Using the Telemetry System as an Element of the Engine Operation Monitoring System of UAS

Teresa Buczkowska-Murawska[1], Mariusz Zokowski[2]
Air Force Institute of Technology[1, 2]
POLAND

[1]teresa.buczkowska-murawska@itwl.pl, [2]mariusz.zokowski@itwl.pl

Keywords: engine, UAS, telemetry, logger.

ABSTRACT

The paper deals with obtaining the engine operating characteristics in real conditions, which seems feasible with the use of telemetry system. The condition of that the telemetry system is fully documentable. In absence of full knowledge, the problem is how to adjust the existing solutions so as not to damage the engine. The paper presents a different approach consisting of adjusting the system to the engine telemetry system in such a way that it would be undetectable to it. The article presents an engineering approach that allows collecting action of engine operation characteristics using built-in telemetry mechanisms. However the innovation, filled with the passive recording system. As a result of the development of the solution, the characteristics of the engine operation in real conditions were obtained and the universal registration tool was built with a wider application than simply the registration of engine operating parameters. The development of the solution allowed measurements to obtained in a passive mode using a distributed architecture for engine monitoring. Engine operation characteristics, which without logger production, would be difficult to obtain and archive especially during flight tests.

1.0 INTRODUCTION

Unmanned Aircrafts Systems (UAS), commonly called drones, are gaining popularity every year. Today, they are used both in the civilian and military applications. Manufacturers, noticing the potential of the UAS, make attempts to build them for transporting critical items like medicines, medical samples as well as for monitoring of border and forest areas. Taking into account the increasing use of UAS, monitoring their condition is an important aspect. The engine should be special observation because in the event of its failure, it usually ends with the failure of UAS. Monitoring is therefore a critical element of the design. Considering UAS as a special automation system, it would be necessary to use a parallel monitoring system, which may be in contradiction with the restrictions on the weight of the object. UAS engines usually have a built-in telemetry system, therefore it is advisable to consider using it for the ongoing monitoring of the UAS state. If it is noted that telemetry information is used to ensure the correct operation of the engine, its undisturbed capture could also meet the conditions for monitoring their operation. The complication may be various communication techniques found in such solutions, such as: single-cable, CAN, Modbus and others, including proprietary solutions. An additional difficulty in such cases may be the lack of knowledge of the protocol according to which data are sent from the transmitter, often from the sensor to the receiver. These buses can also have different architecture, e.g: *point for point* (Fig. 1) or *peer-to-peer* (Fig. 2), influencing the final location of the monitoring elements.

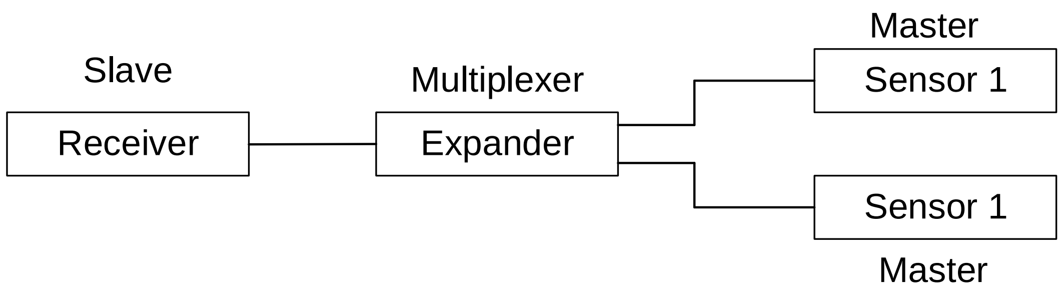

Figure 1. Topology *point to point*.

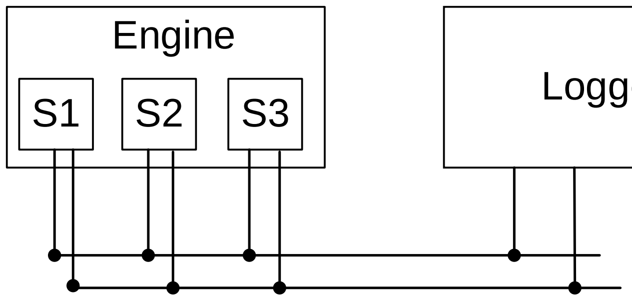

Figure 2. The Bus Diagram.

