Application of Field Programmable Gate Arrays in Instrumentation and Control Systems of NPPs

A new IAEA publication

Janos Eiler

Shanghai, 13 October 2015

IAEA
International Atomic Energy Agency

Outline

- Activities in the area of NPP I&C engineering
- IAEA Nuclear Energy Series Document on the “Application of Field Programmable Gate Arrays in Instrumentation and Control Systems of NPPs”

Technical Working Group

IAEA

International Atomic Energy Agency

Technical Working Group on NPP I&C

Nuclear Power Engineering Section

Operating Reactors Support

- Plant Life Management for Safe Long Term Operation
- Instrumentation and Control Technologies
- Power Uprating in Nuclear Power Plants

Expanding Nuclear Power

- Electric Grid stability
- Nuclear Energy Human Resources Development
- Integrated Management System
- Strategic Support for Expansion of Nuclear Power

Scientific Secretary

Technical Working Group on Nuclear Power Plant I&C

- Hold the biannual general meeting
- Exchange technical & management information
- Identify & discuss issues of common interest
- Schedule and execute the work program

TWG website:
http://www.iaea.org/NuclearPower/Engineering/TWG/TWG-NPPCI/index.html

IAEA

Current members of TWG-NPPIC

- Argentina,
- Brazil
- Canada,
- China,
- Czech Republic,
- Finland,
- France,
- Germany,
- Hungary,
- India,
- Japan,
- Republic of Korea,
- Mexico,
- Pakistan,
- Russian Federation,
- Spain,
- Sweden,
- Switzerland,
- Ukraine,
- United Kingdom,
- United States of America
- International Organizations:
  - IEC TC45,
  - European Commission (JRC)

IAEA

TWG group photo from 2015

- The program for 2016 - 2019 was compiled in the last biennial meeting of the TWG in May 2015

Chairman of the TWG NPPIC

- Richard Wood of ORNL

Chinese presentation in the TWG meeting

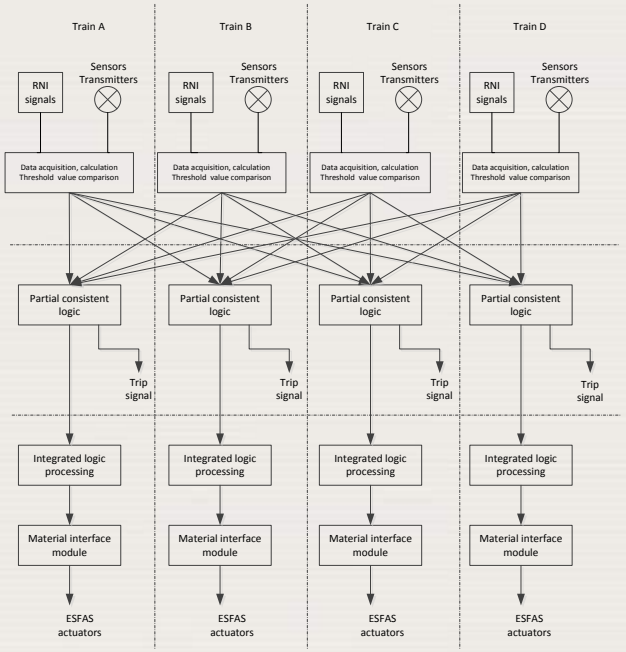
Priority list of recommendations from the 2015 TWG meeting

- I&C architectural approaches;
- Engineering and design aspects of computer security in NPP I&C systems;
- The application of wireless technologies in NPP I&C systems;
- Aging management of electrical equipment and components;
- Commercial dedication, application of COTS, type approval, product certification;
- I&C aspects of computerized operator support systems;
- Computer screen (VDU) based control room technologies;
- I&C support for process performance optimization;
- Application of different sets of codes, standards, and safety classifications;
- Support for newcomer countries and new NPPs.

