

Recommended Application of FPGAs for I&C Systems in Nuclear Power Plant (CAP1400)

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of FPGAs in NPP

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1. Background

2. NuPAC Development

3. NuPAC Licensing

4. RPS Application

1. Background

NuPAC is a FPGA technology based safety digital I&C system platform. It was cooperatively developed by State Nuclear Power Automation System Engineering Company(SNPAS) and Lockheed Martin.



1. Background

NuPAC is the first safety digital I&C system platform which has received the approvals from both China NNSA and the U.S.NRC.



1. Background

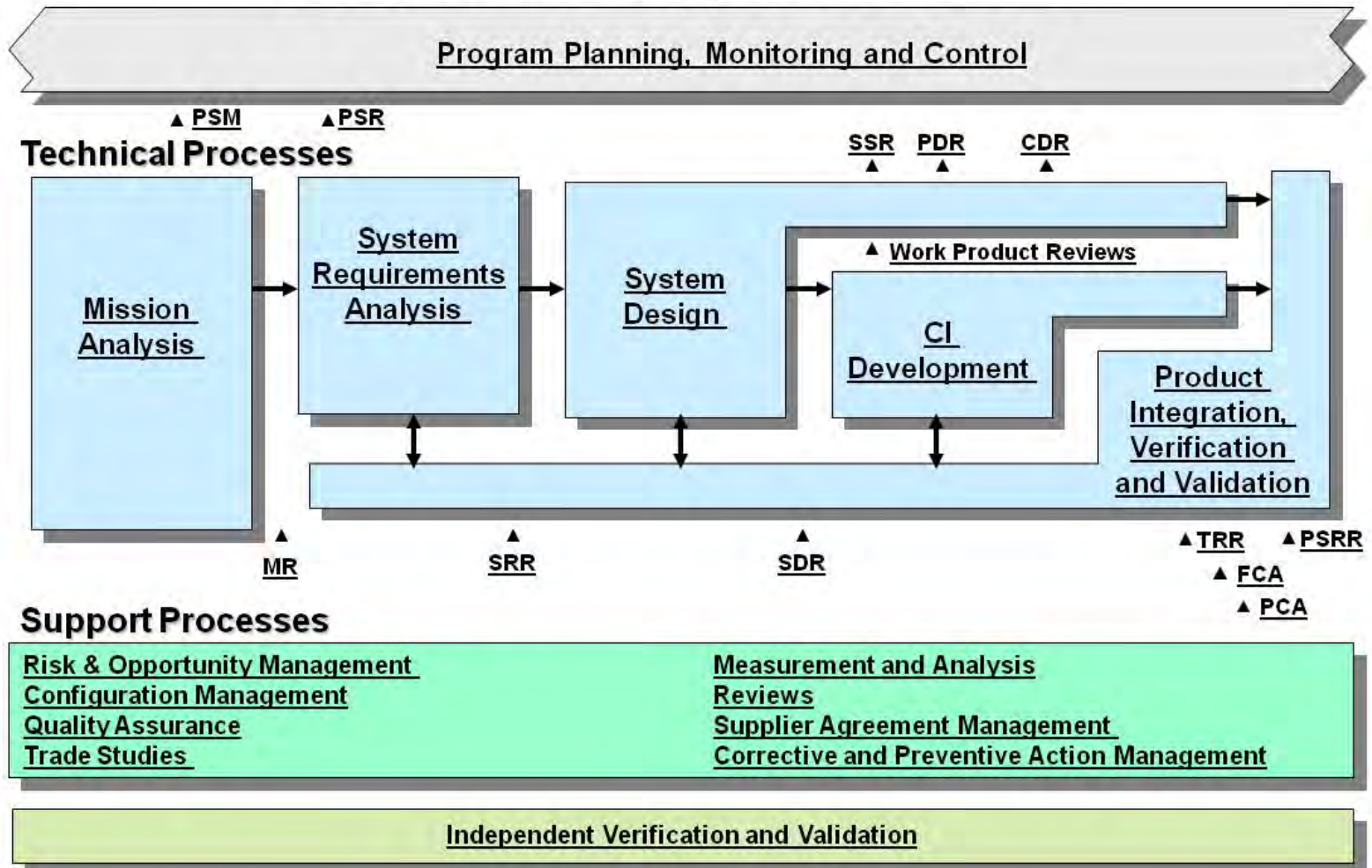
2. NuPAC Development

3. NuPAC Licensing

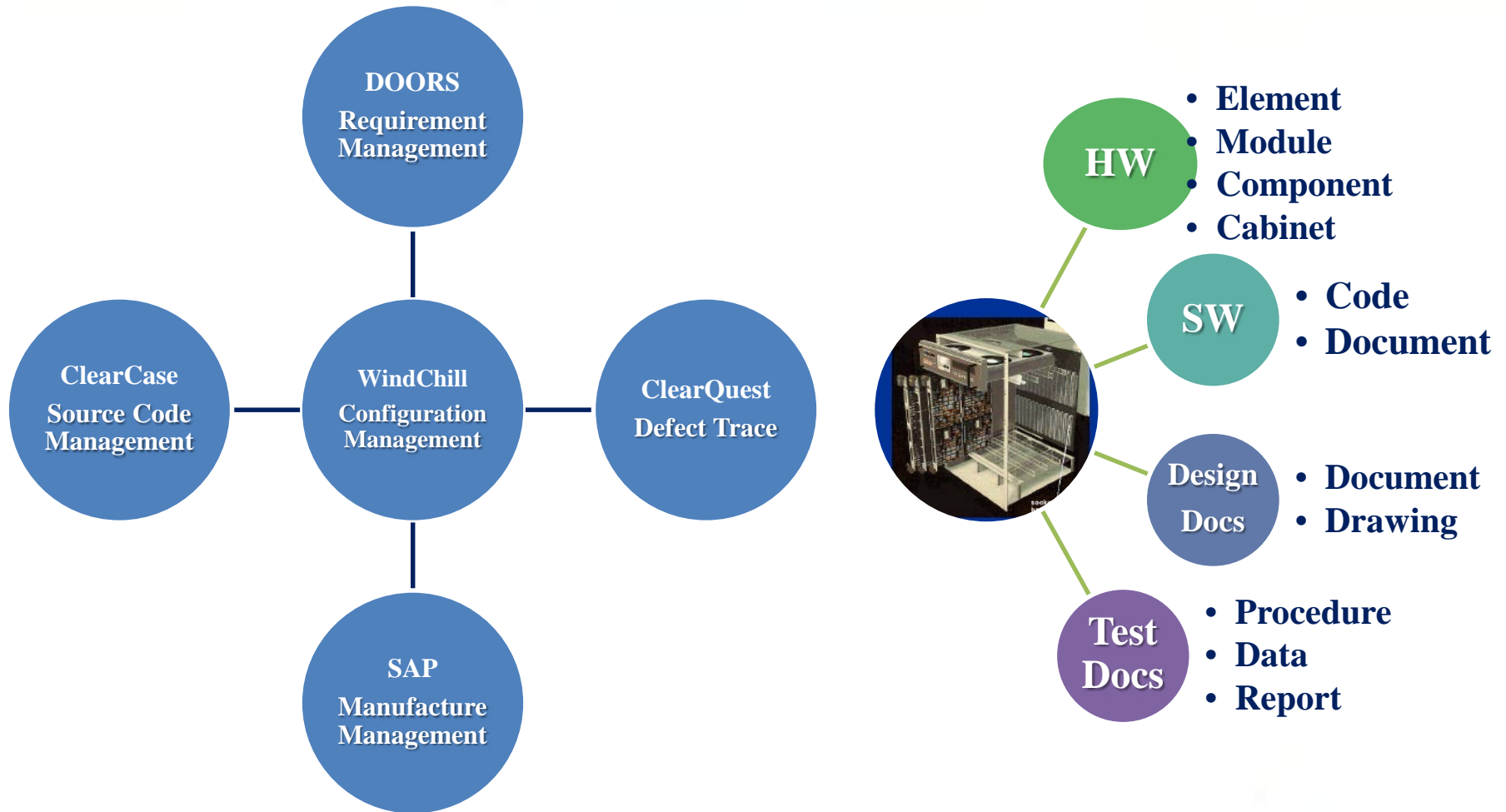
4. RPS Application

2. NuPAC Development

Technical and Support Processes



