APPLICATION FOR GRANT
on scientific research project

Title: DEVELOPMENT AND TESTING OF AN EXPERIMENTAL DETONATION JET ENGINE

Applicant organization: YUZHNOYE State Design Office

Project Manager: Stoliarchuk Vitalii Vasilievich
Testing Engineer of Rocket and Space Technology
Postgraduate student of DNU FTF

Location: Testing base of Yuzhnoye SDO, Dnipro, Ukraine
Implementation period: 1 year
Project cost: EUR 160 000

KEY PERSONNEL

Project Manager: Stoliarchuk Vitalii Vasilievych
Testing Engineer of Rocket and Space Technology, Yuzhnoye SDO.
Postgraduate student at Dnipropetrovsk National University FTF.

Scientific consultant: Zolotko Oleksandr Yevheniiovych
Candidate of Technical Sciences,
Associate Professor of the Department of Engine Development,
Dnipro National University.

Supervisor: Degtyarenko Pavlo Hlibovych
Head of Testing Facilities, Yuzhnoye SDO

Location: Kryvorizka Street 3, 49008, Dnipro, Ukraine

Description of YUZHNOYE

Yuzhnoye State Design Office named after M.K. Yangel (Yuzhnoye) was founded in 1954. The facilities and head office are situated in Dnipro, Ukraine. There are representative offices in Brussels (Belgium) and Kiev (Ukraine).

Yuzhnoye is one of the most well-known and recognized scientific and design companies in the world in the field of space technology development. This recognition is based on the exceptional experience in creation of rocket-space technologies, gained during more than 65 years of the company's life and reinforced by the capability to grow in modern economic and political environment, while providing flexible response to the needs of the global space launch market.

Main developments of Yuzhnoye.

- World-class launch vehicles: Kosmos, Interkosmos, Cyclone-2, Cyclone-3, Zenit-2, Zenit-3SL, Dnepr.

- Liquid Rocket Engines:11 types of main engines with 250 kg to 48 tons of thrust; 6 types of steering engines with 5 to 29 tons of thrust.

- Solid Rocket Motors:11 types of sustainer motors with 150 to 300 tons of thrust, more than 100 types of special-purpose solid rocket motors, cartridge pressure accumulators, and gas generators.

Description of Dnipro National University

The Faculty of Physics and Technology at Dnipro National University was organized in 1951 to train specialists for the enterprises of rocket and space industry, mechanical engineering, and energy.

During the operation of the Faculty, the experienced professionals created scientific basis for the development of space industry and other sectors of the economy. Physical and Technical Faculty cooperates with leading companies and institutions in space industry to conduct research in key areas of rocket and space technology.

The Faculty trains scientific and pedagogical staff through postgraduate and doctoral studies. There are two specialized councils for doctoral and master's theses in the following fields:

- Design, manufacture and testing of aircrafts;
- Engines and power plants;
- Systems and management processes;
- Materials;
- Chemical technology of fuel and combustive materials.

Project manager

Stoliarchuk Vitalii Vasilievich

Date of birth - June 22, 1982.
Nationality - Ukraine.

He obtained Specialist degree in Mechanical Engineering with expertise in rocket and spacecraft engines at Dnipro National University (Faculty of Physics and Technology) in 2006. Since 2006 he has been working at Yuzhnoye SDO with main focus on testing of rocket and space products.

From September 23, 2020 he is a graduate student of Dnipro National University, Faculty of Physics and Technology.

Dissertation topic - Detonation Jet Engines.

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Topicality

A fundamentally new direction in the rocket and space propulsion engineering is the development of engines, that operate on the detonation principle of working fluid energy conversion. The high speed of combustion makes promising the use of detonation in jet and rocket engines. The peculiarity of this process is the large pressure drop before the detonation wave and in the induction zone, where the reaction takes place. The idea of using detonation combustion in engines was expressed at the beginning of the last century, but systematic research on this problem has not been conducted for a long time.

Experimental studies of the possibilities of using detonation processes for the development of engines were made in the work of Nicholls on the hydrogen-air mixture. On the basis of the performed theoretical calculations and experimental researches, the comparative analysis of the origin and development of detonation in hydrogen-oxygen and acetylene-oxygen mixes is made.

