Proceedings of the Estonian Academy of Sciences,
2014, **63**, 2S, 279–285
doi: 10.3176/proc.2014.2S.09
Available online at www.eap.ee/proceedings

SPACE TECHNOLOGIES

Nanosatellite orbit control using MEMS cold gas thrusters

Urmas Kvell[a,b*], Marit Puusepp[b], Franz Kaminski[c], Jaan-Eerik Past[a], Kristoffer Palmer[d], Tor-Arne Grönland[d], and Mart Noorma[a,b]

[a] Department of Space Technology, Tartu Observatory, Observatooriumi 1, 61602 Tõravere, Estonia
[b] Institute of Physics, University of Tartu, Riia 142, 51014 Tartu, Estonia
[c] Department of Aerospace Technology, University of Applied Science Aachen, Hohenstaufenallee 6, 52064 Aachen, Germany
[d] NanoSpace AB, Dag Hammarskjölds väg 36B, SE-751 83 Uppsala, Sweden

Received 18 August 2013, revised 26 March 2014, accepted 31 March 2014, available online 23 May 2014

Abstract. We introduce nanosatellite orbit control using a novel miniaturized cold gas propulsion module based on microelectromechanical systems (MEMS) technology. Firstly, the design and characteristics of the propulsion module suitable for CubeSat class nanosatellites are described. Secondly, mission analyses for in-orbit validation of the propulsion module on a 2-unit CubeSat in 300 km low Earth orbit are presented. The MEMS cold gas propulsion module with 10 cm $\times$ 10 cm $\times$ 3 cm dimensions and 220 g mass is specifically designed for use in CubeSats. In baseline configuration with a tank for 60 g of butane under 2 to 5 bar pressure, it can provide up to 15 m/s delta-V capability for a 2.66 kg satellite. The module includes four individually controllable thrusters with proportional thrust regulation and closed loop control; maximum thrust is 1 mN per thruster with 5 μN thrust resolution. The fully operational satellite with active orbital control is capable of accommodating a 0.64 kg and 10 cm $\times$ 10 cm $\times$ 7 cm additional payload. The analysed mission scenarios have potential for different Earth observation applications. Natural deorbiting, controlled orbit lowering, controlled orbit raising, and orbit keeping at 300 km altitude are simulated. Simulations indicate that the natural orbit lifetime can be extended from 63 days to 193 days with the baseline propulsion module and satellite altitude can be increased to 348 km or lowered to 257 km. Orbit keeping at 300 km is possible for up to 76 days; proportional thrust control could provide a further increase to 204 days.

Key words: nanosatellite, CubeSat, propulsion system, orbit control, MEMS, cold gas thruster, Earth observation.

1. INTRODUCTION

Rapid development of nanosatellites has led to many unique and innovative space applications [1,2]. Advancements of different key subsystems such as attitude control and electrical power have been developed and flown on many CubeSat missions [2–6]. One of the remaining major challenges for the nanosatellite platform is orbit control; achieving this will open up a new frontier of future missions and applications [1,2].

With the growing threat of space debris, the role of nanosatellites will need to adapt for a sustainable use of near-Earth space. The number of nanosatellite launches is rapidly increasing, but the satellites themselves have a short operational lifetime and lack propulsive capabilities [2]. For effective mitigation of the increasing amount of orbiting non-operational nanosatellites, most future nanosatellite launches should be limited to orbits below large operational satellites and manned spacecraft. A relatively low-cost nanosatellite mission in the 300 km orbit would have a unique potential for providing continuous measurements to different Earth science disciplines and the satellite would remain below the International Space Station. A few examples of research fields where measurement instruments require high-accuracy attitude control and orbit control are magnetic field measurements, gravitational measurements, lower thermosphere studies, and atmospheric re-entry research [1,2,5,7–10].