The article will present the advantages and disadvantages of independent control and monitoring systems and a hybrid approach using sensors existing, as shown in Fig. 2. Figure 3 shows an example of a jet engine during the tests.

Transmission of signals under the name of telemetry has found application in many disciplines [1] and depending on their specificity, it is possible to use various transmission technologies. Most of them, however, are not applicable to the Remotely Piloted Aircraft Systems (RPAS). As shown in Vasylenko *et al.* [2], although at that time a single standard had not been adopted, protocols available under the Lesser General Public License (LGPL) license, eg MAVLink, were also developed. An alternative to them is, for example, *JETI*, which is proprietary protocol (company: JETI model s.r.o.). Regardless of the protocol, it is important to minimize the transmission bandwidth. It should be noted that the transmission channel in the transmitter-receiver system has limited speed [3] and this speed is relatively low. The best example of this is presented by Zebrun [4], which shows that long-range telemetry is a difficult task.

As shown in Thompson *et al.* [5] designing control systems architectures is extremely difficult involving a mixture of quantitative and qualitative decisions bringing together data and experience from many different design disciplines. Also in RPAS, there are many parallel requirements, practical issues and trade-offs which need to be considered. It is worth mentioning: reliability, availability, certifiability, weight, number of connectors and other. Having regard to the above, for the safety RPAS in flight, it was decided to adapt the solution *JETI*. In this sense, the developed solution can be categorized *smart sensor*, as part of a distributed control system [6].

2.0 MATERIALS AND METHODS

The test article used in research was the development of methods of supervision of the operation of the

JetCat-220 engine [Fig. 3] as part of tests on the ground and in flight. This engine was equipped with an integrally connected telemetry system that allow basic parameters of its operation to be obtained: engine speed, fuel flow, exhaust gas temperature, remaining fuel, which should be integrated with the Unmanned Aerial Vehicle (UAV) telemetry infrastructure. The problem, however, was that there was no complete documentation of the engine's telemetry system, hence it was decided not to connect it to the UAV telemetry bus [7] as an object subject to control.

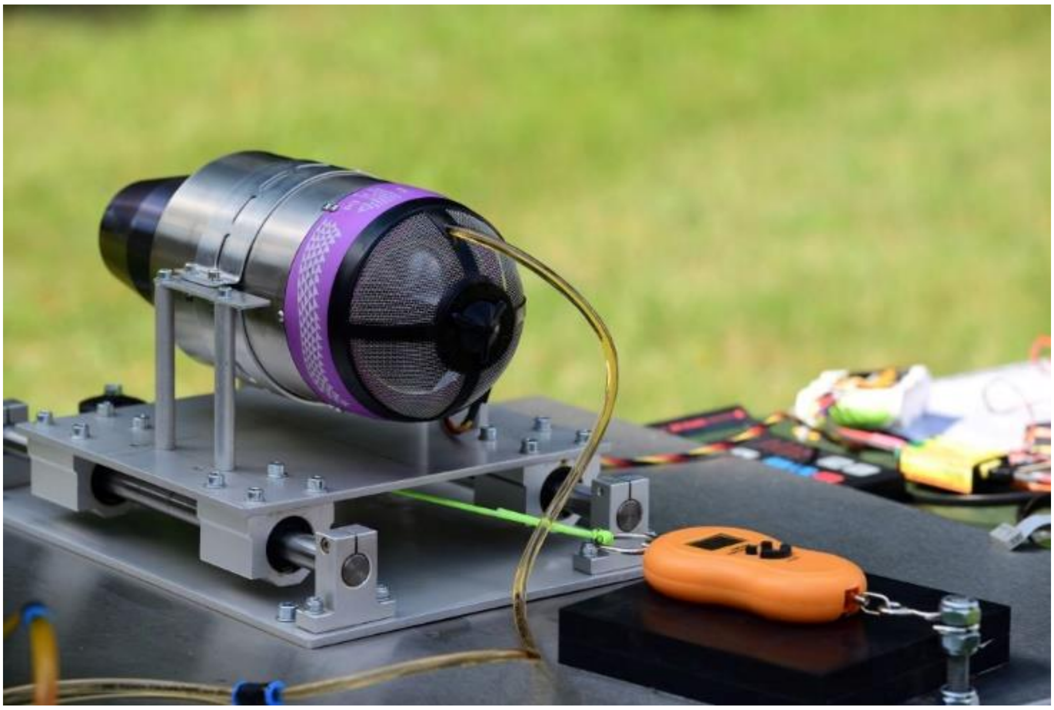

Figure 3. The engine during test.