The research was continued in Hellman's work with the use of ethylene-oxygen and ethylene-air mixtures in detonation pipes varied by geometry and operation principle.

Rotating detonation waves were used in the works of Adamson and Shen to increase the efficiency of combustion and ensure a constant detonation regime.

Possibilities of using standing detonation waves in ramjet and rocket engines was investigated in the work of Dunlop, and stationary spinning detonation was studied in the work of Wojciechowski.

Topicality

Performed studies shown that to obtain acceptable thrust characteristics it is necessary to burn fuel with a frequency of detonation waves of at least 100 Hz.

Introduction of detonation technologies in practice of engine construction is able **to provide a technological breakthrough in the space industry** through the realization of the following properties of detonation engines:

- more economical operation due to the increased thermal efficiency;
- lower specific fuel consumption;
- simplification of engine design by significantly simplifying the fuel supply system and reducing the weight of the engine;
- reducing the pressure of fuel supply to the combustion chamber;
- use of detonation jet engines in a terrestrial, vacuum environment in hypersonic accelerators.

Development and testing of an experimental detonation jet engine under this project will lay the foundation for further serial production and use of detonation jet engines in the rocket and space industry.

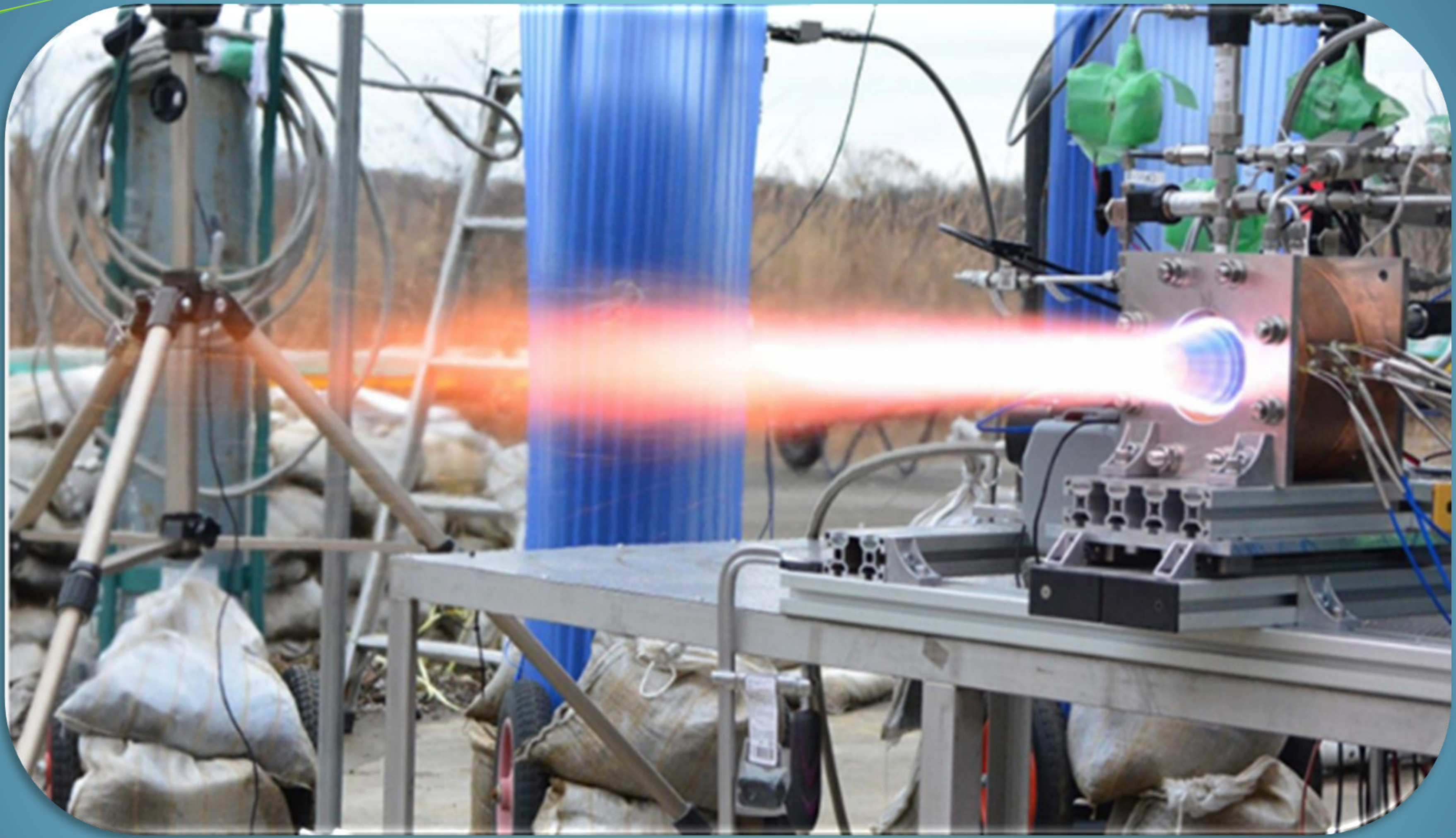

Image of an experimental study of a detonation jet engine

Implementation timeline

Development and creation of an experimental combustion chamber of a detonation jet engine with a thrust of up to 500 kgf. Development and creation of a test bench for testing the experimental combustion chamber №1 in the (terrestrial) environment. Selection of a detonation initiation system. Experimental testing of the combustion chamber №1 (1.1, 1.2, 1.3) on two types of fuel. The duration is 1 .... year.

Reporting:

A report on works implementation and spent budget under the project will be submitted on a monthly basis in the form, approved by the grant sponsor. Virtual or physical meetings could be organized for validation and demonstration of obtained results.

Objective and main tasks of the study

Based on the analysis of achievements and prospects of modern rocket and space engine building as well as accumulated experience of experimental research of rocket engines **to develop and experimentally confirm operation of the selected design of detonation jet engine**.

Specific tasks of the project:

- to develop theoretical and experimental methods for calculating basic parameters;
- to develop schematic and design solutions for structure of elements, units and systems of detonation engines;