IAEA

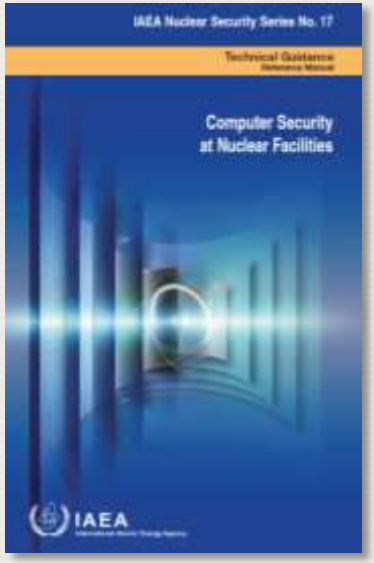
I&C architectural approaches

- Defense-in-depth
  - I&C functions for "Design Extension Conditions"
- Diversity
  - Justification of the required level of diversity
  - Diverse actuation system design
- Sustainability (ease-of-modernization)
- Security zones
- The application of diversity, independence and physical separation between different levels of the I&C system
- Design methods to resolve common-cause failure vulnerabilities



Computer security

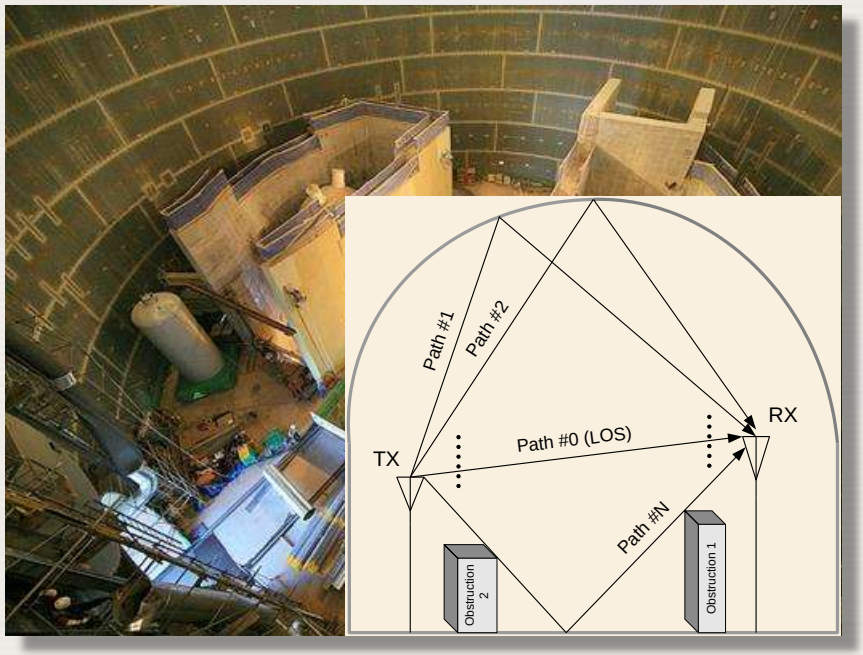
- Nuclear I&C systems provide safety functions
- They may be targeted by adversaries for sabotage resulting in unacceptable or high radiological consequences
- A cyber-attack can cause an initiating event and/or can undermine the performance of a safety function
- IAEA guidance aims to overlay security considerations on top of the systems' safe, reliable, and deterministic behavior to meet safety and security objectives at the same time



IAEA

Use of wireless technologies in NPP I&C

- The technology is finding its way in a wider scope of applications in the nuclear power industry
  - Saving cable costs and installation time
  - Increased flexibility of information gathering through temporary sensor deployment
- IAEA coordinated research project started recently
  - The overall objective is to develop and demonstrate techniques of advanced wireless communication that can be used for transferring process information in a nuclear specific environment
- Chinese participation:
  - Mr. Shuxin YU, SNERDI
  - Mr. Xiaolei CHENG, NCEPU