* Corresponding author, urmas.kvell@estcube.eu

There is a variety of ongoing research on nanosatellite propulsion systems. Since the CubeSat specification limits the use of pyrotechnics and high-pressure systems, most of the propulsion technology development for nanosatellites focuses on cold gas propulsion and electric propulsion [5,7,11,12]. Other concepts plan to utilize solar sailing and tether-based approaches [6,13,14]. Despite the numerous development activities, only very few of the nanosatellites launched to date have carried a propulsion system [1,2,5,15]. One of the first breakthroughs in nanosatellite thruster systems was the CanX-2 mission [5]. CanX-2 was a 3-unit CubeSat (10 cm $\times$ 10 cm $\times$ 30 cm), which incorporated a 50 mN thruster. The CanX-2 propulsion system can be regarded as state-of-the-art as it was successfully launched and operated in 2008. However, it was limited to single axis thrust with a total delta-V of 2 m/s, the whole system weighed 500 g, and occupied around 30% of the available space.

This paper gives an overview of a novel miniaturized cold gas propulsion module based on microelectromechanical systems (MEMS) technology [16–18]. The propulsion module suitable for CubeSat class nanosatellites would satisfy the requirements of mature orbit control as compared to the earlier designs. The key functionalities required are an accurate and proportional thrust from multiple thrusters (typically 8 to 12) on the spacecraft, propellant suitable for low-pressure tanks, and closed loop thrust control. The technical design and mission analyses of a 2-unit CubeSat (10 cm $\times$ 10 cm $\times$ 20 cm) for evaluating the performance of the propulsion module in 300 km low Earth orbit are presented. Natural deorbiting, controlled orbit lowering, controlled orbit raising, and orbit keeping at 300 km altitude are simulated.

2. PROPULSION SYSTEM

The MEMS cold gas propulsion system, developed by NanoSpace, is the first complete system to satisfy the requirements of mature orbit control on the nanosatellite platform. The key functionalities required are accurate and proportional thrust control from four thrusters, butane propellant that is suitable for low-pressure tanks, and closed loop thrust control. Closed loop in this context means that the thruster could be commanded to deliver any value of thrust between zero and full thrust and the actually delivered thrust is measured in real time and used in the control loop of the thruster. The four thruster configuration satisfies typical orbital manoeuvre requirements and enables basic attitude control; the propulsion system could be scaled to eight or twelve thruster configurations if formation keeping or fine grain attitude control are required.

The propulsion module design is complete and self-contained with the exception of an interface electronics board, developed by Space-SI, which connects to the spacecraft power bus and data bus. Figures 1 and 2 show the block schematics and the design of the pro-

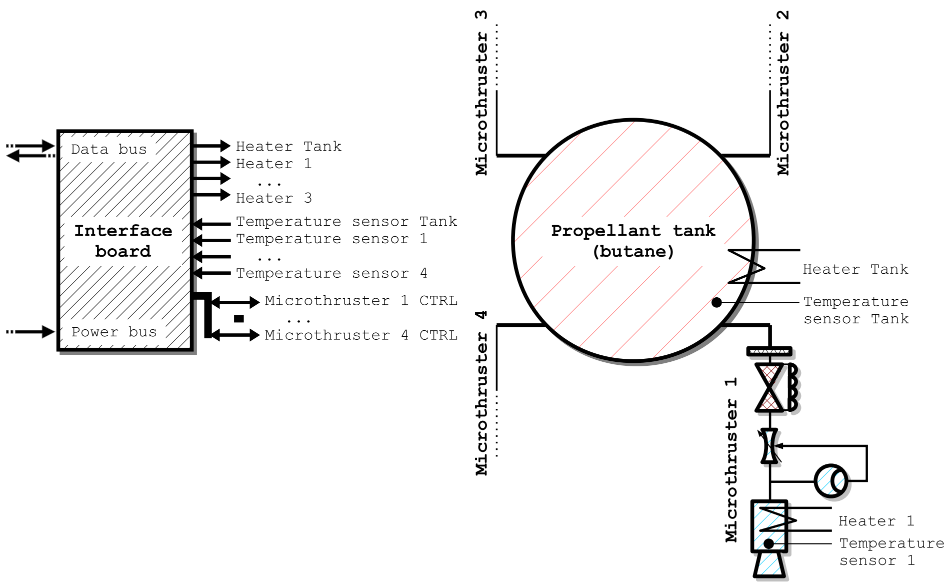

Fig. 1. Complete and self-contained cold gas propulsion system based on MEMS technology and the interface electronics board, which connects to the spacecraft power bus and data bus.

