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First results of PRECISE—Development of a MEMS-based monopropellant micro chemical propulsion system ☆

Markus Gauer [a,*], Dimitri Telitschkin [b], Ulrich Gotzig [b], Yann Batonneau [c], Hakan Johansson [d], Mikhail Ivanov [e], Phil Palmer [f], Remco Wiegerink [g]

[a] Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), Germany
[b] EADS Astrium Space Transportation GmbH, Germany
[c] CNRS, University of Poitiers, Poitiers, IC2MP, France
[d] NanoSpace AB, Uppsala, Sweden
[e] NPO Mashinostroyenia, Moscow, Russia
[f] Surrey Space Centre, University of Surrey, Surrey, GU, United Kingdom
[g] MESA+Institute for Nanotechnology, University of Twente, Enschede, The Netherlands

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ABSTRACT

PRECISE focuses on the research and development of a MEMS-based monopropellant micro chemical propulsion system for highly accurate attitude control of satellites. The availability of such propulsion systems forms the basis for defining new mission concepts such as formation flying and rendezvous manoeuvres. These concepts require propulsion systems for precise attitude and orbit control manoeuvrability. Application-oriented aspects are addressed by two end-users who are planning a formation flying mission for which the propulsion system is crucial. Basic research is conducted aiming at improving crucial MEMS technologies required for the propulsion system. Research and development also focuses on the efficiency and reliability of critical system components. System analysis tools are enhanced to complement the development stages. Finally, the propulsion system will be tested in a simulated space vacuum environment. These experiments will deliver data for the validation of the numerical models.

1. Introduction

PRECISE [1] (chemical μPRopulsion for an Efficient and accurate Control of Satellites for Space Exploration) aims for the advancement of research and technologies needed for the development, manufacturing and operation of Micro Electro Mechanical Systems (MEMS) based monopropellant Micro Chemical Propulsion Systems (μCPS). PRECISE combines European capabilities and know-how from universities, research organisations and experienced space companies for the research and development of a μCPS for future market demands. μCPS has been identified to fill the gap between state-of-the-art electrical and chemical propulsion due to its compactness, low power requirements and low system weight. Due to these reasons the MEMS-based μCPS is considered as one of the key technologies for future satellite missions.

All partners in the consortium possess a sound experience in the topics they are called for and they can all look back on various successful projects in their company's history. Two universities are involved, the University of Twente and the Surrey Space Center of the University of

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* Corresponding author. Tel.: +49 6298 28 734.
E-mail addresses: markus.gauer@dlr.de (M. Gauer), dimitri.telitschkin@astrium.eads.net (D. Telitschkin), ulrich.gotzig@astrium.eads.net (U. Gotzig), yann.batonneau@univ-poitiers.fr (Y. Batonneau), hakan.johansson@sscspace.com (H. Johansson), vpk@npomash.ru (M. Ivanov), P.Palmer@surrey.ac.uk (P. Palmer), r.j.wiegerink@ewi.utwente.nl (R. Wiegerink).

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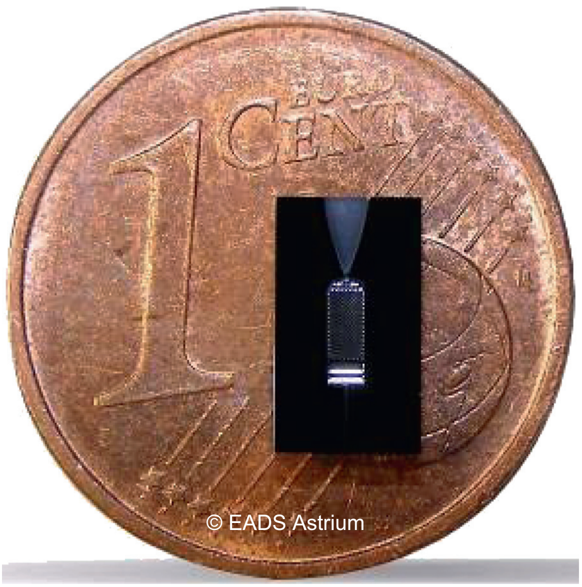

Fig. 1. Illustration of a μThruster in comparison to a one Cent coin.

