very important requirement, because any actuator failure is likely to lead to a serious accident. Any actuator should be made intrinsically reliable and insensitive to other equipment failure. The second feature can be achieved by the multiplication of superior control circuits (data buses, flight computers) and additional power units [2][5][8].

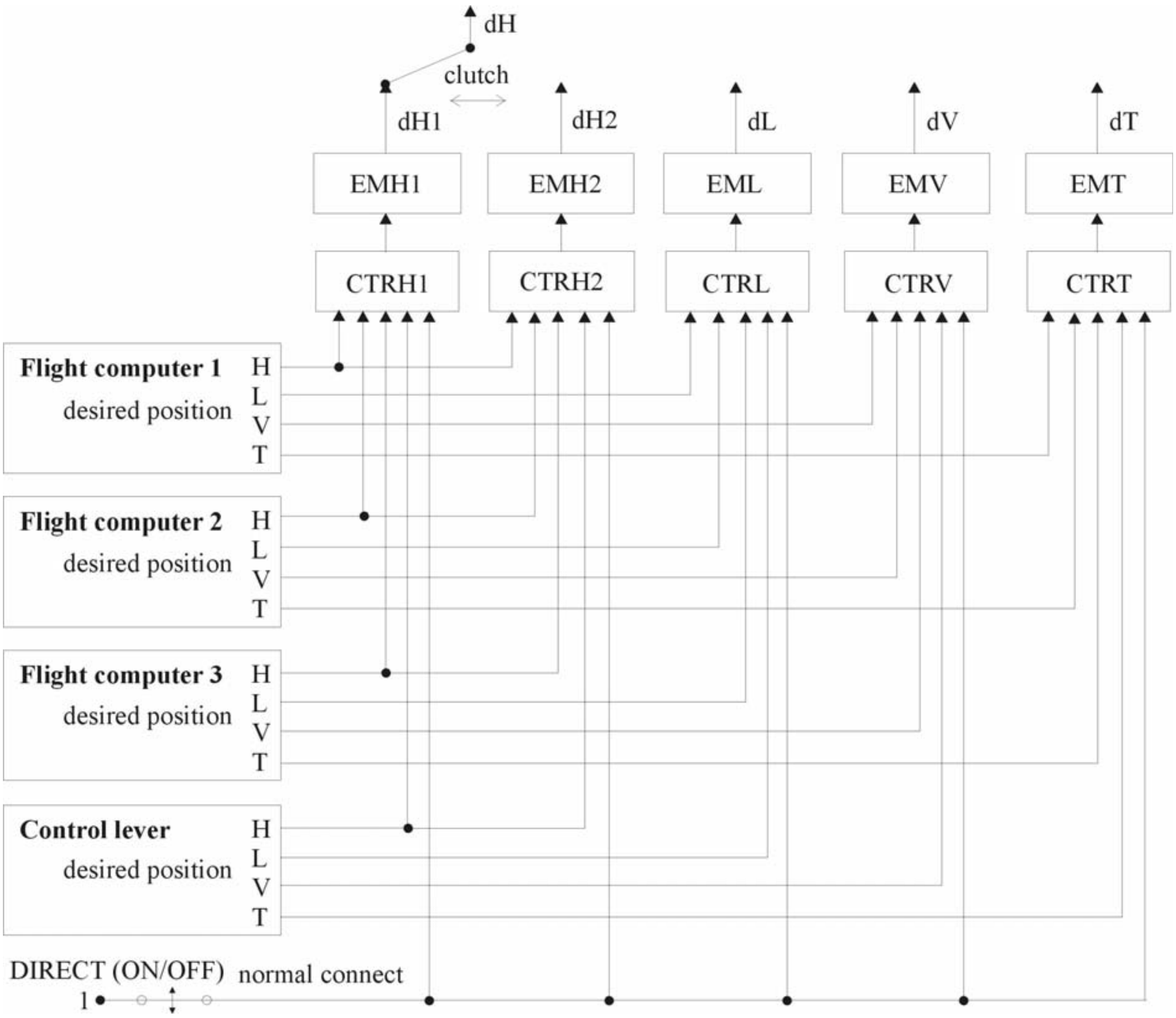

Fig. 2. SPS-1 control system equipped with set of EMA: EMH1/H2/L/V/T – electro-mechanical units, CTRH1/H2/L/V/T – actuator controllers, H – elevator, L – aileron, V – rudder, T – throttle

2. LABORATORY STAND TESTS

In order to perform laboratory tests of the actuators, a special test stand has been constructed [4][5]. This stand enables to perform testing of single actuator at various load conditions, at various driving inputs. A rapid prototyping PC card is used as the test signal source and data acquisition bus. Static tests program included positioning accuracy and allowable load values for various positions of the servo element. Dynamic tests program included the actuator responses to step, harmonic, and special inputs. The test data have been used at adjusting control algorithms, so that the most favorable static/dynamic properties are obtained. The test results are shown in figures 5-6.