In view of the above, it has become necessary to develop a method of obtaining data in a way that minimally interferes with either the existing telemetry infrastructure and the engine's measuring system. In the course of work, it was decided to treat the engine's telemetry infrastructure as passive and to build a device, the so-called logger that would passively collect frames sent on the bus, simulating a sensor. To build the measuring system used *Teensy 3.5* [Fig. 4]. This system was characterized by high work–speed (Processor *ARM Cortex* M4 180MHz), integration with *microSD* card support and full voltage tolerance +5V at logic supply voltage 3.3V, which guaranteed the possibility of trouble-free connection.

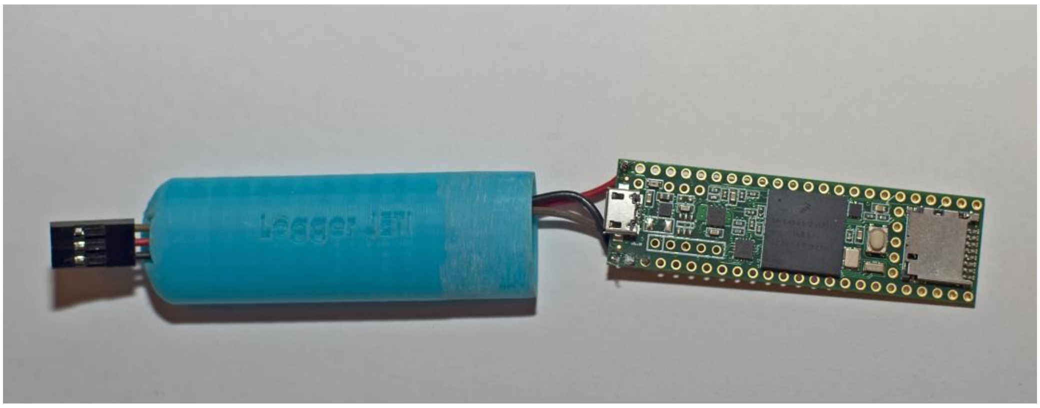

Figure 4. Teensy 3.5 board with dedicated protective case.

The sensor software was written in C using the *Arduino* environment. A particular challenge was that communication via the *JETI* serial bus is carried out with the following parameters: 9600 – 9800 Baud, 9 data bits, 2 stop bits, ODD, logic 0: 1.5V (max); 1: 3.0V (min) thus parameters not typically supported by computer systems. During the work on the software, it also became apparent that the 9-bit transmission is not a constant parameter and the protocol itself forces sending some data in version 8 and in the 9-bit part. Due to the lack of this information in the documentation, this observation, confirmed need for an adopted approach to obtaining telemetry information from the engine in a passive way. The solution to the problem was to use a switchable communication mode (9-8 bits) supported by the *Teensy* processor.

After the software was written, the circuit was connected to a sensor with known characteristics in order to validate the readings taken. Then, the system was connected to the engine's telemetry system [Fig. 5].

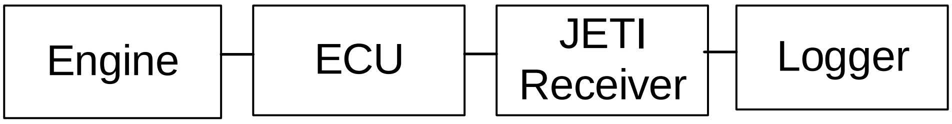

Figure 5. Logger connection diagram.

3.0 RESULTS

The selected and programmed *logger* device was passively reading and decoding messages appearing on the *JETI* bus. The constructed and programmed system allowed for the interception of the full transmission of telemetry data, including data from the engine, as well as for their transmission and archiving. An example of successive decoded transmission frames is included in Table 1.

Table 1. Fragment of telemetry readings acquired by the logger.

