Skoltech
Skolkovo Institute of Science and Technology

Jury Member Report – Doctor of Philosophy thesis.

Name of Candidate: Ignasi Lluch I Cruz

PhD Program: Engineering Systems

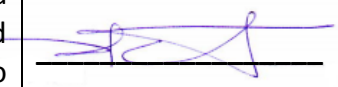
Title of Thesis: A Framework for Architecting Federations of Engineering Systems

Supervisor: Professor Alessandro Golkar

Chair of PhD Defense Jury: Professor Clement Fortin ***Email:*** ***c.fortin@skoltech.ru***

Date of Thesis Defense: September 21, 2017

Name of Reviewer: Zeljko Tekic

The reviewer formulated a possible conflict The author took my PhD course (Ideas to Impact) in Nov-Dec 2015 as a part of Skoltech's PhD curricula. Soon after the course ended, I started working with the author and his cofounder, advising them how to develop business opportunity they identified. As the result of that activity, I am today a mentor and member of advisory board of the startup company Swiftera (www.swiftera.co), one that the author officially established with his cofounder, few months ago. The company (Swifter) and its technology are not related to, or derived from the result presented in this dissertation. I do not have any shares / stake in the company and I am not paid for my job.	**Signature:**  **Date: 02-09-2017**

The purpose of this report is to obtain an independent review from the members of PhD defense Jury before the thesis defense. The members of PhD defense Jury are asked to forward a completed copy of this report to the Chair of the Jury at least 30 days prior the thesis defense. The Reviewers are asked to bring a copy of the completed report to the thesis defense and to discuss the contents of each report with each other before the thesis defense.

If the reviewers have any queries about the thesis which they wish to raise in advance, please contact the Chair of the Jury.

Reviewer's Report

Reviewers report should contain the following items:

- Brief evaluation of the thesis quality and overall structure of the dissertation.
- The relevancy of the topic of dissertation work to its actual content
- The relevancy of the methods used in the dissertation
- The scientific significance of the results obtained and their compliance with the international level and current state of the art
- The relevance of the obtained results to applications (if applicable)
- The quality of publications
- The summary of issues to be addressed before/during the thesis defense

Dissertation of Mr. Ignasi Lluch I Cruz, ***A framework for architecting federations of systems***, submitted for review aims at increasing our understanding of Federations of Systems (FoS) by identifying their existential challenges and developing methods for analyzing their emergence and evolution. Although the research is motivated by satellite federations, it tackles a generalized problem of architecting FoS. The dissertation responds to two research questions: 1. *How can we measure synergy between a set of engineering systems?* and 2. *How can we predict the formation and evolution of federation of engineering systems?*.

The dissertation contains nine logically connected chapters followed by a list of references linked to the topic, and one appendix. The work is systematic and well organized. It starts with an introduction, which gives a descriptive example and helps in setting background. After that, dissertation's scope, objectives and main research questions are outlined (Chapters 1 – 3). The background and motivation for research are well grounded and explained. After the detailed literature review (Chapter 4), which is focused on systems of systems (SoS) literature and the concepts of emergence and synergy, the dissertation develops (Chapter 5) a quantitative framework to assess the conditions for the formation and evolution of federations of systems. Chapter 5 is the central section of this dissertation. It defines FoS, derives, discusses and describes all elements of the framework to answer the research questions. Subsequent chapters (Chapters 6 – 8) offer in-depth case studies of three examples of FoSs: 1) satellite federations for Earth observation; 2) ridesharing and 3) peer-to-peer community wireless networks. These examples are very different at several levels – technology, typology of the systems and stakeholders involved, degree of deployment in the real world, and FoS governance mechanisms. The cases provide illustration of the framework application in more than one domain and, thus, offer robust testbed for its validation. Final chapter (Chapter 9) offers systematic summary of achieved results and applicable limitations. It outlines future research challenges in this field as well.

Mr. Ignasi Lluch I Cruz has presented an interesting, scientifically and practically relevant dissertation. It is the result of an intense research activity. The dissertation presents new integrated framework for solving difficult and emerging engineering tasks – the assessment of the conditions for the formation and evolution of federations of systems. The main contributions of the dissertation are:

1. The definition of federations of systems (the detailed characterization and identification of existential challenges) and its consolidation as type of systems of systems;
2. Introduction and mathematical definition of the concept of synergy in the field of systems engineering and architecting, and its connection to the concept of emergence and resource allocation;

3. Development and validation of a quantitative framework for assessing the conditions for the formation and evolution of federations of systems;
4. Detailed insights in three case studies (satellite systems, transportation and communications).

Based on the results achieved, the dissertation provides systems architects with a tool to characterize and design engineering FoS, and predict their evolution (taking into account the effects exerted from the federation, and to the federation, to/from their particular system of interest).

The author did not develop new methodology, but systematically and smartly combined common components of the systems' architect toolkit – tradespace exploration, Pareto dominance and utility functions (as well as few general approaches).

Using the real cases of Earth observation satellites, ridesharing and peer-to-peer community wireless networks, the author demonstrated how to apply developed framework and proved its validity. All three case studies are deeply analyzed and provide many qualitative and quantitative details.

All contributions are clearly and intelligibly presented in the dissertation. Appearance and language of the dissertation are very good.

The topic is treated well and dissertation content is in clear correspondence with the topic and title of the dissertation. Bearing in mind quick development of fields like Internet of Things, Smart Cities, autonomous cars and intelligent transport, which all offer, in one or another way, many opportunities for developing federations of systems, the topic is very relevant and current.

Provisional Recommendation

☒ *I recommend that the candidate should defend the thesis by means of a formal thesis defense*

☐ *I recommend that the candidate should defend the thesis by means of a formal thesis defense only after appropriate changes would be introduced in candidate's thesis according to the recommendations of the present report*

☐ *The thesis is not acceptable and I recommend that the candidate be exempt from the formal thesis defense*