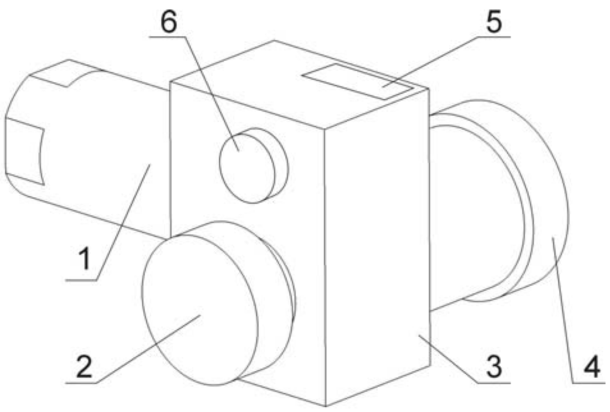

Fig. 3. General view of electro-mechanical unit.

1 – electric engine,
2 – driving roller,
3 – gearbox,
4 – electromagnetic clutch,
5 – electrical connectors (potentiometer to A/D converter, motor powering, powering of electromagnetic clutch),
6 – potentiometer.

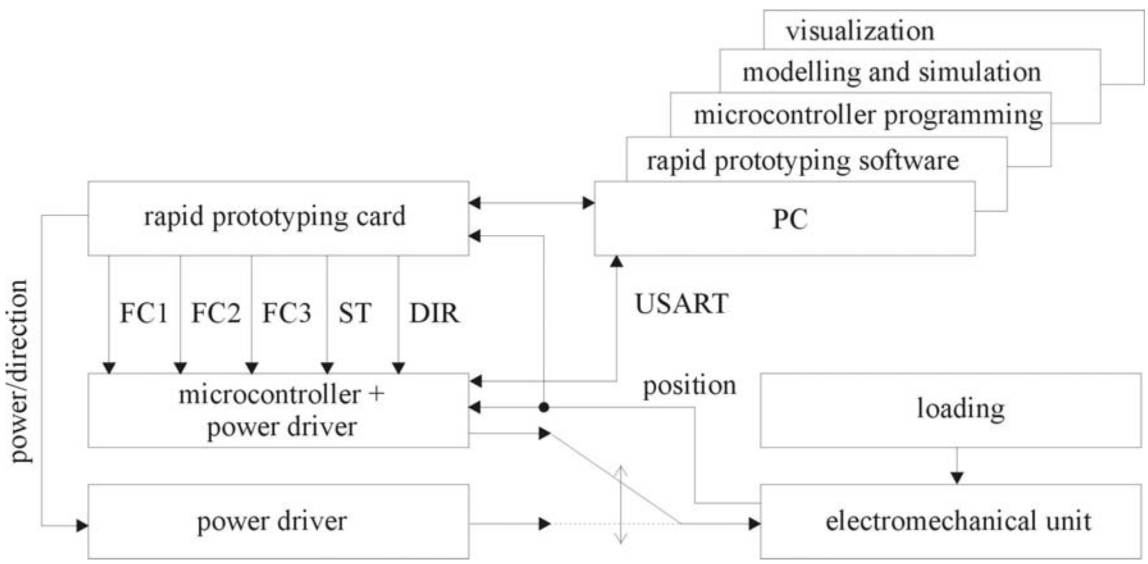

Fig. 4. Block diagram of the laboratory stand, FC1/2/3 – simulated control signals from flight computers, ST – stick position signal, DIR – direct control switch, USART – Universal Synchronous Asynchronous Receiver Transmitter