- to carry out experimental researches of various models of jet detonation engines (application as main air jet engines and in spacecraft under vacuum);
- perform expert analysis using computer testing methods ANSIS and COMSOL Multiphysics with experimental studies of detonation engine models ;
- determination of quantitative and qualitative characteristics of components, units and subsystems of the detonation jet engine;
- development of methods and measures to increase the efficiency of detonation jet engines;

Objective and main tasks of the study

- justification of rational constructive-layout schemes of detonation jet engines;

- determination of quantitative and qualitative characteristics of components, units, and subsystems of the detonation jet engine;

- selection and justification of design parameters and shape of combustion chamber, injector head, the nozzle of detonation jet engine;

- detection of regime factors that determine the nature of non-stationary gas-dynamic processes in the chamber of the detonation jet engine;

- selection of fuel for jet detonation engines, as well as definition of patterns of active additives impact on the processes of detonation initiation and propagation of detonation waves in the flowing part of the combustion chamber of a detonation jet engine;

- to test and confirm the efficiency of the proposed experimental fuel for jet detonation engines;

- to develop technology basis for the manufacture of jet detonation engines for rapid introduction into the production process.

Research methods

Experimental study is provided by model experiments. The research will use methods of mathematical and physical modeling, based on the fundamental laws of hydromechanics, combustion, similarity theory, and planning of a physical experiment, using standardized methods of processing measurement results.

A comparative analysis of the results of mathematical modeling using computer testing methods ANSIS and COMSOL Multiphysics with the results of field experiments and studies of existing jet rocket engines will be performed. It is planned to use Exascale computing technologies to solve the main problems associated with the modeling of the coagulation system

Description of experimental research equipment

The experimental equipment is planned to be placed on a mobile load bearing frame of container size. Experimental combustion chambers will be tested in a horizontal position. Combustion chambers are designed and manufactured to conform and test the basic principles of operation of detonation jet engines. The expected thrust of the demonstrator engine will be up to 800 kgf. The control panel as well as hardware and software complex will be placed at a safe distance from the stand. The entire autonomous structure will require only refueling, high-pressure nitrogen gas, 220 V power supply.

The tests will be performed in compliance with all safety regulations.

