LOW-THRUST GEO TRANSFER OFF-LINE NAVIGATION AND CONTROL*

M.N. Krasilshikov [(1)], **A.V. Fedorov** [(2)], **K.I. Sypalo**[(3)], **D.A. Kozorez**[(4)]

[(1)(2)(4)] *Moscow Aviation Institute (National Research University), Volokolamskoe shosse, 4, Moscow, A-80, GSP-3,125993, phone +7(499) 158-45-51, E-mail:.mai@mai.ru*

[(3)] *The Central Aerohydrodynamic Institute (TsAGI), Chief of the complex perspective developments, phone +7(968)7839498, E-mail: ksypalo@tsagi.ru*

Autonomous maintenance allows space system to be economically viable. In respect to a satellite placed in GEO off-line transfer, station acquisition and station keeping control design should be implemented considering international regulations. Implementation of the "off-line" idea calls for new control and navigation (C&N) technology for entire system lifetime cycle. Electric propulsion allows considerable fuel mass reduction along with payload mass in GEO increase. A multichannel GNSS receiver combined with optoelectronic onboard sensors seems to be efficient for highly accurate navigation. New C&N technology integration with GEO satellite onboard control system is main line to provide maximal efficiency for off-line space system maintenance.

Inter-orbital journey is well known as most complicated phase of GEO satellite lifecycle. Utilization of low-thrust electric propulsion for GEO transfer leads to long (or very long) process duration. Accuracy specifications, as well as orbit elements, attitude and actual thrust vector estimation reliability becomes very significant. It should be noted that traditional navigation source (single GNSS receiver) does not provide desired navigation data both authenticity and accuracy.

Integration of various sources with respect to autonomous GEO transfer control is only the way to ensure accuracy and reliability of navigation. Simplified architecture of suggested navigation system as well as set of various data fusion algorithms is given. The problem under consideration consists in development of fundamentally new algorithm for on board navigation sensor data integration considering GEO satellite lifecycle specificity and trajectory control demands.

With regard to a satellite in GEO the lifecycle under consideration includes: 1) insertion in orbital position vicinity; 2) orbital position acquisition; 3) station keeping; 4) space disposal. Control strategy for the lifecycle phases should consider safety condition. Navigation system plays key role for control because of it supplies control system with state vector (position, velocity), attitude, electric propulsion thrust, state vectors of neighboring objects, as well as

* This work was supported by the Ministry of Education and Science of the Russian Federation, project no. RFMEFI57414X0100

random and fuzzy factors performance. Closed loop orbit control strategy is based on sufficient conditions of optimality in deterministic, stochastic and guaranteeing (min-max) statements. Applied optimal control theory treats the problem as control synthesis with respect to incomplete data. This calls for simultaneous navigation and control algorithm design which does not lead to practically reasonable non-linear solution. The separation theorem proves independent design for linear white-nosed motion model, and linear measurements model only. However, the authors have approved possibility of separate control and navigation solutions for various engineering software. Now we extend the approach to autonomous case. Off-line close loop GEO-transfer simulation included.