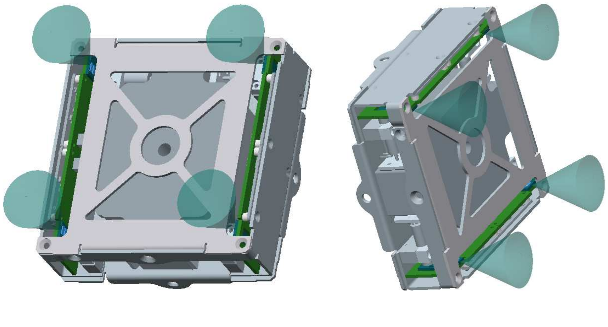

Fig. 2. Mechanical design of the cold gas propulsion module shown from different angles [18]. The cones show gas outflow from the four microthrusters.

pulsion module. The module contains four complete microthrusters, a propellant tank, a fill/drain valve, four isolation valves (one per thruster), and front-end electronics to read sensor signals of the thrusters. Figures 3 and 4 show the schematics and a photo of a single microthruster, which includes the isolation valve, the proportional flow control valve, the thrust chamber including the gas heaters, the mass flow sensor, and the nozzle. Continuous thrust regulation (without steps) in the range from zero to full thrust is ensured with the proportional flow control valve. To achieve the requested thrust output the design utilizes a mass flow sensor for real-time measurements of the gas flow in the feedback signal of the control loop of the flow control valve. To keep the system response time short the internal volume of the system (i.e. the spacing between the valve and the nozzle throat) needs to be minimized. This is achieved by integrating all components and functionality of the microthruster into a single silicon chip. Figure 5 shows the results of the ground-based performance testing of closed loop control using 5 µN steps.

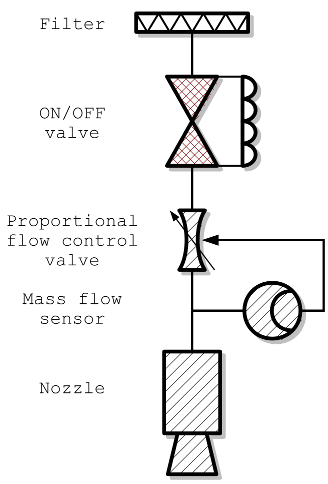

Fig. 3. A single microthruster with all components and functionality integrated into a single silicon chip [18].

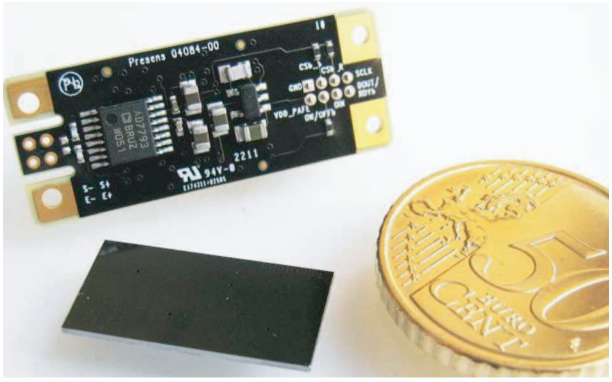

Fig. 4. The thruster chip (bottom) and the front-end electronics (top) [18].

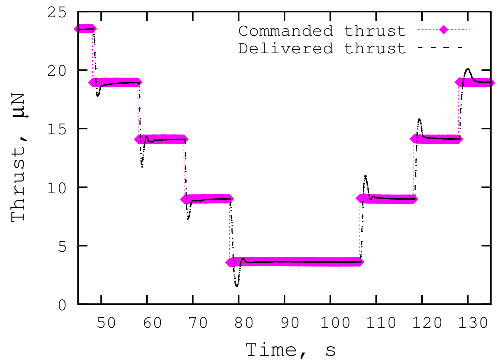

Fig. 5. Closed loop thrust control test with thrust level adjustment in 5 µN steps [18].

The complete propulsion system consists of the MEMS cold gas propulsion module and the interface electronics board. Total maximum impulse of 40 N·s is achieved by placing all four thrusters on the same side. This results in 15 m/s delta-V capability for a 2.66 kg satellite. Each microthruster can provide a maximum of 1 mN thrust with 5 µN thrust resolution. The propulsion module dimensions are 10 cm $\times$ 10 cm $\times$ 3 cm, dry mass is 220 g, and average power consumption during operation is 2 W. The interface board dimensions are 10 cm $\times$ 10 cm $\times$ 2 cm, the mass is 40 g, and power consumption is 0.35 W. In baseline configuration, the propellant capacity is 60 g for butane with 2 to 5 bar operating pressure.