2. NuPAC Development



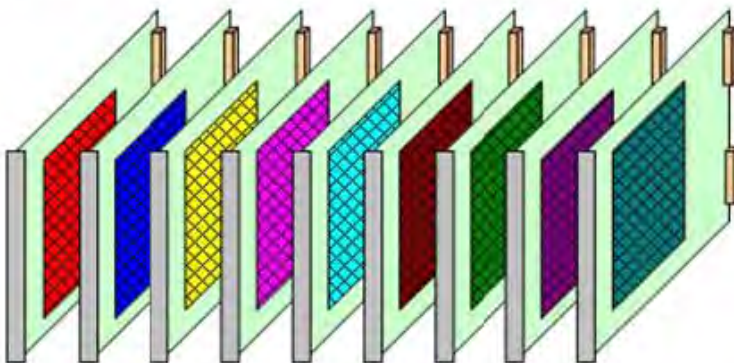
2. NuPAC Development



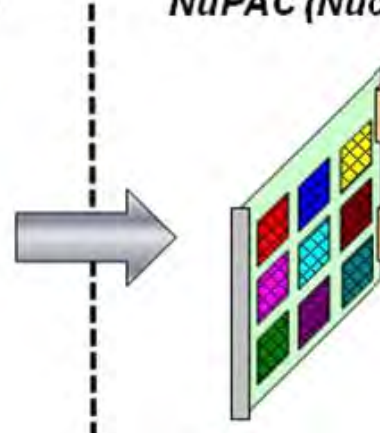
Advanced System Architecture
Parallel operation, Modular design,
High redundancy

Flexible Configuration
Use Generic Logic Module(GLM)
Multi function configuration

Traditional PLCs (Programmable Logic Controller)



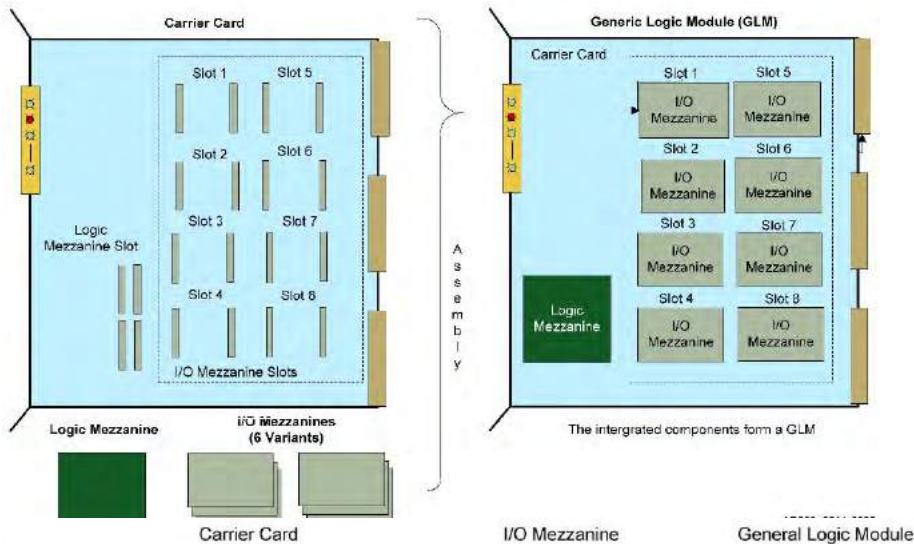
NuPAC (Nuclear Protection and Control)