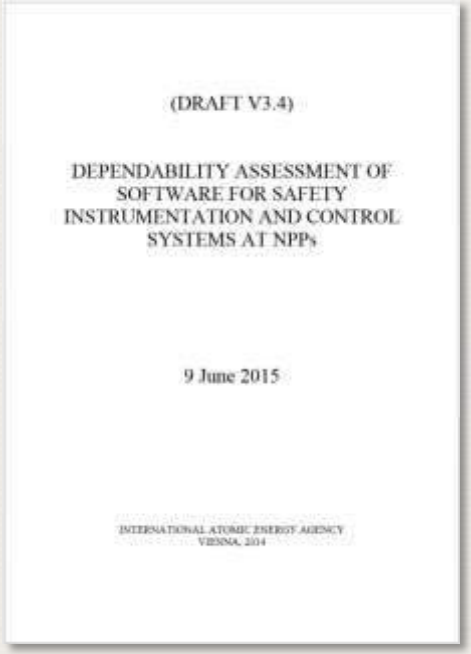
IAEA

Commercial dedication

- Evaluation of COTS I&C equipment and I&C architecture
- Design considerations
- Software-based systems
- Smart devices + embedded digital devices
- Smart field devices, bus communications a
- Regulatory treatment

Issues with software dependability

- The evaluation and dependability assessment of software important to safety is an essential and difficult aspect of digital systems safety justification
- The concern is with detecting and removing residual design errors
- These errors might be a risk of common-cause failure (CCF) that could defeat redundancy or defence-in-depth
- To provide adequate confidence, extensive work is under way at the IAEA on software verification techniques


(DRAFT V3.4)