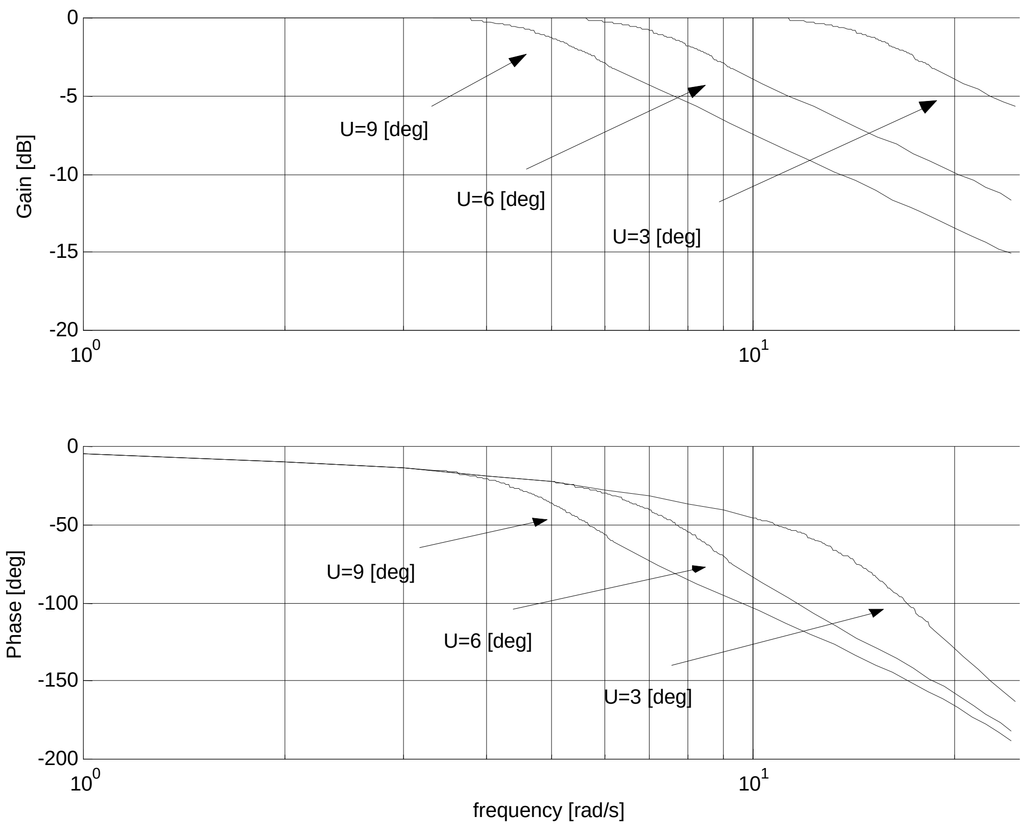

Fig. 5. Frequency characteristics of presented EMA. Characteristics obtained for three different amplitudes of harmonic input function (U)

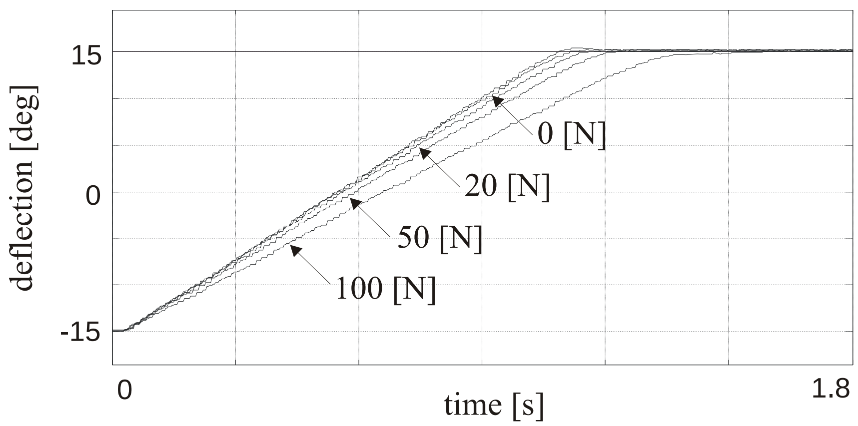

Fig. 6. Responses to step signal, PZL-110 rudder actuator, load: 0, 20, 50 and 100[N]

The tests performed on laboratory stand showed that the actuator controller is able to positioning the control surfaces with established static precision of 0.1 deg (when full range is about ±20 deg). It has been also tested in admitted full load conditions both positive as well as negative. Control algorithm permits to deflect surfaces with maximum power in wide range. Unfortunately speeds are limited by the electromechanical design and due to over saturation, we can only compensate the phase lag. Signal amplitude is suppressed in this case.

