**A Through-life, Integrated and Concurrent Engineering Methodology
for the Responsive Development of Large and Complex Space Systems**

P. Gaudenzi*1, M. Lisi2, G. Palermo1, L. Pollice1\**

*1Sapienza Università di Roma, Dipartimento di Ingegneria Meccanica e Aerospaziale, Rome, Italy*

*2ESA-ESTEC, Noordwijk, The Netherlands*

*\*Corresponding author:* *luciano.pollice@uniroma1.it*

Future space systems will be large and complex infrastructures, requiring large initial investments, very expensive to operate and maintain, meant to last for long periods of time (decades). Examples are the systems for PNT, Earth observation and telecommunications based on constellations of satellites, as well as projects to establish permanent bases on the Moon and on Mars.

Three features are becoming key to the success of these future, service-oriented space projects: affordability, supportability and sustainability. They focus the attention of systems engineering on an optimization of the through-life performance.

Concurrent Engineering (CE), performing real-time multi-domain and multi-purposes design, improving trade-space exploration and enlarging the traditional design boundaries, is a very effective way to obtain valuable high-end products. The importance of a concurrent approach in the preliminary, conceptual design of a space system, assessing feasibility from the technical, programmatic and sustainability points of view, is now widely recognized. So far, however, the focus of CE has been mainly centered on the initial design phase, where indeed the most critical architectural trade-offs are performed. To properly face the challenges of future projects, the space industry should adopt a “Through-life Integrated Concurrent Engineering” (TICE©) approach:

* ***Through-life***: all phases of a space system business are covered (including design and manufacturing, launch, operations, maintenance, service provision and disposal), not just system development;
* ***Integrated***: all disciplines and expertises are integrated in a systemic perspective. All actors (systems architects, designers, MAIT experts, product assurance, management, upstream and downstream functions, supply chain, ...) and stakeholders of the “extended” enterprise are cooperating towards the common objective;
* ***Concurrent***: concurrent and collaborative approaches (with trust and sharing values) and technologies (IT) are widely adopted;
* ***Engineering***: all aspects of the enterprise are engineered and optimized with a holistic development perspective.

Therefore, concurrent and collaborative engineering methods need to be implemented in a more integrated and holistic way and with a through-life perspective, as TICE© approach does. Moreover TICE© methodology might realize, even in the commercial sector, the often chased but never fully achieved, objective of a responsive space industry for responsive and timely delivered large and complex space systems.

As a matter of fact, effective, efficient and flexible design methodogies permit to responsively address very different missions, with optimal choices as far as system architectures and adopted technological solutions are concerned. In the final paper the effectiveness and flexibility of the TICE© methodology, integrating Systems Engineering and Systems Architecting best practices, will be addressed in detail. This methodology is presently being applied to some case-studies in which a responsive development is required, such as the optimization of satellite constellation systems and the design of innovative additive-manufactured space systems.

The TICE© methodology was developed in the frame of the Master in “*Satellite Systems and Services*”, organized by the University of Rome “La Sapienza”. Integrating CE and through-life perspective (comprising operational, maintenance and disposal considerations) with collaborative approaches and large-scale production best practices, it will help the space industry facing the challenges posed by present and future large and complex space systems.