3. SATELLITE LAYOUT

A nanosatellite is designed for in-orbit validation of the propulsion module. The satellite bus is based on ESTCube-1 heritage: it includes computer, attitude control, imaging, telemetry, and power systems [19]. The design is required to accommodate the subsystems needed for the normal operation of the satellite, a propulsion system, and a payload module. The 2-unit

CubeSat standard was selected due to the availability of launch options and the platform scalability. According to the standard, the satellite mass can be up to 2.66 kg [20]. Selecting a 3-unit or a 6-unit satellite size would enable the use of a larger propellant tank or accommodation of a bigger payload package with only minor additions to the satellite layout.

The satellite structure is designed as an aluminium mono-block frame with separate side panels; passive thermal control methods are used to reduce the required mass and power [19]. The on-board computer can provide real-time operations with data management and payload control; the proposed solution has available computing performance for modest on-board data processing [21]. The storage of possibly large mission data is resolved by using flash memory devices. The ultra-high frequency range (UHF) was chosen for a full-duplex communication telemetry system with supported data rates of 9600 bps and 19200 bps [19]. For payload applications that require higher bandwidth, an S-band or X-band transmitter could be used to provide data rates from 1 to 10 Mbps. Depending on the applications of the payload, a proximity operations imaging system that includes a narrow angle and a wide angle camera for various imaging and monitoring purposes could be used [22]. The proposed design uses combined measurements from magnetometers, gyroscopes, and sun sensors for attitude determination and electromagnetic torquers for primary attitude control with 3 degree accuracy; the propulsion system could be used for high-precision attitude control, but detailed analysis is left for future work [4]. The orbit determination system is based on a Global Navigation Satellite System (GNSS) receiver [23–25]. The power system design uses 12 to 16 high-efficiency solar cells for energy harvesting and two lithium-ion batteries for energy storage. This layout allows full operation of the satellite during the whole orbital period and it eases the overall mission planning as any power peaks would be handled by batteries [3]. The power system provides three different voltages to the satellite bus that can be used for payload: 3.3, 5, and 12 V.

The baseline design of the satellite includes the satellite bus and the payload. Figure 6 shows the structural layout with 10 cm × 10 cm × 7 cm of available volume for an additional payload. Table 1 presents the orbit-average power budget with a conservative 20% margin. The estimated orbit-average electrical power production is 2.2 W. The baseline design provides 0.44 W orbit-average power to the payload, resulting in 20% payload power fraction. Table 2 shows the mass budget with a 20% margin. The baseline design can accommodate a payload package of 0.64 kg, resulting in 24% payload mass fraction.

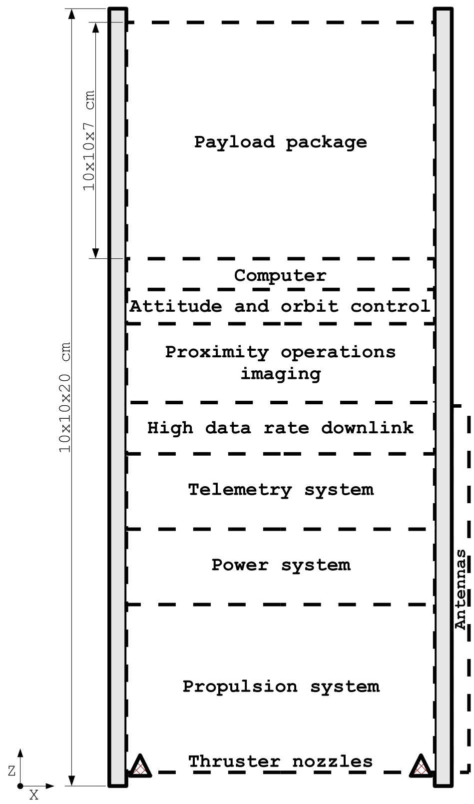

Fig. 6. Baseline design of the 2-unit CubeSat that includes the satellite bus and the payload.