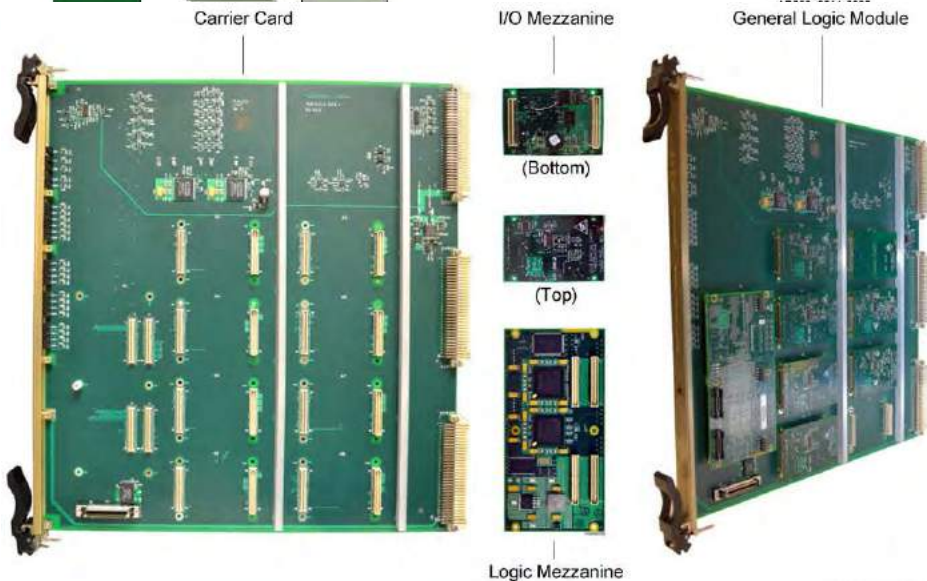
Functionality:

- Controller
- Analog Input
- RTD
- Thermocouple
- Digital Input
- Analog Output
- Digital Output
- Relay
- Serial Comm

2. NuPAC Development



NuPAC HW
Carrier Card
Logic Mezzanine
I/O Mezzanines
Chassis/RTMs



2. NuPAC Development



High Reliability

Use FPGA technology
Hardware logic only, No software
Point to point communication

