

Article

Introducing Robust Statistics in the Uncertainty Quantification of Nuclear Safeguards Measurements

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Abstract: The monitoring of nuclear safeguards measurements consists of verifying the coherence between the operator declarations and the corresponding inspector measurements on the same nuclear items. Significant deviations may be present in the data, as consequence of problems with the operator and/or inspector measurement systems. However, they could also be the result of data falsification. In both cases, quantitative analysis and statistical outcomes may be negatively affected by their presence unless robust statistical methods are used. This article aims to investigate the benefits deriving from the introduction of robust procedures in the nuclear safeguards context. In particular, we will introduce a robust estimator for the estimation of the uncertainty components of the measurement error model. The analysis will prove the capacity of robust procedures to limit the bias in simulated and empirical contexts to provide more sounding statistical outcomes. For these reasons, the introduction of robust procedures may represent a step forward in the still ongoing development of reliable uncertainty quantification methods for error variance estimation.

Keywords: robust statistics; nuclear safeguards; one-way random effect model; ANOVA; Q-estimator



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1. Introduction

Nuclear safeguards involve measures designed to deter and detect the diversion of nuclear material from the fuel cycle for illicit purposes [1]. The monitoring for possible data falsification by operators that could mask diversion is based on the statistical analysis of paired (operator, inspector) verification measurements. Significant deviations between the operator declarations and the corresponding inspector measurements may be the consequence of problems with their measurement systems. However, they could also be the result of the operator falsifying the data. In this context, the fundamental elements for a trustworthy analysis are (i) a proper measurement error model and (ii) an efficient and unbiased uncertainty quantification (UQ), i.e., the estimation of its uncertainty components.

Concerning this second point, two approaches are available: the bottom-up and the empirical top-down approach [2]. The former consists on quantifying and then propagating the uncertainty in all key steps of the assay, in order to derive the resulting uncertainty of the measured values. The latter, instead, relies fundamentally on modeling measurement data as a one-way random effect model with two variance components, one accounting for the variation within and the other for that between groups. A group is typically defined as an inspection period, within which the measurements are assumed to have the same random error. Between inspection periods, instead, the systematic error captures the changes that may occur in the metrological conditions, such as instrument calibration, change of inspectors, change of background radiation, and so on [3]. The two variance components with data from past inspections are estimated through the classical analysis of variance (ANOVA), [4], or using the Grubbs estimator [5], depending on the scope of the analysis.

In empirical application, the outcomes of the bottom-up and the empirical top-down approach could significantly diverge. Specifically, bottom-up estimations are often larger

Mathematical And Statistical Methods In Nuclear Safeguards

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Quantitative Assessment in Arms Control Rudolf Avenhaus,2012-12-06 This book originates in a series of contributions to the 1983 Systems Science Seminar at the Computer Science Department of the German Armed Forces University Munich Under the topic Quantitative Approaches to Arms Control that seminar attempted to review the present state of the art of systems analysis and numerical methods in arms control To this end the editors invited a number of experts from Europe the United States and Canada to share and discuss their views and assessments with the faculty and upper class computer science students of the university as well as numerous guests from the defence community and the interested public In three parts this book presents a selection of partly revised and somewhat extended versions of the seminar presentations followed in most cases by brief summaries of the transcripts of the respective discussions In addition to an introduction by the editors part I contains six papers on the present state and problems of arms control with emphasis on START Strategic Arms Reduction Talks INF Intermediate range Nuclear Forces negotiations and MBFR Mutually Balanced Force Reduction talks The seven contributions to part II are devoted to mathematical models of arms competition and quantitative approaches to force balance assessment of both the static and dynamic variety Part III presents five papers which address technical and operational aspects and legal implications of arms control negotiations and verification

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Computer Science Department of the Federal Armed Forces University Munich on the topic of Quantitative Assessment in Arms Control 1 There was wide agreement among the contributors to that seminar and its participants that those efforts to assess the potential contributions of systems and decision sciences as well as systems analysis and mathematical modelling to arms control issues should be expanded and a forum should be provided for this activity It was further agreed that such a forum should include political scientists and policy analysts working in the area of arms control *Publications of Los Alamos Research* Los Alamos National Laboratory, 1985

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