Table 1. Spacecraft orbit-average power budget with a given payload power fraction. All power consumers are duty-cycled

Spacecraft system	Value
Propulsion system, W	0.02
High data-rate downlink, W	0.45
Proximity operations imaging, W	0.09
Computer, W	0.19
Power system, W	0.15
Telemetry system, W	0.39
Attitude and orbit control, W	0.17
20% margin, W	0.37
Total without payload, W	1.76
Payload effective, W	0.44
Total, W	2.20
Payload power fraction, %	20

Table 2. Spacecraft mass budget with a given payload mass fraction

Spacecraft system	Value
Propellant, kg	0.06
Propulsion system, kg	0.22
High data-rate downlink, kg	0.25
Proximity operations imaging, kg	0.06
Computer, kg	0.05
Power system, kg	0.29
Telemetry system, kg	0.08
Passive thermal control, kg	0.01
Attitude and orbit control, kg	0.18
Structure, kg	0.44
20% margin, kg	0.44
Total without payload, kg	2.02
Payload effective, kg	0.64
Total, kg	2.66
Payload mass fraction, %	24

4. MISSION ANALYSIS AND RESULTS

The General Mission Analysis Tool (GMAT) was used to simulate the following mission scenarios: natural deorbiting, controlled orbit raising, controlled orbit lowering, and orbit keeping [26]. A circular very low Earth orbit of 300 km altitude and 79 degree inclination was selected as a starting orbit for the simulations with 01.01.2015 12:00 epoch. The altitude of 150 km was chosen as the lower limit for mission lifetime; from there the satellite deorbits naturally within a few days depending on the exact atmospheric drag. The Runge–Kutta combined order 8 and 9 scheme integrator was chosen for high-accuracy orbit propagation [27]. The MSISE90 atmosphere model and JGM-2 gravity model were used to evaluate the drag on the spacecraft [28,29]. Solar radiation pressure and Earth–Moon perturbations were not taken into account as their effect is small compared to the atmospheric drag at 300 km. The propulsion system was modelled to use finite burns within the performance limit of the microthrusters. All sensors and actuators were modelled as being ideal since noise and delay effects are negligible for mission lifetime analysis.

Natural deorbiting simulation sets a baseline for mission lifetime, modelling a 2-unit CubeSat without a propulsion system. Orbit raising and orbit lowering simulations are modelled with a full thrust spiral transfer at the beginning of the mission. Orbit keeping simulation is designed with a simple control loop that applies full thrust when the altitude reaches 300 km limit; the orbit-average altitude will be slightly above 300 km. An on-board GNSS receiver provides the necessary feedback for the orbit maintenance.

Figure 7 shows mission lifetime of the orbit control scenarios. Natural deorbiting occurred within 63 days. The transfer time for controlled orbit lowering and orbit raising was 4 h and resulted in nearly circular orbits of 257 km and 348 km; the total lifetime was 18 days for orbit lowering and 193 days for orbit raising. Orbit keeping simulation maintained a stable corridor at 304 km average altitude with 315 km upper limit and 293 km lower limit. The control loop applied a single thrust manoeuvre every orbit. The thrust time changed in accordance with the atmospheric drag and was usually 10 to 40 s long. The 300 km orbit was maintained for 76 days, after which natural deorbiting occurred within 59 days.