High Level Information Security

We developed all the source codes
Effective against cyber attacks
No backdoor



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3. NuPAC Licensing

U.S.NRC

LM & SNPAS
2011 submittal

BL1.3.2

TSC



China NNSA

SNPAS HAF601
2012 submittal

Phase1 BL1.3.2

TSC

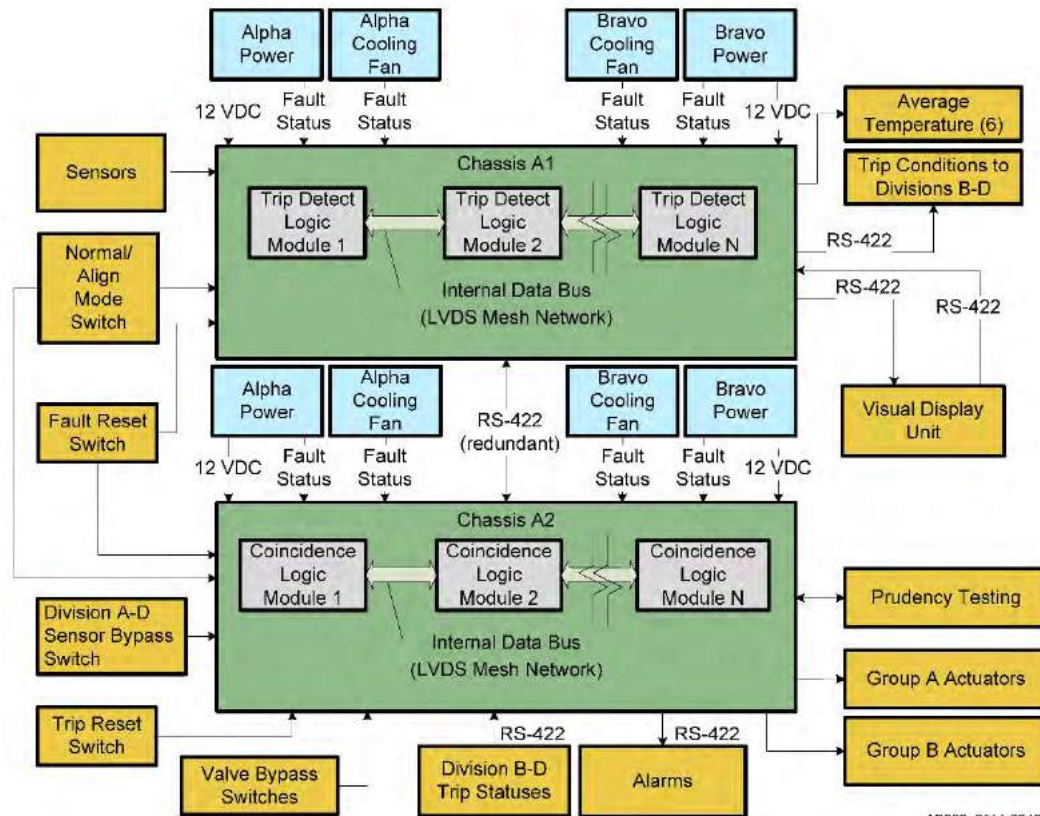
Phase2 BL2.0

Testkits

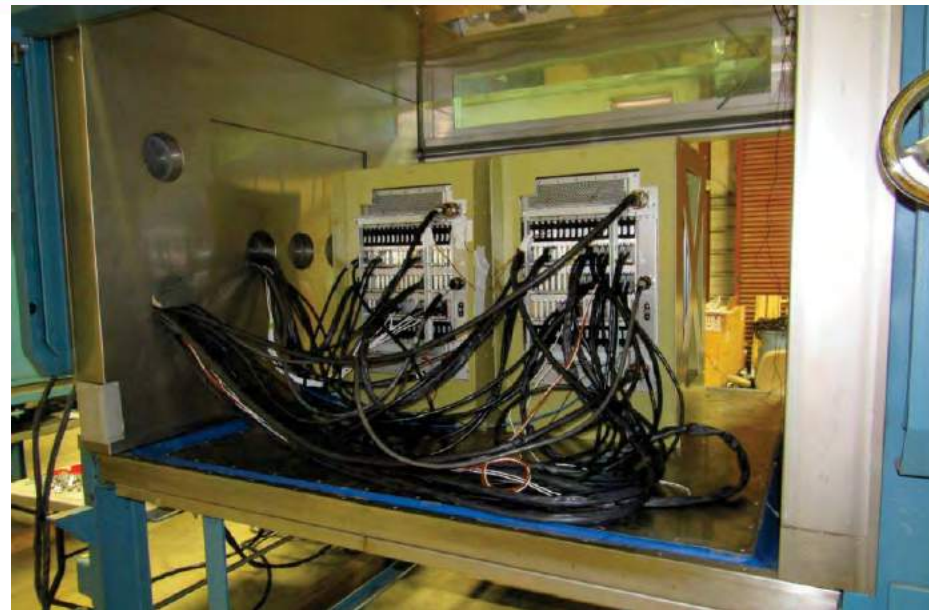
3. NuPAC Licensing

NRC TSC Architecture

U.S.NRC completed all technical reviews by May 2016 and released the Final SER by March 2017.



