Available online at www.asric.org

ASRIC Journal on Natural Sciences 1 (2022) 14-35

Spacecraft Attitude and Orbit Determination from the Cost and Reliability Viewpoint: A Review

Tamer Mekky[1], Ahmed Habib

[1]National Authority for Remote Sensing and Space Science, Cairo, Egypt

Corresponding Authors Email: tamermekky@hotmail.com

Received 28 May 2021; revised 31 June 2021; accepted 20 August 2022

***Abstract* – Spacecraft attitude and orbit control subsystem (AOCS) is responsible for about 30% of the failures of spacecraft. Spacecraft Attitude and orbit determination (SAOD) are two main tasks which are executed by an AOCS. For some spacecraft missions, mission success criterion is related directly to the performance of AOCS. A typical SAOD process is composed from software and hardware. SAOD software has many functions such as management of normal and abnormal operation, in addition to state estimation. SAOD hardware is composed from various sensors, processors, and peripherals. Thus, calculating and increasing the reliability of these interconnected components is a real challenge taking into account the constraints associated with AOCS design. These constraints contain and not limited to high reliability, limited processing power, overall subsystem mass, overall subsystem cost, and limited electric power capabilities. Thus, to increase system reliability against failures, subsystem cost should be carefully considered and minimized. The current article reviews the methods of SAOD in addition to reliability and cost associated with it.**

***Keywords* – Spacecraft, Attitude, Orbit, Cost, reliability.**

I. INTRODUCTION

The spacecraft attitude and orbit control subsystem (AOCS) is considered to be one of the critical subsystems those directly affecting the spacecraft mission performance. Formally, this subsystem is responsible for providing four tasks. They are namely: Spacecraft attitude monitoring, Spacecraft orbit monitoring, Spacecraft attitude control, and finally Spacecraft orbit control. The first three tasks are usually done over all of the spacecraft flown till today, while as the fourth task may or may not exist onboard a spacecraft. This is because of the reason that many spacecraft are designed without the ability of orbit control. The tasks of spacecraft attitude and orbit monitoring are considered to be the main subjects of the current review article. The task of spacecraft attitude and orbit control is not considered herein. The task of spacecraft attitude and orbit monitoring requires some form of integration among hardware and software components. A block diagram of such components is shown in Fig. 1.

Reliability is defined as “The probability that a device will function without failure over a specific time period or amount of usage.” [1], [2]. The basic reliability is defined as “The probability that a device will function without failure of any kind over a specific time period or amount of usage”. Another definition of reliability is that “The probability that the system will function as expected” [3].

Spacecraft subsystems such as AOCS tend to be relatively expensive or extremely complex, or both. In addition, in most cases, they are not repairable. This is because of the reason that, once the spacecraft goes into space, it never comes back again for repair. Hence, the AOCS onboard a 3-axis stabilized spacecraft is required to be reliable. Usually, the AOCS is considered to be of crucial importance for on-orbit operation [4]. Its degradation can greatly affect the whole spacecraft operation, and may lead to mission failure. The tasks of attitude and orbit monitoring are usually two main tasks implemented by the AOCS.

Cost effectiveness of a reliable AOCS is thought to be a challenge. There are several methods of cost estimation and cost reduction. These methods are discussed in a subsequent section. These methods are discussed within the framework of faster, cheaper, and better paradigm.