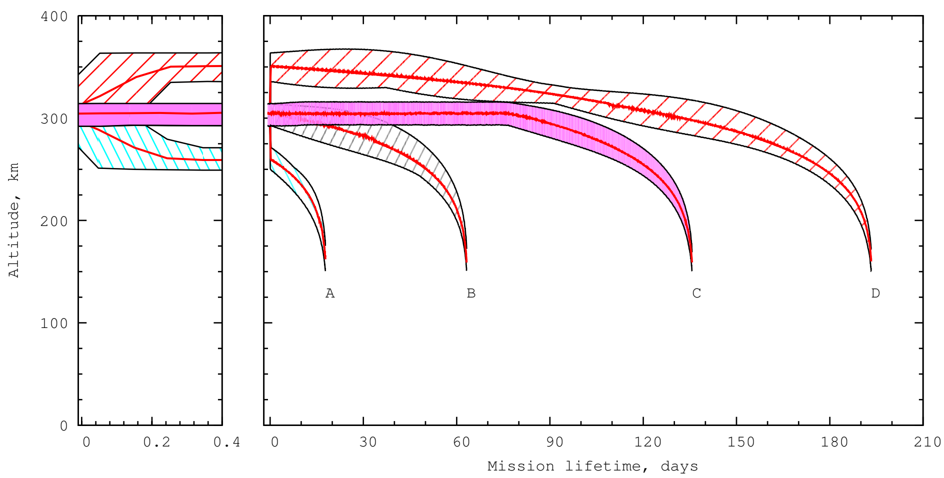

Fig. 7. Mission lifetime from a circular 300 km altitude and 79 degree inclination orbit for (A) controlled orbit lowering, (B) natural deorbiting, (C) orbit keeping, and (D) controlled orbit raising.

However, proportional thrust regulation would in principle increase the orbit keeping time as the thrust output could be adjusted according to variations in the atmospheric drag. This would reduce the propellant consumption required for orbit keeping as full thrust is not always needed. Full thrust provides a high acceleration with a high propellant consumption; for orbit keeping, a smaller thrust level would be more practical as a small more constant acceleration is ideally required. The orbit keeping scenario was analysed using four different fixed thrust levels: full thrust, 30% thrust, 10% thrust, and 5% thrust.

Thrust regulation to smaller levels results in an increased orbit maintaining time and in a small shift of the orbit keeping corridor to a lower altitude. The average corridor altitude with lower thrust levels was 296 km with 311 km upper limit and 285 km lower limit. Reducing the full thrust to the 30% level increases the orbit keeping time slightly, from 76 days to 85 days. The total thrust time increased from 0.3% to 1.5% of the mission time. The change is more significant with the 10% thrust level where the orbit was maintained for 117 days and the thrust time was 4.9% of the mission time. The 5% thrust level resulted in 204 days of orbit keeping; the thrust time was 5.5% of the mission time and the average propellant consumption was 0.29 g per day.

5. DISCUSSION

Accurate and proportional thrust control opens an interesting possibility of keeping a stable very low Earth orbit for long periods. This capability on the nanosatellite platform has unique potential for Earth observation applications; 76 to 204 day mission time would be sufficient for medium-term measurement data. Together with miniaturized measurement devices, the proposed 2-unit CubeSat could enable lower thermosphere studies, magnetic field measurements, and gravitational measurements to be performed at relatively low cost. Additional benefits of utilizing the CubeSat standard are the regular availability of launches to various low Earth orbits and the possibility of using identical satellites on biannual launches to similar orbits for acquiring long-term measurement data.

The QB50 network of 50 nanosatellites, where we were accepted to participate, is one of the first nanosatellite missions to provide simultaneous multi-point measurements [7]. This would be excellent for researching dynamic processes in various Earth science disciplines, for example in atmospheric chemistry research and in atmospheric aerosol characterization. However, mature propulsion systems on nanosatellites could enable formation flight in this type of large-scale missions. A high degree of autonomy and ultra-fine accuracy attitude control would still be required for these missions and should be considered for future research studies.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge everyone from NanoSpace and Space-SI who contributed to the project. We would also like to thank all the participants of the Estelle CubeSat team.