DEPENDABILITY ASSESSMENT OF SOFTWARE FOR SAFETY INSTRUMENTATION AND CONTROL SYSTEMS AT NPPs

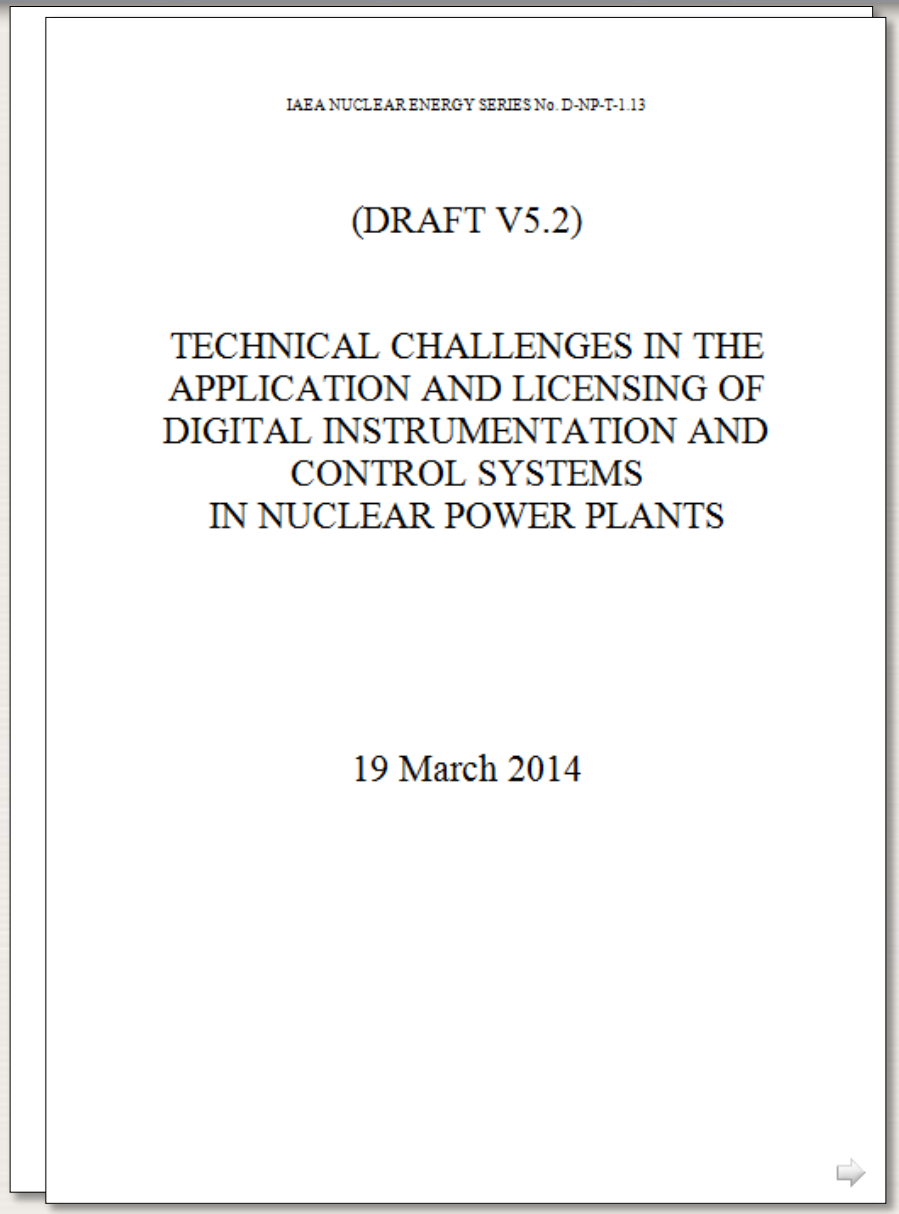
9 June 2015

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 2014

IAEA

Harmonization of licensing practices

- Products accepted by regulators in one country are frequently difficult to obtain acceptance by another regulator
- Harmonization efforts are underway but progress is very slow
- IAEA TECDOC and new draft guidance



IAEA NUCLEAR ENERGY SERIES No. D-NP-T-1.13

(DRAFT V5.2)

TECHNICAL CHALLENGES IN THE APPLICATION AND LICENSING OF DIGITAL INSTRUMENTATION AND CONTROL SYSTEMS IN NUCLEAR POWER PLANTS

19 March 2014

IAEA

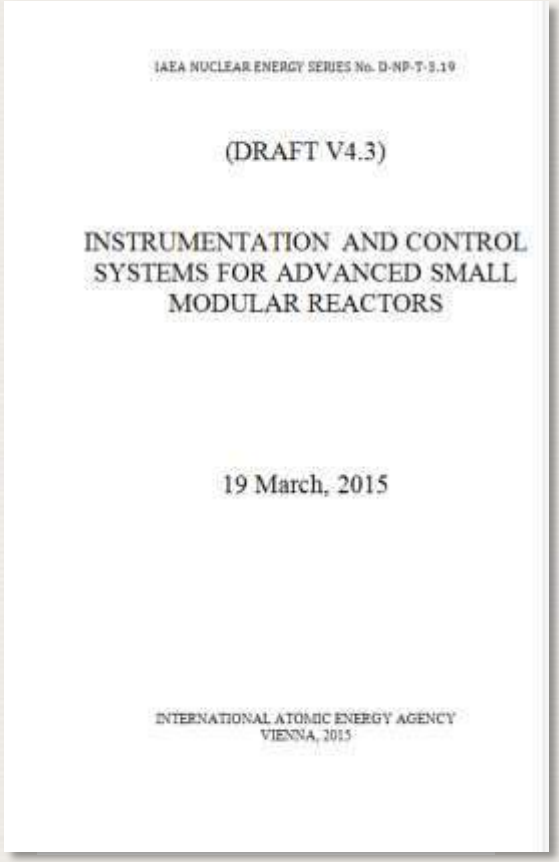
Coping with aging and obsolescence

- As most of the I&C systems are replaceable, ageing systems are not likely to create obstacles that could compromise long term operation
- However, some components, including power and signal cabling, are very difficult to replace
- The IAEA has already released a number of reports related to I&C ageing management
- A recent CRP covered low voltage cable aging
- Aging management of electrical equipment needs attention form the IAEA

