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V. T. MARCHENKO[1], O. A. PETLIAK[2], N. P. SAZINA[1], P. P. KHOROLSKYI[1]

METHODOLOGICAL APPROACH TO SPACECRAFT DEVELOPMENT COST CALCULATION

[1]*Institute of Technical Mechanics*
of the National Academy of Sciences of Ukraine and the State Space Agency of Ukraine
15 Leshko-Popel St., Dnipro 49005, Ukraine; e-mail: sazinana@ukr.net

[2] *Yuzhnoye State Design Office*
3 Kryvorizka St., Dnipro 49008, Ukraine

The aim of this work is to develop a methodological approach to the development of a unified, common for all developers, computer-aided branch procedure for spacecraft development cost estimation based on a spacecraft cost model and practical recommendations on computer-aided branch procedure development.

The cost parameters of the development, manufacturing, and operation of new spacecraft and their technical level (perfection) are the determining factors in competitiveness assessment. To decide on the advisability of starting or resuming the development of a new spacecraft, one has to correctly estimate the development cost.

Using the standardized calculation method in estimating the development cost for new space hardware is unacceptable for lack of bug-free design and production documentation, which is the end product of any development activity.

Parametric methods (the basic methods used to estimate the spacecraft development cost in the USA and Europe) cannot be used in the development of a high-quality procedure for spacecraft development cost estimation for lack of a branch statistical database on spacecraft development labor intensiveness and materials consumption at the State Space Agency of Ukraine. This calls for a nonstandard cost model of spacecraft development.

The authors' cost model is based on a method of componentwise analogy for simple spacecraft components, moving (up and down) along the edges of a weighted oriented tree graph that models the spacecraft technical structure, and fuzzy analysis methods. The tree graph Gi(V(C),D) models the spacecraft technical structure (V, C, and D are the sets of graph vertices and edges and spacecraft components, respectively; to each graph vertex there corresponds a spacecraft component).

The paper presents a nonstandard cost model of spacecraft development, which in its essence is close to a nonlinear parametric cost model, and a scientific methodology for the development of an advanced branch procedure for spacecraft development cost calculation with component and stage detailing.

Keywords: *spacecraft, cost model, weighted oriented tree graph, spacecraft technical structure, development activity, procedure.*

1. Procedure for determining the cost effectiveness of research and development activities and their commercialization. Joint Order by the Ministry of Economic Affairs of Ukraine and the Ministry of Finance of Ukraine No. 218/446 of September 25, 2001. URL: http://www1.nas.gov.ua/infrastructures/Legaltexts/ Others/me_mf/Pages/218-446.aspx (last accessed on July 20, 2020). (in Ukrainian).

2. Methodological recommendations on R&D cost estimation for organizations (enterprises) of different forms of property and management (except for budget organizations). Order by the Ministry of Education and Science of Ukraine No. 119 of February 21, 2006. URL: https://zakon.rada.gov.ua/rada/show/v0119290-06#Text (last accessed on July 20, 2020). (in Ukrainian).

3. Procedure for Determining the Cost Effectiveness of R&Ds and their Commercialization. Kyiv: Ministry for Development of Economy, Trade, and Agriculture of Ukraine, 2006. 18 pp. URL: https://me.gov.ua/ Documents/Detail?lang=uk-UA&id=72a08214-1710-4e5e-9526-9fede7dc8f63&title= MetodikaViznachenniaEkonomichnoiEfektivnostiVitratNaNaukoviDoslidzhenniaIRozrobki TaYikhVprovadzhenniaUVirobnitstvo (last accessed on July 20, 2020). (in Ukrainian).

4. Standard regulations for R&D cost planning, accounting, and calculation (Regulation by the Cabinet of Ministers of Ukraine No, 830 of July 20, 1996, Kyiv). Document 96-p, invalidated by the Cabinet of Ministers of Ukraine's Regulation No. 2019-419-2019-p of January 1, 2020. (in Ukrainian).

5. Tsvetkov A. B. Issues of project management effectiveness in the space industry: Russian and international experience. Proccedings of the 2nd International Conference " Space Industry Logistics" SPACELOG-2017. Moscow, 2017. URL: http://www.sms-corp.ru/images/publication/Spacelog2017.pdf (last accessed on July 22, 2020). (in Russian).

6. Review of hardware cost estimation methods, models and tools applied to early phases of space mission planning, URL: http://titania,ctie,monash,edu,au/papers/trivailo-2012,pdf (last accessed on May 21, 2020).

7. Development of the Small Satellite Cost Model 2019 (SSCM19). URL: https://aerospace.org/sites/default/files/2020-05/SSCM19 %20paper.pdf (last accessed on August 10, 2020).

8. Scherrer D., Chedevergne F., Grenard P., Troyes J., Murrone A.. et al. Recent CEDRE Applications. AerospaceLab. 2011. Pp. 1-28. hal-01182477 URL: https://hal.archives-ouvertes.fr/hal-01182477/document (last accessed on August 18, 2020).

9. Alford B., Hamilton B. A., Andy Prince A. (October 2016). NASA Project Cost Estimating Capability: New Analyses for Spacecraft Estimating. ICEAA 2016 International Training Symposium. URL: http://www.iceaaonline.com/ready/wp-content/uploads/2016/10/GP03-ppt-Alford-NASA-Project-Cost-Estimating.pdf (last accessed on August 18, 2020).

10. Broder M., Mahr E., Barkmeyer D., Burgess E. Alvarado W.. Toas S., Hogan G. (June 2010). Review of Three Small-Satellite Cost Models. 2010 ISPA/SCEA Conference. San Diego CA. June 2010. URL: http://www.iceaaonline.com/ready/ wp-content/uploads/2017/09/EST01A-Broder.pdf (last accessed on August 18, 2020).

11. Gorbulin V. P., Kushnariov O. P. Prediction models for technical and economical indices of rocket complexes and for choosing optimum strategy of their testing. Kosm. Nauka Tehnol. 2012. V. 18, No. 5. Pp. 66-73. (in Russian). https://doi.org/10.15407/knit2012.05.066

12. Ore O. Graph Theory. Moscow: Nauka, 1980. 336 pp. (in Russian).

13. Malyshev G. V. Design of Automatic Spacecraft. Probabilistic Analysis Methods. Moscow: Mashinostroyeniye, 1982. P. 28.

14. Shtovba S. D. Introduction to Fuzzy Set Theory and Fuzzy Logic. URL: http://matlab.exponenta.ru/ fuzzylogic/index.php (last accessed on April 10, 2021). (in

Russian).

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