



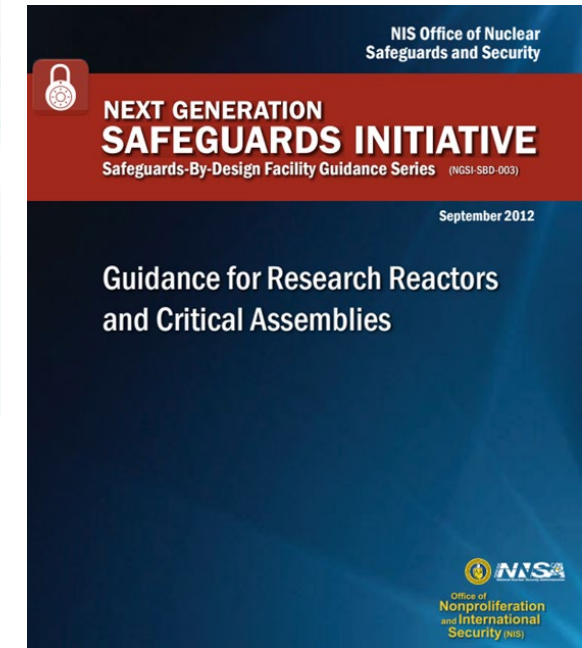
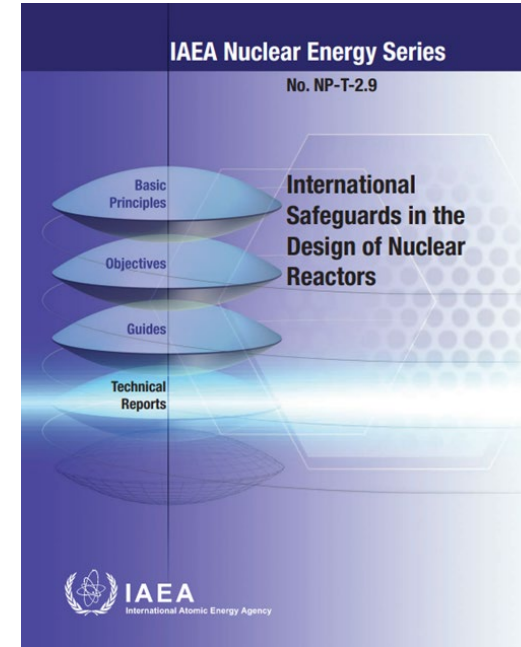
# **SOLO SAFEGUARDS & PHYSICAL SECURITY Design Requirements**

June 17 | USNRC HQ VideoConference

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# Background

- In our meeting of May 5 at NRC HQ, we presented the global scheme of the Terra Innovatum approach to International Safeguards & Safeguards by Design, detailing all different aspects of the project that may be subject to international safeguards and describing the different technologies that will be implemented in SOLO reactor in agreement with the applicable following guidelines and regulatory:
  - Design of Nuclear Reactors Guide series N0.NP-T-2.9 (IAEA Nuclear Energy Series) International Safeguards in the design of Nuclear Reactors
1. Next Generation Safeguards Initiative, Guidance for Research Reactors and Critical Assemblies (NNSA)



**In this meeting, we concentrate only to the Design Requirements of the SOLO Safeguards & Physical Security described in a Topical Report that will be submitted to NRC for review and approval.**

# SOLO Safeguards & Physical Security Guidelines Introduction

- The SOLO RTR microreactor uses LEU (<5% U-235). LEU fits into the definition of *Special nuclear material of low strategic significance* also referred to as *Category III* quantity of material
- The SOLO RTR microreactor uses LEU (<5% U-235) and is not subject to 10 CFR Part 74 Subparts D–E that apply to higher-risk special nuclear material, but adheres to Subpart B, “General Performance Requirements,” for MC&A compliance and Subpart C “Special Nuclear Material of Low Strategic Significance”
- Because SOLO will be licensed as a RTR and it is fueled by LEU several exemptions apply (e.g. cfr para 73.6)
- The Topical Report (TR) presents the guidelines that will be followed for SOLO reactor safeguards and security framework design, consistent with the regulatory requirements in **10 CFR Part 73** and in accordance with guidance provided in **NUREG-1537, Part 1, Chapter 12**.
  - The document is also briefly introducing a Global SOLO MMR overview with the selected method to verify the Fresh Fuel and consequently allowing the appropriate accountancy before the loading of the fuel inside the reactor.
- The safeguards program encompasses physical protection systems (PPS), insider threat mitigation, cybersecurity, and material control and accounting (MC&A).
- The goal is to ensure compliance with NRC regulations and guidance, including 10 CFR Part 73, and to provide a clear framework for the detection, delay, and response to unauthorized access or diversion of special nuclear material (SNM).