3. NuPAC Licensing



5 rounds
Requirements
updates

3 rounds
HW design
updates

4
Audits

6
LTR updates

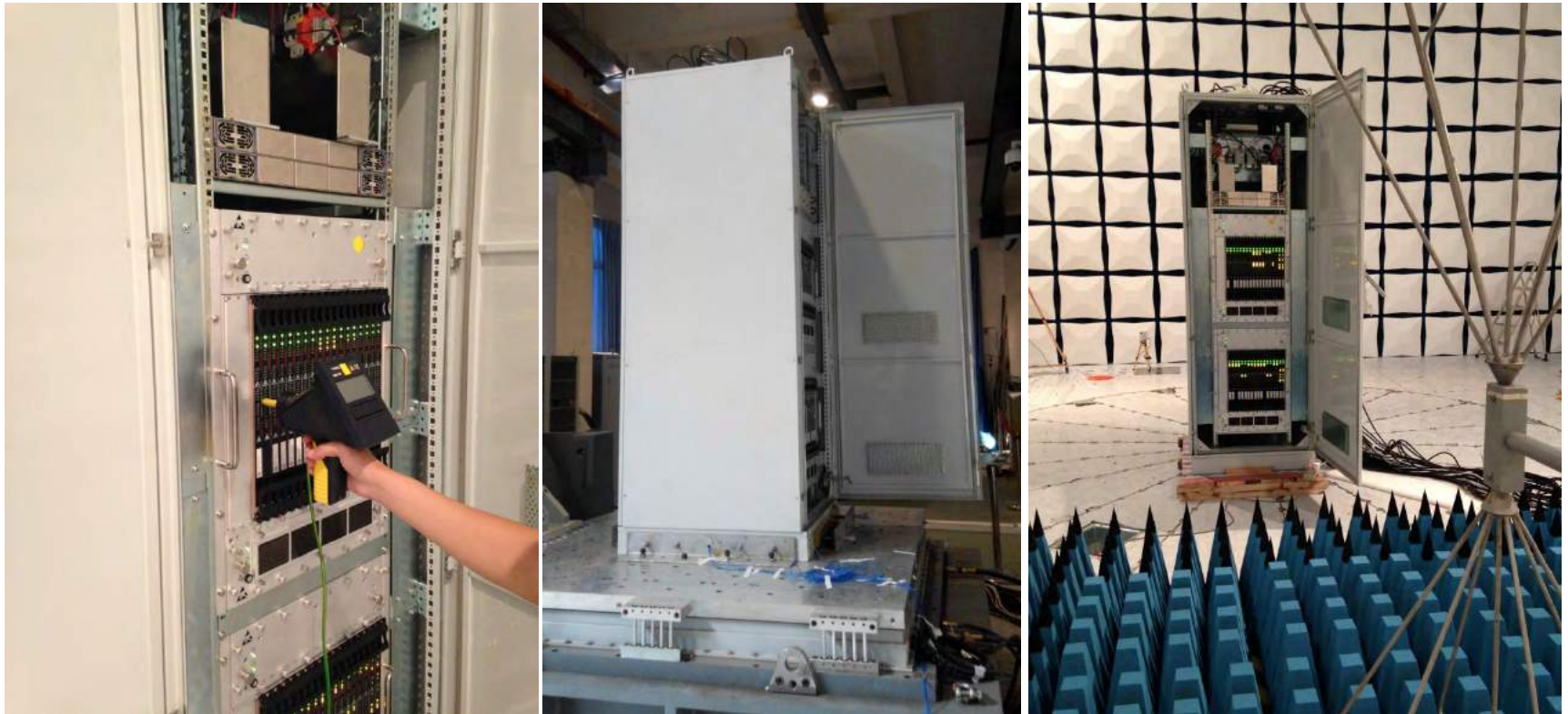
3. NuPAC Licensing

China NNSA HAF601 Approach

	NNSA Phase 1 TSC	NNSA Phase 2 TK
Platform HW Design	√	—
Hardware Manufacture	√	—
Core Programmable Logic	√	—
Equipment Qualification	√	√
Requirements Analysis	√ (TSC)	√ (RPS application)
System Design	√ (TSC)	√ (RPS application)
Detailed Design	√ (TSC)	√ (RPS application)
Integration and Testing	√ (TSC)	√ (RPS application)
Independent V&V	√ (TSC)	√ (RPS application)

NNSA phase 1 TSC architecture is similar to the U.S.NRC TSC, but added the cabinet and power supplies.