[21] http://www.cmosis.com/news/latest_news/cmosis_participates_in_esa_sun_sensor_on_a_chip_project.
[22] http://www.sciteclibrary.ru/eng/catalog/pages/951.html
[23] Mortari, D., "Moon-Sun Attitude Sensor", Journal of Spacecraft and Rockets, Vol. 34, No. 3, May-June 1997.
[24] Danrongask, B." Development of Micromachined Electromechanically Suspended Gyroscope", PhD Thesis, University of Southampton, 2009.
[25] Samaan, M." Toward Faster And More Accurate Star Sensors Using Recursive Centroiding And Star Identification", PhD Thesis, Texas A&M University, 2003.
[26] http://www.ballaerospace.com/page.jsp?page=104.
[27] http://en.wikipedia.org/wiki/Global_Positioning_System.
[28] http://kobi.nat.uni-magdeburg.de/patrick/pmwiki.php?n=BEng.TheGPSReceiver.
[29] Itzhack Y. Bar-Itzhack, and Biton, I., " Improved Direct Solution of the Global Positioning System Equation", Journal of Guidance Control and Dynamics, Vol.21, No.1, 1998, pp. 45-49.
[30] Shorshi, G., Itzhack Y. Bar-Itzhack, "Satellite Autonomous Navigation Based on Magnetic Field Measurements", Journal of Guidance Control and Dynamics, Vol.18, No.4, 1995, pp. 843-850.
[31] Naqvi. N., "Attitude Determination of Small Satellite Using Global Navigation Satellite System", ISNET/TUBITAK UZAY Workshop on Small Satellite Engineering and Design for OIC Countries, Oct, 2014.
[32] http://www.computerworld.com/article/2855604/the-orion-spacecraft-is-no-smarter-than-your-phone.html.
[33] http://uzay.tubitak.gov.tr/sites/images/en_bilgegilgamis_tekyon.pdf.
[34] Homar, A., "AOCS Fault Detection, Isolation And Recovery: A Model-Based Dynamic Verification & Validation Approach", MSc thesis, Luleå University of Technology, 2014.
[35] http://helios.gsfc.nasa.gov/magnet.html.
[36] http://www.bbc.co.uk/schools/gcsebitesize/science/21c/chemicals_in_our_lives/minerals_in_britainrev2.shtml.
[37] Wander, A. and Forstner R. "Innovative Fault Detection, Isolation and Recovery strategies on-board spacecraft: State of the art and research Challenges", Deutscher Luft- und Raumfahrtkongress, 2012.
[38] Abd Elmageed, A., "Launchers", National Authority for Remote Sensing and Space Sciences, Technical Report, Issue 3, 2014.
[39] Ha, J., Marshall, M., and Landshof, J., "Cost-Effective Mission Operations", Acta Astronautica, Vol.39, No.1-4, 1996, pp. 61-70.
[40] Trivailo, O., Sippel, M., and Sekercioglu, Y., "Review Of Hardware Cost Estimation Methods, Models And Tools Applied To Early Phases Of Space Mission Planning", Progress in Aerospace Sciences, Vol.53, 2012, pp. 1-17.
[41] Tafazoli M., "A Study of On-Orbit Spacecraft Failures", Acta Astronautica, Vol.64, 2009, pp. 195-205.
[42] Ahadi, A., Ghadimi, M., and Mirabbasi, D., "Reliability Assessment For Components Of Large Scale Photovoltaic Systems", Journal of Power Sources, Vol.264, 2014, pp. 211-219.
[43] Castet, J., and Saleh, J. "Beyond Reliability, Multi-State Failure Analysis Of Satellite Subsystems : A Statistical Approach", Reliability Engineering and System Safety, Vol.95, 2010, pp. 311-322.
[44] Chandrasekar, S., et al. "An Intelligent Fault-Tolerant Satellite Attitude Control System with-out Hardware Redundancies", 11th International Conference on Control, Automation, Robotics, and Vision, Singapore, 2010.
[45] Hu, C., Si, X., and Yang, J. "System Reliability Prediction Model Based On Evidential Reasoning Algorithm With Nonlinear Optimization", Expert Systems with Applications, Vol 37, 2010, pp. 2550-2562.
[46] Pontuschka, M., and Fonseca, I., "FDIR for the IMU Component of AOCS Systems", Mathematical Problems in Engineering, Vol 2014, 2014, pp. 1-9.
[47] Liddle, D., et al, "A Low-Cost Geostationary Mini-satellite Platform", Acta Astronautica, Vol 55, 2004, pp. 271-284.
[48] Garro, A., et al, "Reliability analysis of an Attitude Determination and Control System (ADCS) through the RAMSAS method", Journal of Computational Science, Vol 5, 2014, pp. 439-449.
[49] Castet, J., and Saleh, J. "On The Concept of Survivability, With Application to Spacecraft and Space-Based Networks", Reliability Engineering and System Safety, Vol.99, 2012, pp. 123-138.
[50] Bozzano, M., et al, "Spacecraft Early Design Validation Using Formal Methods", Reliability Engineering and System Safety, Vol.132, 2014, pp. 20-35.
[51] Patton, R., et al, "Robust FDI Applied to Thruster Faults of a Satellite System", Control Engineering Practice, Vol.18, 2010, pp. 1093-1109.