REFERENCES

1. Selva, D. and Krejci, D. A survey and assessment of the capabilities of Cubesats for Earth observation. *Acta Astronaut.*, 2012, **74**, 50–68.
2. Woellert, K., Ehrenfreund, P., Ricco, A. J., and Hertzfeld, H. Cubesats: cost-effective science and technology platforms for emerging and developing nations. *Adv. Space Res.*, 2011, **47**(4), 663–684.
3. Pajusalu, M., Ilbis, E., Ilves, T., Veske, M., Kalde, J., Lillmaa, H. et al. Design and pre-flight testing of the electrical power system for the ESTCube-1 nanosatellite. *Proc. Estonian Acad. Sci.*, 2014, **63**(2S), 232–241.
4. Slavinskis, A., Kulu, E., Viru, J., Valner, R., Ehrpais, H., Uiboupin, T. et al. Attitude determination and control for centrifugal tether deployment on the ESTCube-1 nanosatellite. *Proc. Estonian Acad. Sci.*, 2014, **63**(2S), 242–249.
5. Sarda, K., Eagleson, S., Caillibot, E., Grant, C., Kekez, D., Pranajaya, F., and Zee, R. E. Canadian advanced nanospace experiment 2: Scientific and technological innovation on a three-kilogram satellite. *Acta Astronaut.*, 2006, **59**, 236–245.
6. Lappas, V., Adeli, N., Visagie, L., Fernandez, J., Theodorou, T., Steyn, W. et al. CubeSail: a low cost CubeSat based solar sail demonstration mission. *Adv. Space Res.*, 2011, **48**, 1890–1901.
7. Gill, E., Sundaramoorthy, P., Bouwmeester, J., Zandbergen, B., and Reinhard, R. Formation flying within a constellation of nano-satellites: the QB50 mission. *Acta Astronaut.*, 2013, **82**(1), 110–117.
8. Friis-Christensen, E., Luhr, H., and Hulot, G. Swarm: a constellation to study the Earth's magnetic field. *Earth Planets Space*, 2006, **58**(4), 351–358.
9. Gill, E., Maessen, D., Laan, E., Kraft, S., and Zheng, G. Atmospheric aerosol characterization with the Dutch–Chinese FAST formation flying mission. *Acta Astronaut.*, 2010, **66**(7–8), 1044–1051.
10. Albertella, A., Migliaccio, F., and Sanso, F. GOCE: the Earth gravity field by space gradiometry. *Celest. Mech. Dyn. Astr.*, 2002, **83**(1–4), 1–15.
11. Lozano, P., Martınez-Sánchez, M., and Lopez-Urdiales, J. M. Electrospray emission from nonwetting flat dielectric surfaces. *J. Colloid Interf. Sci.*, 2004, **276**(2), 392–399.
12. Patel, K. D., Bartsch, M. S., McCrink, M. H., Olsen, J. S., Mosier, B. P., and Crocker, R. W. Electrokinetic pumping of liquid propellants for small satellite microthruster applications. *Sensor. Actuat. B-Chem.*, 2008, **132**, 461–470.

13. Johnson, L., Whorton, M., Heaton, A., Pinson, R., Laue, G., and Adams, C. NanoSail-D: a solar sail demonstration mission. *Acta Astronaut.*, 2011, **68**, 571–575.
14. Janhunen, P. Electrostatic plasma brake for deorbiting a satellite. *J. Propul. Power*, 2010, **26**, 370–372.
15. Miller, D., Saenz-Otero, A., Wertz, J., Chen, A., Berkowski, G., Brodel, C. et al. SPHERES: a testbed for long duration satellite formation flying in micro-gravity conditions. In *AAS/AIAA Space Flight Mechanics Meeting*. Clearwater, 2000, AAS 00-110.
16. Grönland, T., Rangsten, P., Nese, M., and Lang, M. Miniaturization of components and systems for space using MEMS-technology. *Acta Astronaut.*, 2007, **61**(1–6), 228–233.
17. Grm, A., Grönland, T., and Rodic, T. Numerical analysis of cold gas micro propulsion system for micro and nano satellites. *Eng. Computation.*, 2011, **28**(2), 184–195.
18. Grönland, T., Johansson, H., Jonsson, K., Bejhed, J., and Rangsten, P. MEMS makes a difference in satellite propulsion. In *Proceedings from the Small Satellite Systems and Services Conference*. Portoroz, 2012.
19. Lätt, S., Slavinskis, A., Ilbis, E., Kvell, U., Voormansik, K., Kulu, E. et al. ESTCube-1 nanosatellite for electric solar wind sail in-orbit technology demonstration. *Proc. Estonian Acad. Sci.*, 2014, **63**(2S), 200–209.
20. *CubeSat Design Specification Rev. 12*. The CubeSat Program, Cal Poly SLO. California, 2009.
21. Laizans, K., Sünter, I., Zalite, K., Kuuste, H., Valgur, M., Tarbe, K. et al. Design of the fault tolerant command and data handling subsystem for ESTCube-1. *Proc. Estonian Acad. Sci.*, 2014, **63**(2S), 222–231.
22. Kuuste, H., Eenmäe, T., Allik, V., Agu, A., Vendt, R., Ansko, I. et al. Imaging system for nanosatellite proximity operations. *Proc. Estonian Acad. Sci.*, 2014, **63**(2S), 250–257.
23. Wermuth, M., Hauschild, A., Montenbruck, O., and Kahle, R. TerraSAR-X precise orbit determination with real-time GPS ephemerides. *Adv. Space Res.*, 2012, **50**, 549–559.
24. Chiaradia, A. P. M., Kuga, H. K., and Prado, A. F. B. A. Single frequency GPS measurements in real-time artificial satellite orbit determination. *Acta Astronaut.*, 2003, **53**, 123–133.
25. D'Amico, S., Ardaens, J. S., and De Florio, S. Autonomous formation flying based on GPS – PRISMA flight results. *Acta Astronaut.*, 2012, **82**(1), 69–79.
26. Hughes, S. P. *General Mission Analysis Tool (GMAT)*. NASA Technical Reports. Greenbelt, 2007.
27. Hughes, S. P. *General Mission Analysis Tool (GMAT) Mathematical Specifications*. NASA Technical Reports. Greenbelt, 2012.
28. Hedin, A. E. Neutral Atmosphere Empirical Model from the surface to lower exosphere MSIS90. *J. Geophys. Res.*, 1991, **96**, 1159–1172.
29. Nerem, R. S., Lerch, F. J., Marshall, J. A., Pavlis, E. C., Putney, B. H., Tapley, B. D. et al. Gravity model development for TOPEX/POSEIDON: Joint Gravity Models 1 and 2. *J. Geophys. Res-Oceans.*, 1994, **99**(C12), 24421–24447.