Composition of the experimental equipment

● **Mobile load bearing frame.** All test equipment is made of carbon steel and located on the frame (30 meters – channel bar №120, 20 meters - angle № 60, 10 meters - angle № 25, four sheets - 4x1200x2500 mm.);

● **Emergency protection systems.** It consists of a protective cover (four sheets 4x1200x2500 mm.), fire extinguishing system;

● **Video recording system.** It consists of two high-resolution video cameras, cable network, drive, computer.

Composition of the experimental equipment

● **Propellant supply system** to the experimental chamber. All elements are made of stainless steel and includes two tanks V = 20 liters with a supply pressure P = 5 atmospheres, two filters T513, four valves T 122, four valves T 114, throttle, pipelines (24x2 - 10 meters, 14x2 - 10 meters), two metal arms of Du 20 - 1 meter with nipple connection, two metal arms of Du 10 - 1 meter with nipple connection, two shut-off valves T 208, two shut-off valves T 222, eight angles Du 20, nipples and fittings (Du 6 - 12 pcs., Du 8 - 12 pcs., Du 10 - 12 pcs., Du 20 - 20 pcs.);

● **Pressurizing system** for component supply to the experimental chamber (extrusion system) and purge of the chamber. It consists of three cylinders of high-pressure nitrogen with a capacity of V = 120 liters, P = 150 atmospheres, pipeline Du 10 - 12 m., two metal hoses Du 10 - 500 mm;

● **Telemetry system.** System for registration of initial parameters and control of the testing process. It consists of eight pressure sensors (1 ÷ 10 atm.-2 pieces, 1 ÷ 60 atm.- 2 pieces, 1 ÷ 200 atm.-4 pieces), eight temperature sensors (1 ÷ 40 C^0 - 2 pcs., 1 ÷ 800 C^0 - 2 pcs., 1 ÷ 1900 C^0 - 4 pcs.) Auto-ignition system (piezo elements, remote control), cable network (in assortment), hardware-software complex (computer, converter), traction sensor (1-1000 kg / cm^2)..