Surrey. In addition, two large research organisations are participating, the National Center for Scientific Research (CNRS) and the German Aerospace Center (DLR) who is coordinating the project. Finally, three industrial partners namely EADS Astrium Space Transportation, NanoSpace and NPO Mashinostroyenia are completing the consortium.

The term chemical micro propulsion is used for propulsion systems with thrust levels in the order of microNewtons (μN) up to several milliNewtons (mN) and generating thrust primarily by means of chemical energy of the propellant itself. A revolutionary feature is the highly compact, lightweight and modular architecture. The micro thruster weighs only few grams and is etched on a silicon wafer as illustrated in Fig. 1. The thrust range is targeted to lie within $F=1–10$ mN with a minimum specific impulse of $I_{sp}=180$ s. This results in a mass flow rate of approximately 6 mg/s per thruster. The primary objective is the development of a μCPS necessary for highly accurate attitude control maneuvers of satellites as they were not feasible until today with propulsion systems of this size.

Several aspects need to be considered for a consistent development of the μCPS:

– Definition of requirements and specifications, comprising S/C demands.
– Research of critical propulsion aspects.
– Development of crucial components.
– Elaboration of the test facility infrastructure.
– Development of diagnostic tools.
– Further development of numerical flow simulation tools and comparison.
– Manufacturing, assembly, integration and testing of the μCPS.

The thoughts for a dedicated approach to build up a μCPS network were initiated in 2005 since potential application fields were recognized and the feasibility of MEMS technologies for space propulsion was demonstrated. The μCPS development roadmap was elaborated by ESA in the European Space Technology Harmonisation on Chemical Propulsion and Micro-Propulsion, with main emphasis on the harmonization of running European activities under the technical coordination of an industrial partner. On this basis the set-up of a competence network to advance the development of μCPS in Europe was started. Key partners were identified holding know-how and infrastructures for MEMS technologies and components, system aspects, satellites and mission design. Astrium has established a close cooperation with the consortium partners and aims to extend the collaboration with research and development initiatives along the μCPS roadmap to unite the activities and create synergies within one large μCPS European Technology Network.

2. Necessity of micro chemical propulsion systems

Formation flying on LEO and GEO trajectories as well as deep space missions for the realization of novel telecommunication concepts, utilization of flexible space based instruments or even earth observation are some typical applications which address the need for new approaches and place new demands on the propulsion system. Compared with the current technology of mono-spacecraft the realization of distributed systems entails obvious benefits like increasing reliability, flexibility, low cost solutions and a reduced development time. All these aspects are reflected in the current growth of satellites with masses in the range between 10 and 50 kg. Small satellite platforms as well as distributed formation flying require precise control capacities especially for:

– attitude control and de-orbiting.
– precise positioning of spacecraft(s) within satellite constellations and formation flying 'swarms', e.g. to provide the required fine adjustment of space based instruments.
– realization of precise proximity maneuvers for inspection and rendezvous.

Therefore, low thrust levels in the milli-Newton range and low impulse bits are required. For micro- and nano-spacecraft, the severe mass and volume limitations act as "bottlenecks" to the spacecraft capability. By developing a propulsion system that increases the impulse whilst at the same time decreasing the mass of the technology, the capability of the whole spacecraft can be immensely increased.

The need of propulsion systems capable of thrust levels in the range of a few μN to 1 N is emerging and has also been identified by ESA. Due to this reason, the roadmap for chemical propulsion/micropropulsion [1], was defined which specifies the proposed development approach. It is emphasized that the logical way of pursuing the development of high performance (MEMS) propulsion is to gradually increase the complexity by going from cold gas to hot gas to catalytic decomposition (monopropellant) and