Frame Id	JET frame	Parameter	Value	Unit
1353470	JetCat/0209a410/9	FuelFlow	352	ml/m
1353558	JetCat/0209a410/10	Altitude	650	m
1353558	JetCat/0209a410/11	Thrust	57	N
1353647	JetCat/0209a410/12	RpmSet	72000	/min
1353647	JetCat/0209a410/1	EGT	23	°C
1353735	JetCat/0209a410/2	Rpm	40000	/min
1353735	JetCat/0209a410/3	Pump	3,35	V
1353824	JetCat/0209a410/4	EngBattery	10,5	V
1353824	JetCat/0209a410/5	EngCurrent	1,2	A
1353912	JetCat/0209a410/6	BattCapa	0	mAh
1353912	JetCat/0209a410/7	State/Flags	0	
1354001	JetCat/0209a410/8	RestFuel	100	ml
1354001	JetCat/0209a410/9	FuelFlow	352	ml/m
1354089	JetCat/0209a410/10	Altitude	650	m

From data obtained in this way, it was possible to determine the nature of engine operation during its test and to verify the relationship engine speed *vs.* fuel flow *vs*. exhaust gas temperature *vs*. remaining fuel [Figure 6, 7, 8, 9].

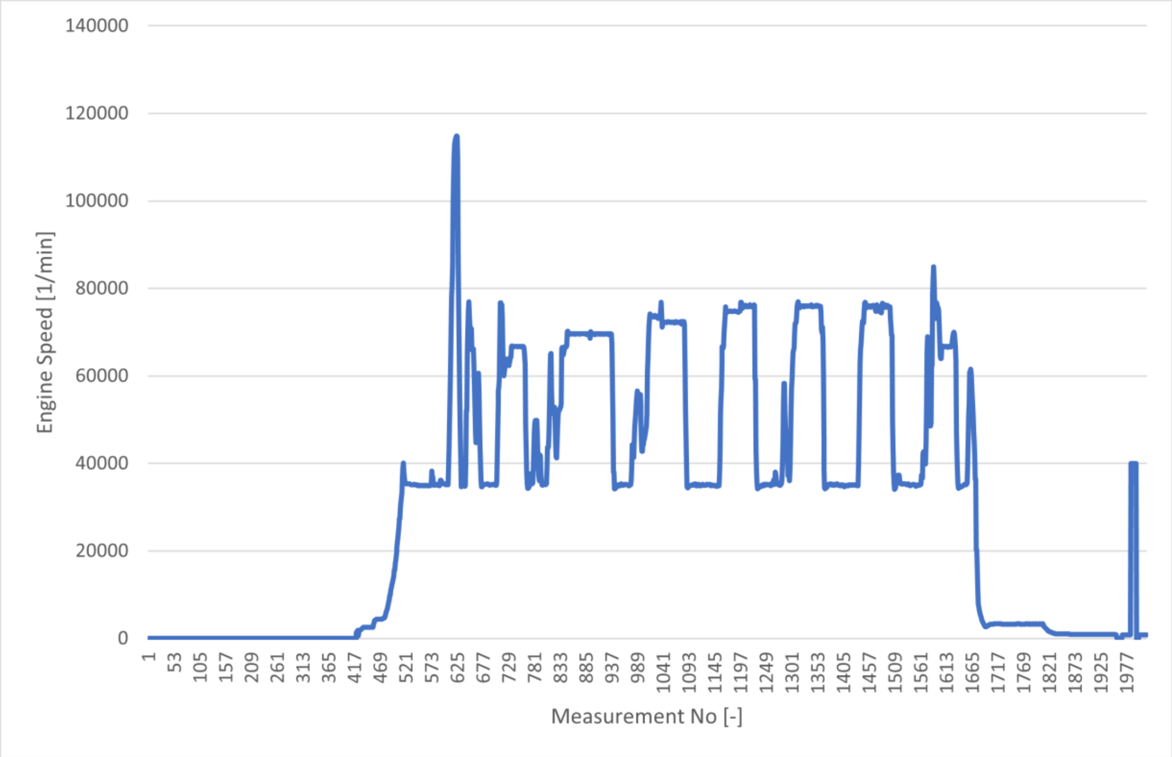

Figure 6. A sample registration of engine speed.