3. NuPAC Licensing

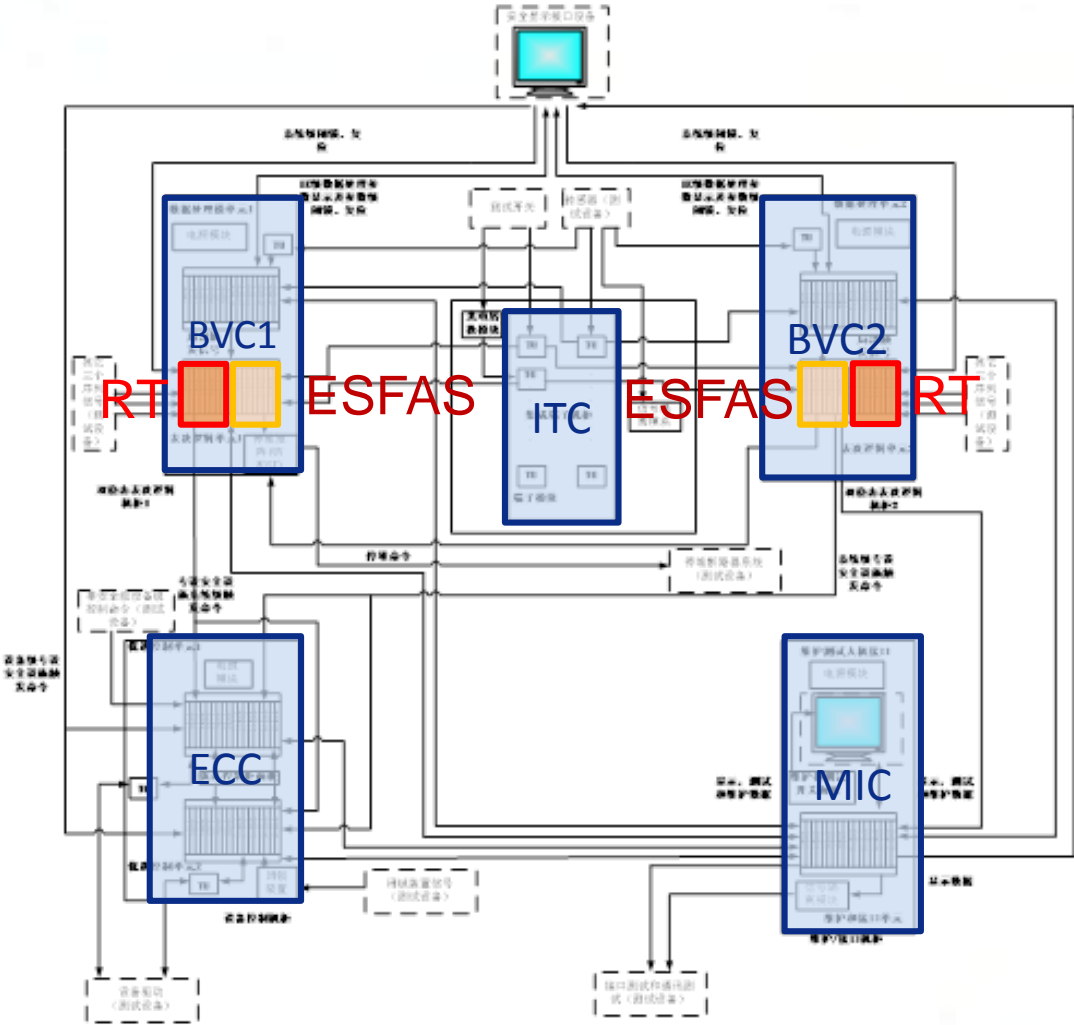


Nuclear and Radiation Safety Center and Northern Regional Office(NRO-NNSA) reviewed the NuPAC design documents and manufacture processes and made several audits including Equipment Qualification(EQ).

3. NuPAC Licensing

NNSA Phase 2 Test Kits

The first application is
based on AP/CAP1000
RPS division B.
5 typical cabinets



3. NuPAC Licensing



1. Background

2. NuPAC Development

3. NuPAC Licensing

4. RPS Application

Developed
based on
NNSA Phase 2
Test Kits



4. RPS Application

2013.6

TSC complete



2014.10

Testkits complete



2016.11

RPS complete



4. RPS Application

“Nu Series” Family



NuCON

控制系统平台

NuBAC[®]

多样化
驱动系统平台



NuPAC

新一代基于FPGA技术的
反应堆保护系统平台

NuSIM[®]

核电站
全范围模拟机

NuTEC[®]

核电站特殊监测系统
和地震监测系统

NuNIS[®]

堆内测量和堆外核测系统

NuRAD[®]

辐射监测系统

NuRIC[®]