YUZHNOYE
design office

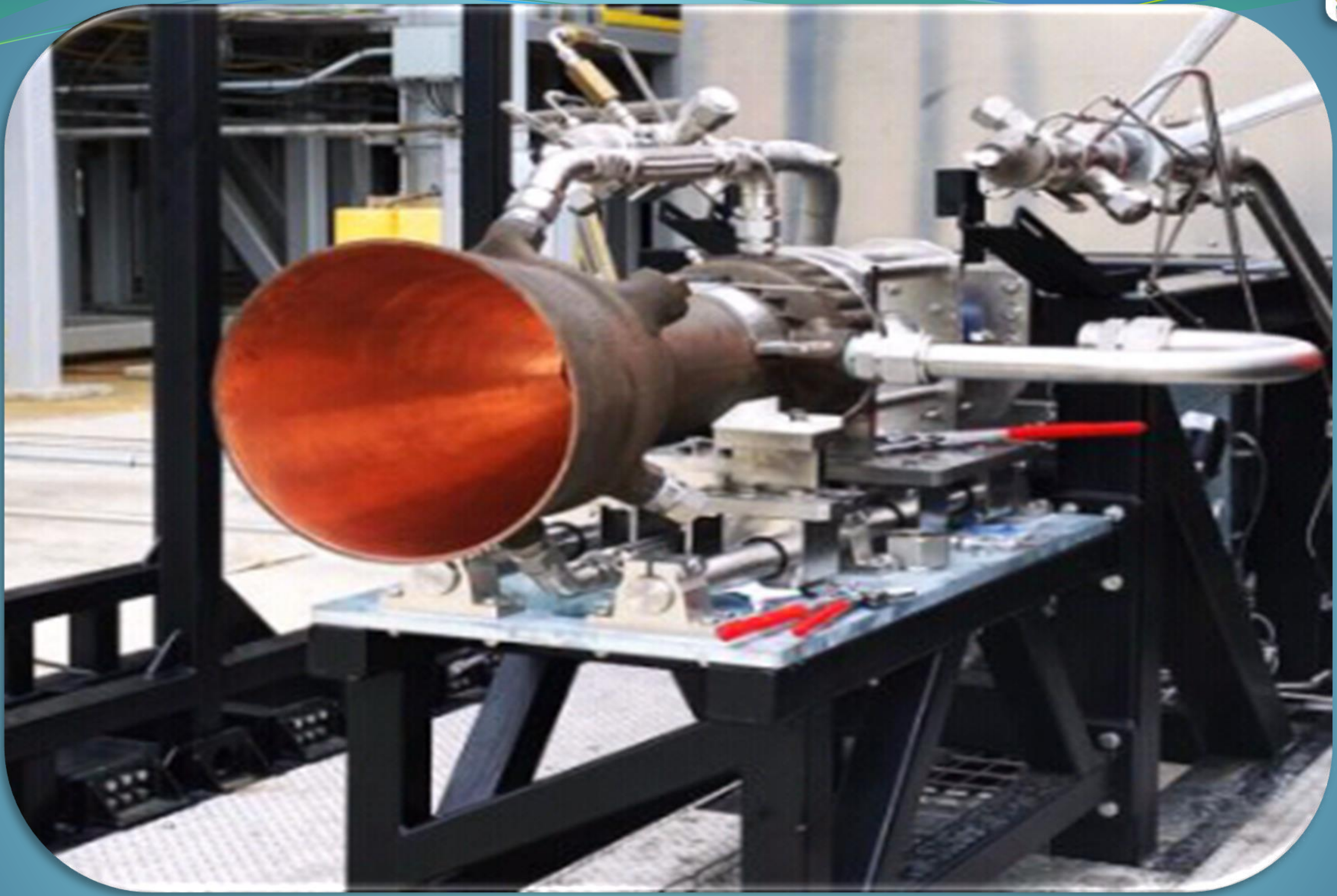

Image of a similar bench installation for jet engines testing

List of deliverables

- Pneumatic and hydraulic diagram of the test bench in the drawing.
- Schematic arrangement of the equipment on the power frame, assembly diagram in the drawing.
- Technological passport of the bench installation.
- Drawings of the experimental combustion chamber.
- Technological process of manufacturing a combustion chamber.
- Plan schedule of creation of experimental equipment (stand, combustion test chamber, nozzle, initiation element).
- Plan of location of experimental equipment with reference to the terrain.
- Cost estimation for the creation of experimental equipment (stand, combustion test chamber, nozzle).
- Cost estimation for testing of jet detonation engine using experimental propellant (testing of combustion chamber, nozzles, igniter)

YUZHNOYE design office

List of deliverables

- Technological process of testing;
- Test report for detonation jet engine on experimental fuel:
- Scientific works

Patent for combustion chambers.

Patent for PZE initiation element.

Scientific papers about the research of this project (3 papers).

Cost estimation for the project

The requested funding is 160 000 euros.

Project budget	
Personnel costs	**66750**
Materials	**30700**
Subcontracting	**37900**
Other direct costs	**10100**
Indirect costs	**14545**
Total costs	**159995**

Justification for materials and subcontracting

Purchase of materials and components: 30 700 euros

- 8 pressure sensors (1 ÷ 10 atm.- 2 pcs., 1 ÷ 60 atm.- 2 pcs., 1 ÷ 200 atm.- 4 pcs.) – 2 800 euros;
- 8 temperature sensors (1 ÷ 40 C^0 - 2 pcs., 1 ÷ 800 C^0 - 2 pcs., 1 ÷ 1900 C^0 - 4 pcs.) – 1 600 euros;
- auto-ignition systems (piezo elements, remote control) – 1 900 euros;
- cable network – 2 000 euros;
- hardware and software complex (computer, converter) – 3 700 euros;
- traction sensor (1-1000 kg / cm^2) – 4 500 euros;
- two video cameras, a drive, a computer – 3 500 euros;
- rocket fuel for the engine – 5 500 euros;
- consumables – 2 400 euros;
- licensed software – 2 800 euros;

Subcontracting: 37900

- manufacturing of an experimental combustion chamber – 37 900 euros

Expected results, risks, and future financing of the project

The project will result in creation of a detonation jet engine with confirmed characteristics, which can be used for both launch vehicles and satellites, the market for which is growing today, attracting billions of investments. Occupying a niche of innovators, we will be able to benefit from the use of this technology.

This project was not provided for public review because of non-disclosure considerations.

Terms of project implementation will be specified after signing the Memorandum of Intent considering all risks and insurance aspects.

Additionally, the possibility of additional fund raising and production of a demonstrator for potential customers after using the main grant funding is under consideration.