IAEA

I&C systems for SMRs

- Some SMRs would operate differently from current reactors and would, therefore, need new I&C approaches
- A recently completed IAEA report evaluates the current situation and provides guidance on:
  - SMR design characteristics that impact I&C
  - SMR economic considerations
  - Regulatory considerations
  - Distinctive I&C features and issues
  - Approach to I&C design
  - I&C architecture, technologies and equipment
  - Fabrication and site integration issues
  - Concepts important for operation of SMRs
  - Maintenance


IAEA NUCLEAR ENERGY SERIES No. [illegible]

(DRAFT V4.3)

INSTRUMENTATION AND CONTROL SYSTEMS FOR ADVANCED SMALL MODULAR REACTORS

19 March, 2015

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 2015

IAEA

Review Missions

IAEA
International Atomic Energy Agency

IERICS missions

- IERICS: Independent Engineering Review of Instrumentation and Control Systems
  - To review the design, prototype, testing, operation, maintenance, and modernization of I&C systems
  - Conducted by a team of international experts from complementary technical areas
  - Based on appropriate IAEA documents, such as Safety Guides and Nuclear Energy Series Reports
  - Findings include a list of recommendations, suggestions and identified good practices
- IERICS mission website: http://www.iaea.org/NuclearPower/IandC/IERICS/index.html
- Some Chinese organizations have expressed interest

IAEA

IERICS missions completed to date

- Doosan Heavy Industries & Construction Co., RoK, 2010
- Research and Production Corporation Radiy, Ukraine, 2010
- Joint Stock Company VNIIAES, Russia, 2012
- Joint Stock Company SRPA “Impulse”, Ukraine, 2013

IAEA

Meetings, Workshops, Conferences

IAEA
International Atomic Energy Agency

Meetings, workshops, conferences

- 5 consultancy meetings on average in each year
- 3 technical meetings on average in each year
- 1 - 2 co-sponsorship agreements to international conferences and workshops in each year
- 2 - 4 TC training courses / workshops in each year

IAEA

2nd China I&C Technology Conference
16-19 April 2013, Xian, China

3rd China I&C Technology Conference
9-11 April 2015, Shanghai, China

Meetings planned for 2015

- 9th NPIC & HMIT 2015 Charlotte, NC, 22-26 February 2015
- Last consultancy meeting on I&C systems for Small Modular Reactors (SMRs)
- Two consultancy meetings on Software dependability assessment
- 1st Research Coordination Meeting on the Application of wireless technologies in NPP I&C systems, 30 March -02 April, Vienna, Austria
- 3rd China International conference on NPP I&C technology, 8-10 April 2015, Shanghai, China, (IAEA co-sponsorhip)
- 25th Meeting of the Technical Working Group on Nuclear Power Plant Instrumentation and Control, 27-29 May, Vienna, Austria
- 8th International Workshop on the Application of FPGAs in NPPs, 13-16 October 2015, Shanghai, China

---

- Technical meeting on Aging management of electrical equipment and components at nuclear power plants, 27-30 October, Vienna, Austria
- Follow-up IERICS mission at SRPA “Impulse”, Severodonetsk, Ukraine
- Consultancy meeting on I&C architectural approaches, 7-11 Dec, Vienna

IAEA

Meetings planned for 2016

- Technical meeting on I&C architectural approaches, Q3, Grenoble, France
- Technical meeting on Visual Display Unit Based Control Rooms at Nuclear Power Plants, Q2, Beijing, China
- Research Coordination Meeting on the Application of wireless technologies in NPP I&C systems
- Consultancy meetings on I&C architectural approaches
- Consultancy meetings on computer security for NPP I&C systems
- 9th International Workshop on the Application of FPGAs in NPPs
- Potential IERICS missions at Chinese organizations