3. IN FLIGHT TESTS

The controller operation has been checked in many possible situations. Positive results of laboratory test made it possible to install it on the board of PZL 110 “Koliber” airplane, as a component of the experimental SPS-1 Fly-By-Wire system. The servo systems complete with microcontroller have been installed on the board of PZL-110 „Koliber” aircraft. To achieve higher safety level in SPS-1 system, a redundant elevator servo and controller system has been adopted. Total of 12 flight hours with inputs and responses at various flight conditions being recorded, have been accumulated. Tests performed in flight (July-November 2003) supported the laboratory results. The results of aileron and elevator servos testing are shown in figures 7-8.

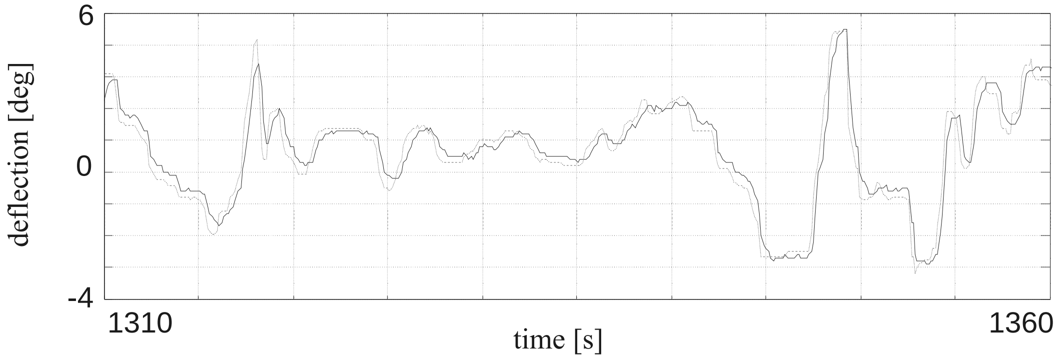

Fig. 7. Aileron positioning during flight tests (2003-10-24, start: 08:47:59 GMT); solid – aileron deflection, dotted – desired value

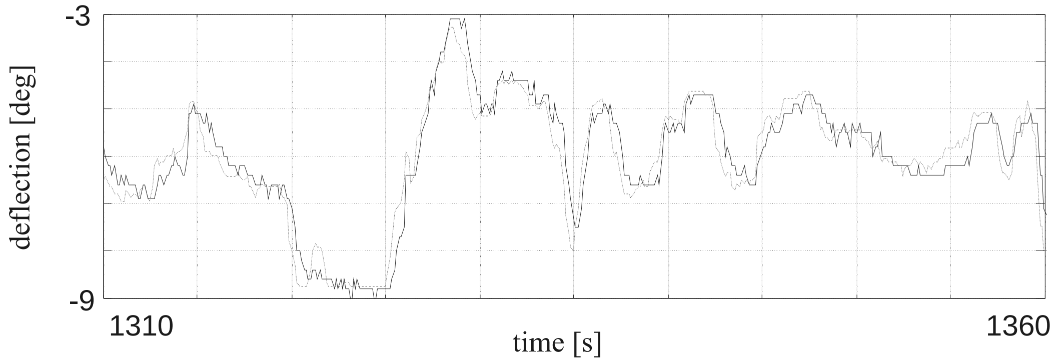

Fig. 8. Elevator positioning during flight tests (2003-10-24, start: 08:47:59 GMT); solid – elevator deflection, dotted – input function

4. CONCLUSIONS AND FUTURE RESEARCH

In order to achieve more reliable solution and perform more advanced real-time tests, two additional CAN type buses will be applied. They will replace the Pulse Width Modulation (PWM) control signals coming from the on-board computers [2]. As a data transmission protocol a *CAN Aerospace* will be used [6]. The next task it will be designing special software for the calibration of operational circuits and testing of the properties of the system operating on this concept. Partial failure of actuators and auto/manual flight commutating will be researched in further step.