棒控棒位系统

4. RPS Application



Rongcheng Plant



Bailong Plant



Zhanjiang Plant

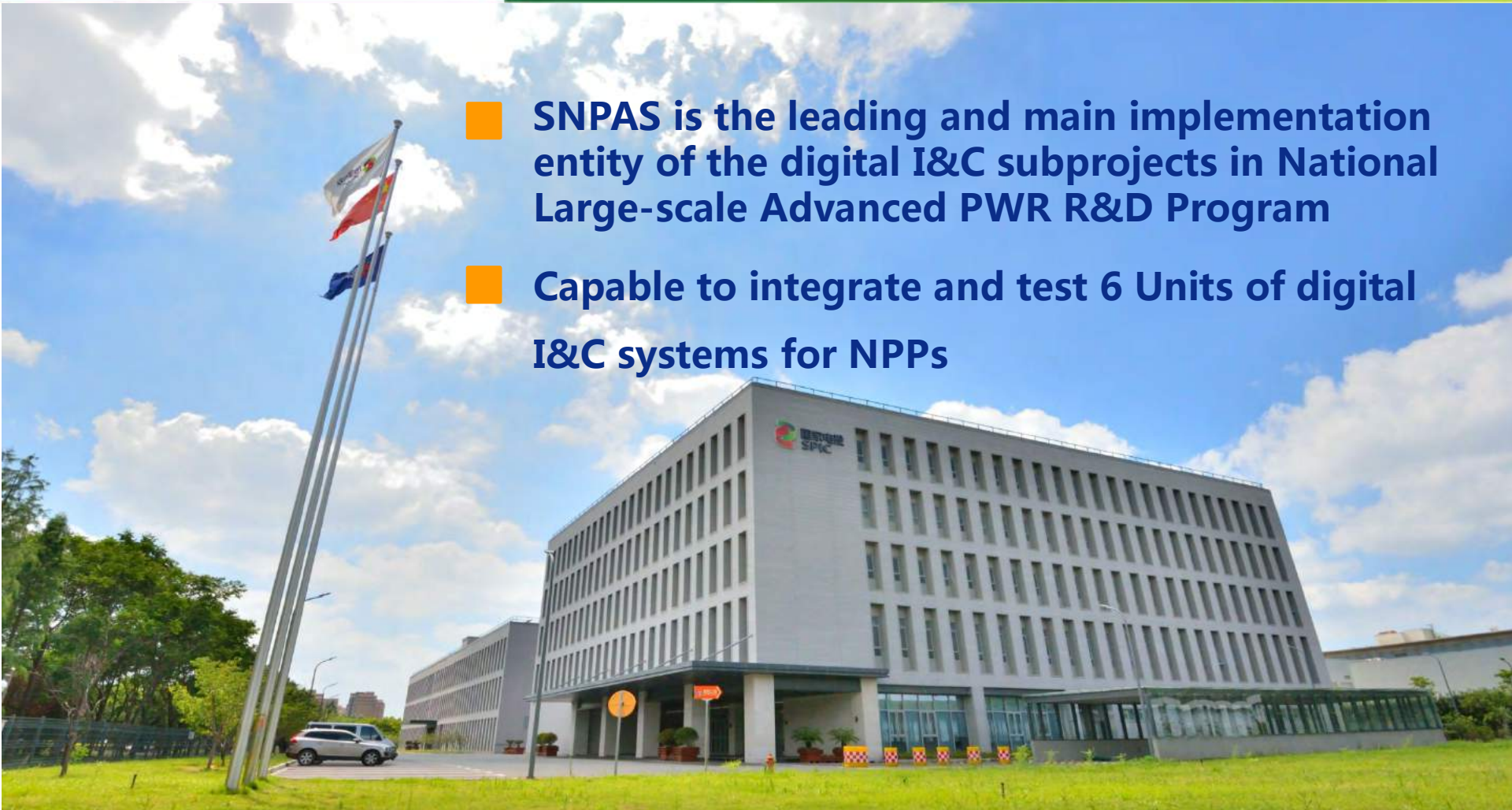


Haiyang Plant

The first Unit to use the NuPAC is CAP1400 Demonstration Plant in Rongcheng site. NuPAC will be used in future new build CAP1000+, CAP1400 and other type of nuclear power reactors.

4. RPS Application

- SNPAS is the leading and main implementation entity of the digital I&C subprojects in National Large-scale Advanced PWR R&D Program
- Capable to integrate and test 6 Units of digital I&C systems for NPPs



谢谢！
THANK YOU！