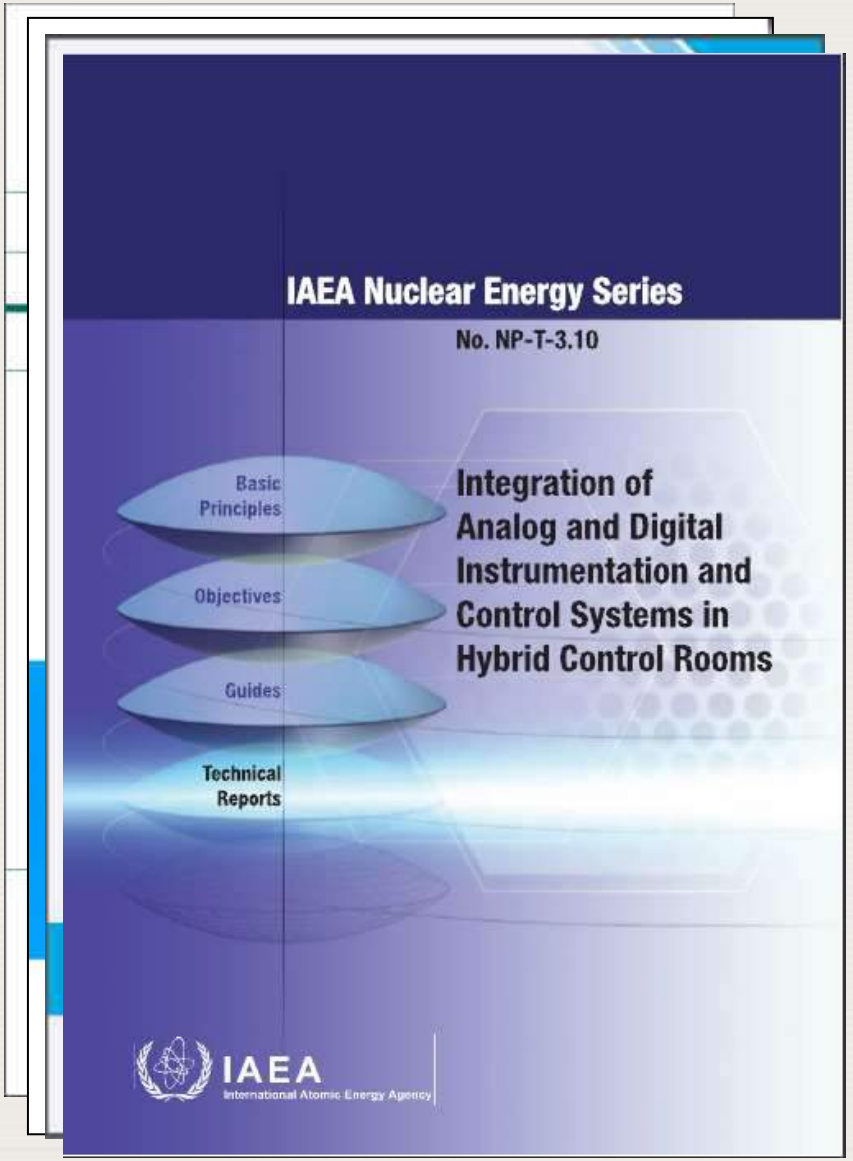
IAEA

Publications

IAEA
International Atomic Energy Agency

Publications

- Nuclear Safety Guides (NSG)
- Technical Report Series
- TECDOCs
- Nuclear Energy Series



IAEA

IAEA Nuclear Energy Series Document on the "Application of FPGAs in I&C Systems of NPPs"

IAEA

International Atomic Energy Agency

The need for an IAEA publication

- The IAEA has played a significant role and co-sponsorship in the international discussion on FPGAs
- The technology is finding its way very rapidly and the Member States needed guidance in the area
- To date, there has been no IAEA report available on the application of FPGAs

Objective

- To summarize current knowledge, best practices and issues associated with the application of FPGA based solutions in nuclear power plants
- To describe development processes and tools as well as licensing issues
- The document is intended to be used by Member States to support the design, licensing, and implementation of FPGA-based systems. Potential users are:
  - Nuclear power plant operators
  - Technical support organizations
  - Regulatory bodies
  - Research and development organizations
  - Manufacturers/ vendors