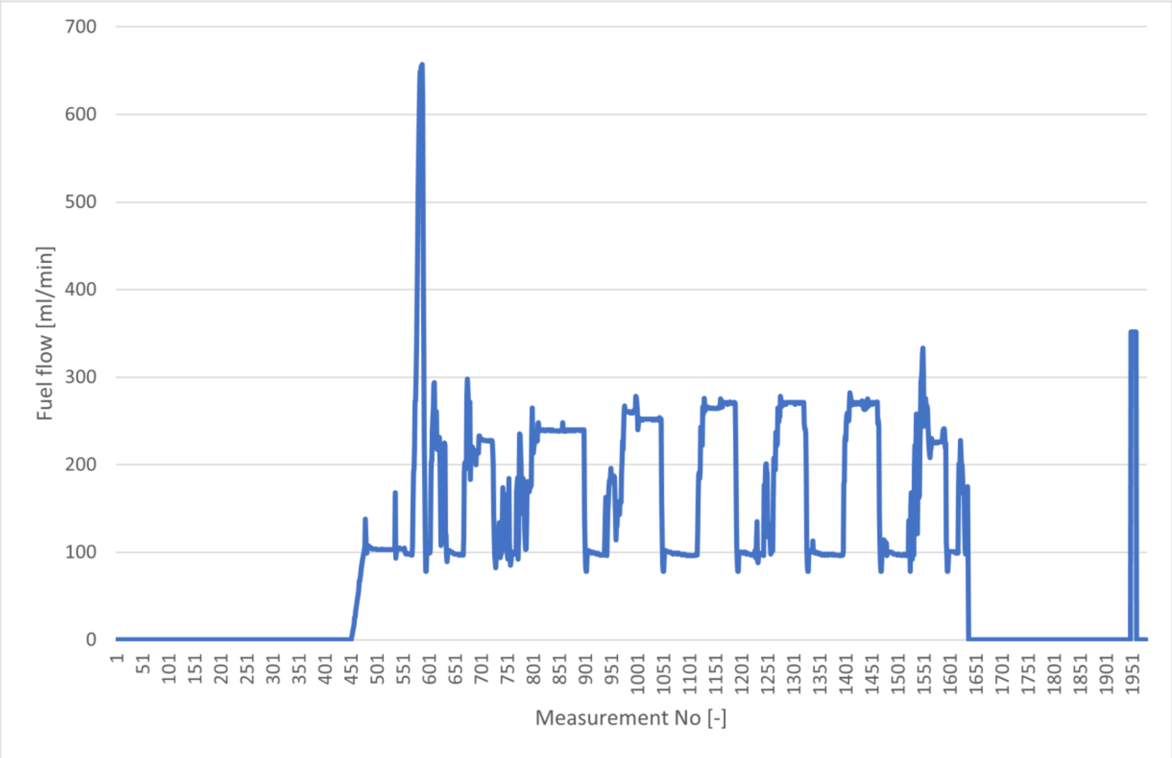

Figure 7. A sample registration of fuel flow.