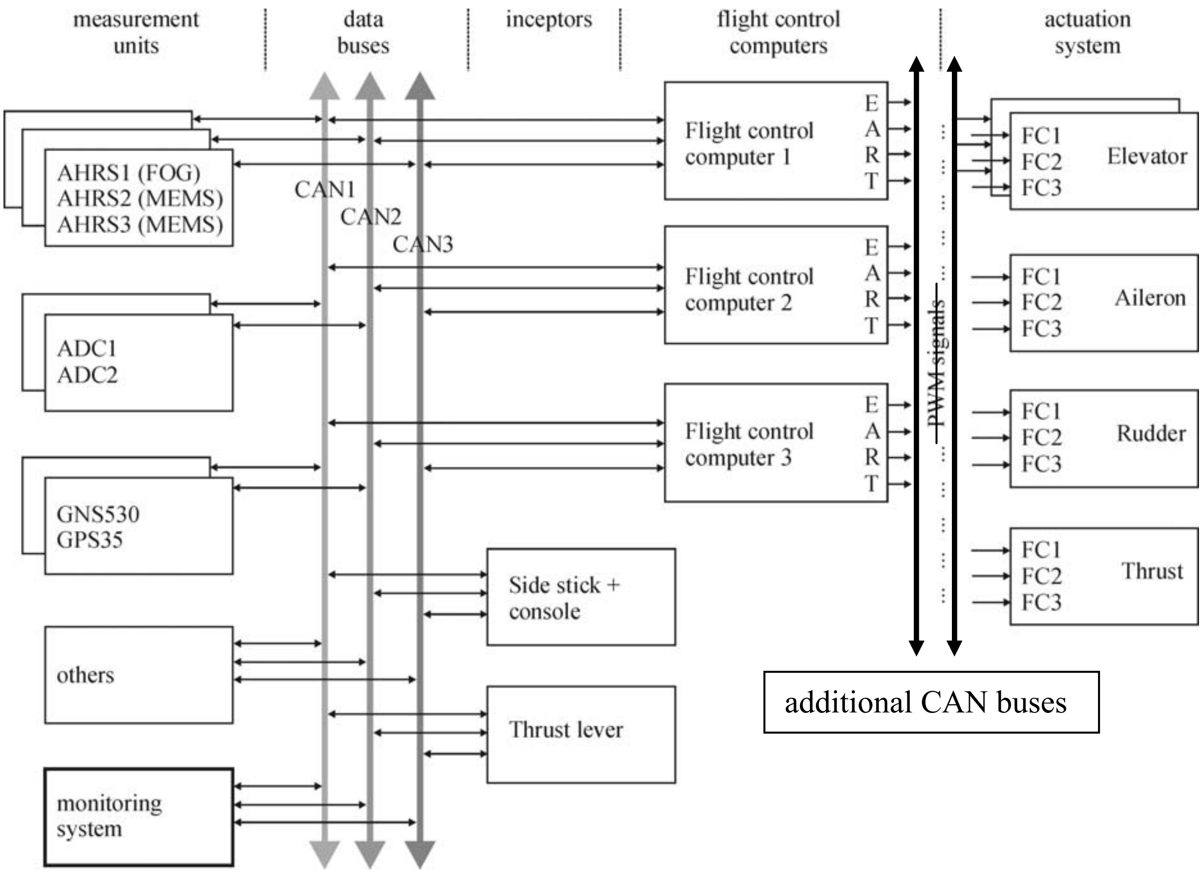

Fig. 9. Structure of SPS-1 control system equipped with two additional CAN data buses dedicated for communication between flight computers and EMA's

5. REFERENCES

[1] Gruszecki J., Grzybowski J., Rzucidło P. (2004), *Electro-Mechanical Actuators for General Aviation Fly-By-Wire Aircraft*, VI International Seminar on RRDPAEIE, Riga, 14-16 October 2004.

[2] Grzybowski, J. and Rzucidło, P. (2003), *Actuators Controller for Small FBW Aircraft*, International Multidisciplinary Conference, Baia Mare, 23-24 May 2003, pp. 193-199.

[3] Jensen S. C., Jenney G. D., Dawson D. (2000), *Flight Test Experience with an Electromechanical Actuator on the F-18 Systems Research Aircraft*, NASA Report: NASA-TM-2000-209015.

[4] Rogalski, T. and Dołęga, B. (2003), *The Laboratory Stand Intends to Test and Prototype Control System for Small Transportation Aircraft*, International Multidisciplinary Conference, Baia Mare, 23-24 May 2003, pp. 125-131.

[5] Rzucidło P. (2004), *Monitoring and Data Acquisition System for Experimental General Aviation Fly-by-Wire Aircraft*, AVIATION-2004, Vilnius, 9-10 December 2004.

[6] Stock M. (2004), *CAN Aerospace Interface specification for airborne CAN applications V 1.6*, Revision 1.6, 12.01.2004, www.stockflightsystems.com.

[7] Tomczyk, A. (2003), *Experimental Fly-By-Wire Control System for General Aviation Aircraft*, AIAA-2003-5776, AIAA Guidance, Navigation and Control Conference and Exhibit, Austin, Texas.

[8] Tomczyk, A. [red.] (2003), *Integrated Control System for General Aviation Aircraft* (in polish), Polish State Committee for Scientific Research 8 T12C 049 20, Rzeszów.