IAEA

Meetings to produce the document

- "Position paper" drafted in the 4th and 5th FPGA workshops in 2011 and 2012
- First Consultancy Meeting
  - Vienna, 11-14 February 2013
- 6th FPGA workshop
  - Kirovograd, Ukraine, 8-11 October 2013
- Last Consultancy Meeting
  - Vienna, 17 to 21 March 2014

IAEA

4th Workshop on the Application of FPGAs November 2011, Chatou, France

IAEA

5th Workshop on the Application of FPGAs October 2012, Beijing, China

IAEA

List of participants of the 1st CS meeting

- Andrashov, A. — Radiy, Ukraine
- Naser, J. — EPRI, United States of America
- Arndt, S. — US NRC, United States of America
- Seaman, S. — Westinghouse, United States of America
- Eiler, J. — International Atomic Energy Agency
- Glockler, O. — SunPort SA, Switzerland
- Thuy, N. — EdF R&D STEP, France
- Zeng, H. — SNPAS, China

IAEA

6th Workshop on the Application of FPGAs 8-11 October 2013, Kirovograd, Ukraine

IAEA

Break-out sessions to review the draft

1. Introduction to the FPGA Technology
   Sergio Russomanno
2. Methods and Tools for Development and Verification
   Nguyen Thuy
3. Qualification and Licensing, Doc. chapter: Mark Lawford
4. Applications, FPGA-based Replacement Systems and New Designs, Steve Seaman