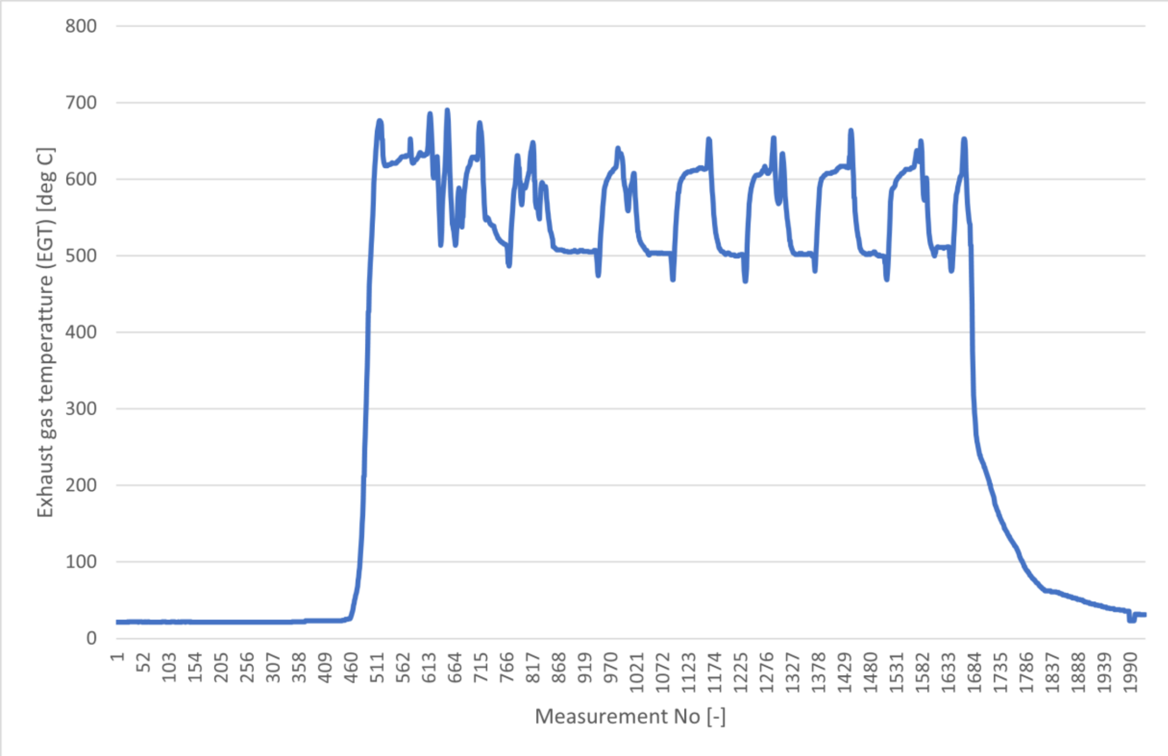

Figure 8. A sample registration of exhaust gas temperature.

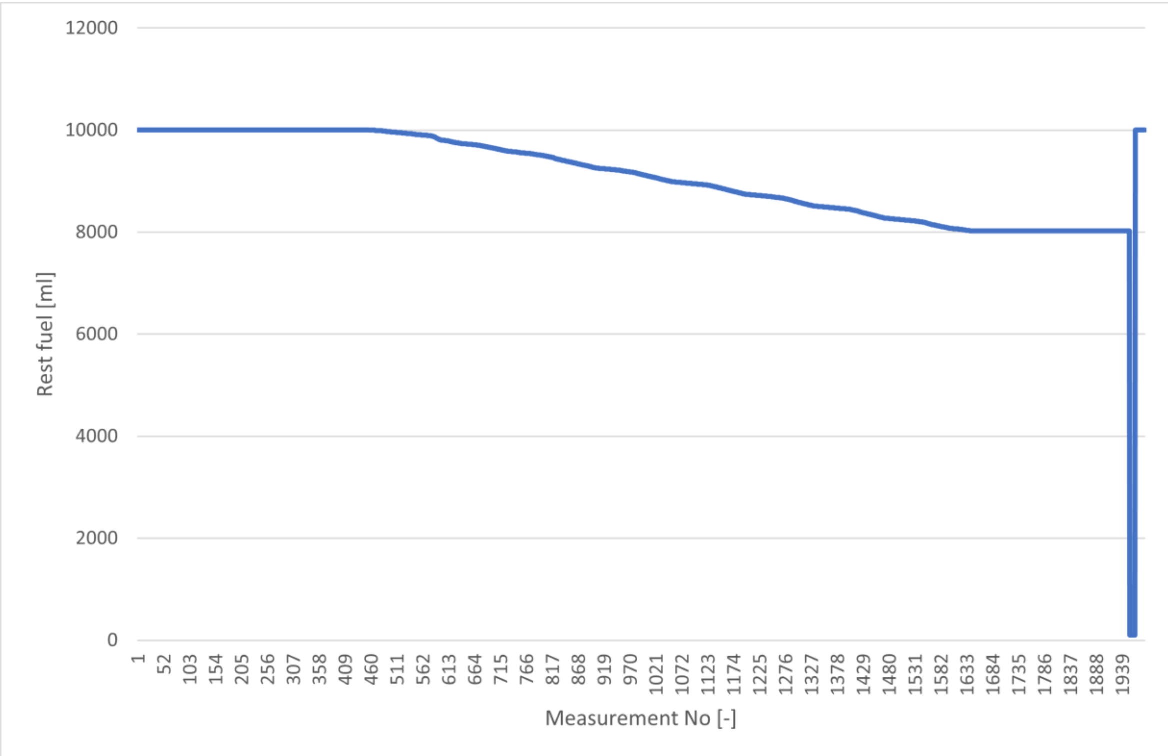

Figure 9. A sample registration of remaining fuel.