Nanosatelliitide orbiidi muutmine mikroelektromehaaniliste külmgaasi tõukemootoritega

Urmas Kvell, Marit Puusepp, Franz Kaminski, Jaan-Eerik Past, Kristoffer Palmer, Tor-Arne Grönland ja Mart Noorma

Mikroelektromehaaniliste süsteemide (*microelectromechanical systems* – MEMS) tehnoloogial põhinev külmgaasi tõukemootor võimaldab orbiidi muutmist nanosatelliitidel. Tõukemootorite moodulit iseloomustavad parameetrid on katseliselt määratud ja mooduli testimiseks kosmosekeskkonnas on analüüsitud kaheühikulise kuupsatelliidi missioonide stsenaariume 300 km kõrgusel Maa orbiidil. Külmgaasi tõukemootorite moodul on valmistatud kuupsatelliidi standardile vastavatele nanosatelliitidele, see kaalub 220 g ja selle mõõtmed on 10 cm $\times$ 10 cm $\times$ 3 cm. Baasmudeli kütusepaak mahutab kuni 60 g butaani 2…5 bar rõhu all. Moodul koosneb neljast eraldi juhitavast tõukemootorist, millel on realiseeritud proportsionaalne tõukejõu reguleerimine kinnise tagasiside ahelaga. Maksimaalne tõukejõud ühe mootori kohta on 1 mN, 5 µN sammuga. Selline tõukemootorite moodul võimaldab 2,66 kg nanosatelliidi orbitaalkiirust muuta 15 m/s ulatuses. Käesolevas kaheühikulise kuupsatelliidi disainis on lisaks satelliidi põhisüsteemidele ja kirjeldatud tõukemootorite moodulile ruumi lisa- või eksperimendisüsteemidele massiga kuni 0,64 kg ning mõõtmetega kuni 10 cm $\times$ 10 cm $\times$ 7 cm. Analüüsitud stsenaariumid on potentsiaalselt rakendatavad Maa kaugseire missioonides: juhitav ja loomulik orbiidi langetamine, juhitav orbiidi tõstmine ning orbiidi hoidmine 300 km kõrgusel. Simulatsioonide tulemused näitavad, et tõukemootori mooduli baasmudeliga saab nanosatelliidi eluiga orbiidil pikendada 63 päevalt 193 päevani. Satelliidi orbiidi kõrgust saab tõsta kuni 348 km või langetada 257 km. Orbiiti saab hoida 300 km kõrgusel kuni 76 päeva, tõukejõu proportsionaalse reguleerimisega aga kuni 204 päeva.