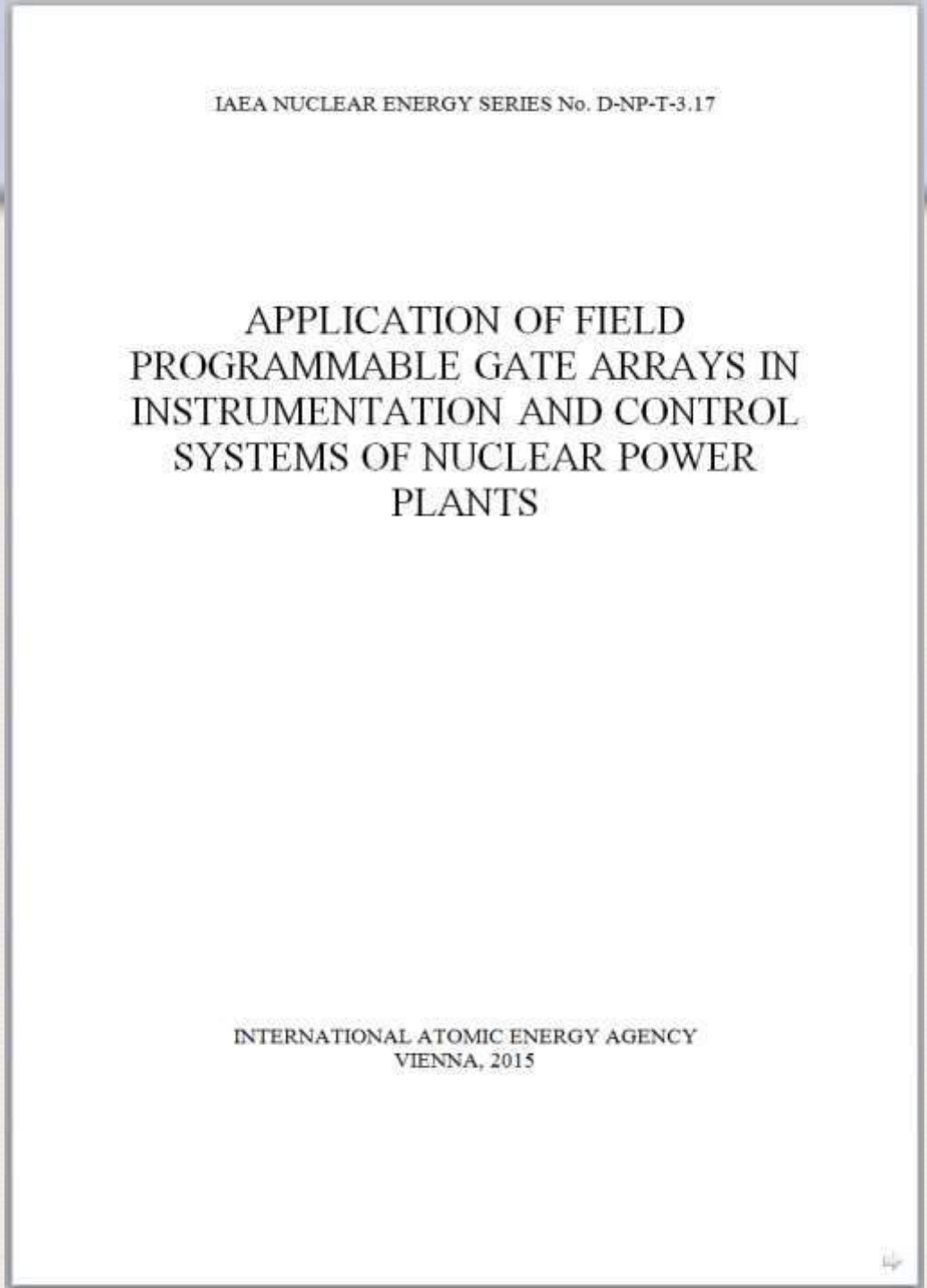

List of participants to the last CS meeting

- Eiler, J. — International Atomic Energy Agency
- Russomanno, S. — Global Nuclear Solutions Inc., Canada
- Thuy, N. — EdF R&D STEP, France
- Gassino, J. — IRSN, France
- Arndt, S. — US NRC, United States of America
- Naser, J. — EPRI, United States of America
- Glockler, O. — SunPort SA, Switzerland

IAEA

The IAEA report

- Nuclear Energy Series
  - NP-T-3.17
- Chairman: Joe Naser
- 79 pages
- 6 main chapters



Structure

- Foreword
- 1. Introduction
- 2. Introduction to FPGA technology
- 3. Methods and tools for development and verification
- 4. Licensing
- 5. Replacement systems and new NPP designs
- 6. Summary
- References
- Annex I: Specific application examples and experience
- Annex II: Typical life cycle for an FPGA platform
- Glossary

IAEA

Introduction to FPGA technology

- FPGAs within the HDL family
- Differences between HDL and software
- What are FPGAs?
  - Comparison between FPGAs and CPLDs
  - FPGA related technologies
  - FPGA programming process
  - FPGA based systems development life cycle
- General application areas suited to FPGA based implementations
- Advantages of FPGA based I&C systems
- Challenges with FPGA based I&C systems

Methods and tools for development and verification

- Design guidelines
  - 12 subsections (e.g. pre-developed designs, coding rules, fault tolerance, diversity, testability, etc.)
- Verification and validation
  - 7 subsections (e.g. simulation, test coverage, formal verification, hardware testing, etc.)
- Tools
  - 4 subsections (quality, integration, cyber security, and life cycle)

Licensing

- Environmental qualification
- Functional demonstration
  - 7 subsections (e.g. acceptance process of the pre-developed resources, development life cycle, analysis and verification, integration and validation, etc.)
- Regulatory perspectives on FPGA technology, licensing and standards
  - 14 subsections, e.g.
    - the application of existing software based guidance for FPGA licensing
    - standards for FPGAs
    - documentation
    - reduction in variations in standards and countries' regulations
    - simplification of regulatory requirements and structure

FPGA based replacement systems and new NPP designs

- Replacements and upgrades in existing plants
  - One-for-one module replacements or upgrades
  - Multiple module replacement
  - Replacement of entire systems
- FPGA based I&C systems and devices for a new NPP design

Publication

- Expected publication date is still in 2015
- The report will be available on the IAEA publications website
  - http://www.iaea.org/Publications/index.html
- The draft is available from me if you would like a copy


Thank you for your attention!