4.0 DISCUSSION

Built and programmed electronic system - passive logger allowed to collect engine performance characteristics. As can be seen, the relation engine speed *vs.* fuel flow *vs.* exhaust gas temperature has the nature of a similarity relationship differing essentially not so much in the nature of the work as in the achievable values. The correlation between the signals of the variables was analysed by used Spearman correlation (Table 2). As the fuel consumption increases, Rpm increase and exhaust gas temperature increase, and the remaining fuel value decreases.

Table 2. Correlation between measured values.

Spearman correlation
Marked wsp. correlations are relevant with $p < 0.05$

Parameter	FuelFlow	Rpm	EGT	RestFuel
FuelFlow	1,00	0,92	0,78	-0,23
Rpm	0,92	1,00	0,80	-0,42
EGT	0,78	0,80	1,00	-0,37
RestFuel	-0,23	-0,42	-0,37	1,00

The logger system can be used both during ground tests to collect engine performance characteristics and in flight as a form of *e.g.* a black box for the purpose of subsequent assessment. Considering the fact that during the tests, the system recorded the readings from 12 sensors, which could then be analyzed after the flight, this proposal seems fully justified. At a later stage of work, the developed telemetry system will serve as a module for the currently under development Health Usage Monitoring System (HUMS) [8]. Its further expansion will require a software change.

5.0 CONCLUSIONS

The development of what allowed to record the measurement characteristics important from the point of view of the engine. More importantly, it took place without any active interference with the engine system, which, with fragmentary documentation, could lead to an unintentional change of its operating parameters. The developed solution is universal and can be used with motors equipped with integrated telemetry systems compatible with the *JETI* bus and in applications developed by Air Force Institute of Technology (AFIT) with the use of jet propulsion. For many years AFIT has been developing unmanned jet powered aerial target system, that are used in military applications.

By using a *smart sensor*, the possibility of expanding the system towards distributed engine control was verified. Engines used for UAVs smaller than 150 kg are usually dedicated to modeling, hobby or sports applications. Before using these engines for military application, they should be tested on the ground [9] and in flight. The developed solution allows to obtain data about the engine during flight tests. This is important because in flight, for safety reasons, we cannot interfere with the engine control system of UAV.

The obtained results and experience gathered as a result of this issue will be used to develop HUMS dedicated to unmanned solutions.

REFERENCES

[1] Misurec, Jiri. (2012). The Possibilities of Data Communication for Telemetry Systems in Energetics. International Journal of Advances in Telecommunications, Electrotechnics, Signals and Systems. 1. 10.11601/ijates.v1i1.3.

[2] Vasylenko, Mykola & Karpyuk, I.. (2018). Telemetry System of Unmanned Aerial Vehicles. Electronics and Control Systems. 3. 10.18372/1990-5548.57.13244.

[3] Tristancho, Joshua & Barrado, Cristina & Mansilla, Sonia & Pastor, Enric. (2009). A telemetry modeling for intelligent UAV monitoring. 7.C.1-1. 10.1109/DASC.2009.5347421.

[4] Żebruń K.; Łazik Perseverance już nadaje z Marsa - kto na Ziemi odbiera te dane i w jaki sposób?; https://www.benchmark.pl/testy_i_recenzje/mars-perseverance-komunikacja-z-ziemia.html; (18.04.2021).

[5] Thompson H. A. & Fleming P. J (1998). Multi-disciplinary optimisation of distributed aero-engine control system architectures. Copyright©IFAC Automatic Control in Aerospace.

[6] Culley D. E. & Paluszewski P. J. & Storey W. & Smith B. J (2009). The case for distributed engine control in turbo-shaft engine systems. NASA/TM-2009-215654, AHS 2009 080366.

[7] JETI model; "JETI Telemetry communication protocol", http://www.jetimodel.com/en/Telemetry-Protocol/JETI-Telemetry- Communication-Protocol/. (18.04.2021)

[8] Żokowski M. (2020). Autodiagnostics for Remotely Piloted Aircraft Systems, Conference: 2020 Mechatronics Systems and Materials (MSM), DOI: 10.1109/MSM49833.2020.9201641.

[9] Dudziak, D., Buczkowska-Murawska, T., Żokowski M. (2020). Assessment of the unmanned aircraft system's airworthiness in the aspect of certification. Scientific Journal of Silesian University of Technology. Series Transport. ISSN: 0209-3324. DOI