Extended abstract
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Title: The need for a systemic perspective in aircraft deicing: a proposal of a risk and safety analysis method combining FRAM and fuzzy logic.

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Abstract. Safety is a top priority. This is especially true when it comes to highly controlled systems as aviation. Aircraft on-ground deicing operations are a significant contributor to the safety of aviation and perform a critical and essential task. The context of application for deicing operations is a complex one characterized by dynamic interactions of social and technological components. Operations are to be executed in a strict manner in accordance with guidelines and regulations to ensure high reliability and desired safety levels. Operations are conducted under temporal constraints and in extreme weather conditions. In recent years, advances in aircraft deicing as the centralization of operations and the improvement of applied technology increased the efficiency and effectiveness of applied deicing procedures. Despite the high levels of reliability and safety in deicing operations, the growing complexity of such a system and the continuous technological advancements require continuous research and improvements to maintain adequate performance and tackle any arising challenges. With the exception of a few studies, research projects conducted in the field of aircraft deicing focus on the technical and operational aspects. However, limiting the scope of analysis without considering the emergent and complex properties of a sociotechnical system does not provide

a complete picture of the system status. To provide a more complete and comprehensive picture, safety and performance analyses should additionally adopt a more holistic and systemic perspective considering contextual, organizational and human factors as well. Considering above-mentioned aspects, the objective of our research project is to present a possible systemic approach through the combination of the Functional Resonance Analysis Method (FRAM) and fuzzy logic.

FRAM is a systemic analysis method, proposed by Erik Hollnagel in 2004, which describes successful and failed outcomes as a result of performance variability and functional resonance. FRAM is especially suitable for studying non-linear relationships and complex contexts, which can be difficult to represent in quantitative terms. Fuzzy logic, on the other hand, is much older and was introduced by Lotfi Zadeh in 1965. Fuzzy logic resembles human reasoning and allows for a mathematical representation of linguistic scales, on which FRAM relies to evaluate variability. Through the integration of fuzzy logic into FRAM and designing the FRAM functions as rule-based fuzzy inference systems, the advantages of both methods can be utilized to provide more representative and comprehensive results. Relying on literature and research work conducted by our team over recent years, the deicing context was simulated and characterized in terms of functions, which describe the set of activities necessary to successfully perform the deicing of airplanes. The functional characterization describes how the various tasks are related and how the outcomes' variability can resonate and affect performance negatively or positively. A list of contextual performance conditions was used as an evaluation parameter to assign a quality score on a ten-point scale for each selected factor. A rule-based fuzzy inference system was constructed to fuzzify the scores of all respective performance conditions and generate an aggregated quantifier for the potential internal variability of each function. The internal variability factor was then linked to a higher-order fuzzy inference system in addition to the other incoming aspects from upstream functions to generate a numerical output for the function in question. The numerical outcome represents an indicator for possible variability, whether negative or positive, in the function's output. On a spectrum between 0 and 1.5, 1 represents a non-variable output. Any value below 1 represents negative variability, while any value above 1 represents positive variability.

The preliminary results of the simulation in MATLAB are promising and present a comprehensible example on how to construct such a model. The defined functions described human (individual or organizational) activities that constitute the deicing context and the relationships and couplings that affect the system's performance on a wide scale. A realistic analysis scenario inspired by actual accidents and events was constructed and a few assumptions concerning the performance conditions were formulated to induce variability such as inadequate airliner guidelines, present extreme weather conditions, inadequate training of flight crew and high temporal stress. The assumptions made translated into creating a context

that impacted the performance of several functions. The addition of fuzzy logic to FRAM allowed for the calculation of numerical quantifiers for the quality of the outputs to represent the potential for variability based on the defined scenario. The proposed framework presented a complex system analysis of the deicing context, which modelled human activities as functions and characterized the resulting variability due to performance adjustments. The principle of functional resonance provided a better understanding for the dynamic relationships among functions and the emergence of successful or undesired outcomes. The simulation was a simplification of reality and was constructed based on a hypothetical scenario. The process of characterizing the functions and generating the fuzzy inference systems can be time- and effort-exhaustive and the simulation requires high computing resources as well. To avoid the problem of creating unfeasible rule bases, the characterization of the functions and the selection of influential factors and variables have to be simplified and limited in number. The analyst performing the analysis should therefore be knowledgeable in the system he/she intends to analyze. Further experiments and optimization work are still needed to validate the proposed model and ensure its reliability. Nonetheless, the improved method promises to provide a supportive tool, which can be complementary to the established classical methods and present a different needed perspective.