# Purpose & Scope

- The Topical Report outlines the **Design Requirements** for SOLO MMR in terms of:
  - **Physical security**
  - **Cybersecurity**
  - **Personnel reliability, Insider threat mitigation and emergency response interface**
  - **Material control and accounting (MC&A)**

as seen by TERRA INNOVATUM for the SOLO Micro-Modular-Reactor

These design requirements are submitted to NRC for evaluation and approval

# SOLO Defense in Depth guidelines for Physical Security

- The design philosophy for the Defense-in-Depth applicable to SOLO MMR as strategy and to deter and mitigate threats from both internal and external adversaries. The Physical Protection System (PPS) will meet the general performance objectives of §73.40 and the design guidelines of §73.55
- The key design principles adopted in the SOLO Micro Reactor are:
  - Integration with MC&A and cybersecurity programs
  - Early detection with reliable assessment capabilities
  - Layered barriers to provide sufficient delay for neutralization
  - Rapid armed response coordination with local law enforcement

# SOLO Defence in Depth guidelines for Physical Security

The design requirement document for SOLO MMR on DiD is addressing the :

- FACILITY ACCESS AND PERIMETER PROTECTION
  - DELAY MECHANISMS
  - CENTRAL ALARM STATION (CAS)
  - ACCESS AUTHORIZATION AND SCREENING
  - INSIDER THREAT MITIGATION & BEHAVIOR OBSERVATION AND PERSONNEL SCREENING
  - ACCESS LEVELS
- PLEASE NOTE THAT A DETAILED TR ON PHYSICAL SECURITY IS FORECASTED TO BE PRESENTED TO NRC IN 2025.
    - PHYSICAL SECURITY PLAN WILL BE ADDRESSED FOLLOWING RG 5.59
  - The PPS meets the general performance objectives of §73.40 and the design guidelines of §73.55 and 73.67, tailored to the SOLO reactor's threat environment, REF. 10 CFR Part 73, including § 73.56

Access Tier	Example Areas	Who Can Access	Controls
Tier 0: General	Lobby, offices, breakrooms	All staff, visitors with escort	Visitor badges, sign-in logs
Tier 1: Controlled Access	Control room (without controls), maintenance shop, non-SNM labs	Operations staff, maintenance, authorized researchers	Keycard or biometric badge, behavior observation
Tier 2: Protected Area	Reactor vault, SNM storage, instrumentation calibration room	Licensed operators, SNM custodians, security staff	Background check per §73.56, 2FA access, CCTV, logs
Tier 3: Vital Area	Reactor control interface, digital I&C systems, physical protection server room	Limited core team (OIC, cyber lead, security manager)	Dual authentication, escort requirement for others, full access log review
Tier 4: Safeguards Information Access	S&G records, cyber threat reports, detailed vulnerability assessments	Only S&G-cleared personnel	S&G training, document control logs, encrypted storage

# SOLO Cybersecurity Technical Control

To ensure the cybersecurity and physical protection of critical digital assets and systems associated with the SOLO Microreactor, the following technical controls will be implemented in accordance with NRC regulatory guidance (e.g., 10 CFR 73.54, RG 5.71, and NEI 08-09):

- Access Management & Authentication
- Role-Based Access Control (RBAC): Access will be limited based on user roles aligned with safety and security functions.
- Multi-Factor Authentication (MFA): Required for all access to safety-significant and safeguards-critical digital systems.
- Least Privilege Enforcement: All users are assigned only the minimum access rights necessary to perform their functions, reducing the potential for insider threats and misuse.

# Cybersecurity Technical Control

Network Protection and Segmentation will be implemented with:

- Air-Gapped Networks: Critical reactor control systems are physically separated from external and business networks to prevent remote access or cyber intrusion.
- Firewalls: Configured at network boundaries to control and restrict traffic between segmented zones based on security classification.
- Unidirectional Gateways (Data Diodes): Used to transmit operational data from the reactor control system to monitor environments while blocking any inbound communication.
- System Monitoring and Integrity & Controlled Remote Access & Data Security
- Security Logging and Audit Trails: All access to critical systems is logged and monitored.

# SOLO Lifecycle Management & Cybersecurity

*This table provides a summary of key cybersecurity topics as Guidelines expected to be implemented in the SOLO Microreactor technical controls and lifecycle management, aligned with applicable NRC regulations and guidance.*

- Security controls for the SOLO Microreactor will be sustained through a structured cybersecurity lifecycle program that integrates into system engineering, operations.
- The Design and Procurement of digital components follows a secure protocol for SOLO reactors through a validated supply chain, including vendor vetting and component verification.
- All the embedded firmware and software are scanned for vulnerabilities during acceptance testing of the I&C system selected for integration within the SOLO MMR.
- Selected I&C from qualified and licensed provider will be objective of a detailed Topical Report that will be transmitted to NRC later.

Topic	Description	Applicable Regulations / Guidance
Access Management & Authentication	RBAC, MFA, least privilege, user access control	10 CFR 73.54; NIST SP 800-53 (AC family); RG 5.71; NEI 08-09
Air-Gapped Control Systems	Physical separation of control networks from external networks	RG 5.71 Appendix B; NEI 08-09 Section 3.1
Firewalls & Network Segmentation	Control communication between segmented trust zones	10 CFR 73.54; RG 5.71 Section B.1; NIST SP 800-82
Unidirectional Gateways (Data Diodes)	Enforce one-way data flow for monitoring without exposing control systems	RG 5.71 Appendix B.2; NEI 08-09 Section 4.3.3
Jump Servers & Two-Person Integrity (2PI)	Controlled maintenance access with dual-person	NEI 08-09 Section 3.5.4; RG 5.71 B.1; 10 CFR 73.55
Security Logging & Monitoring	Centralized log collection, intrusion detection, audit trails	RG 5.71 Section B.1.14; NIST SP 800-92 ; NEI 08-09 Appendix D
Encryption & Data Protection	Protect data at rest and in transit	NIST SP 800-53 (SC-12 to SC-13); FIPS 140-2; RG 5.71 B.1.13
System Deployment & Baselines	Secure installation and configuration hardening	NEI 08-09 Section 4.2; RG 5.71 Section B.1.3
Patch & Configuration Management	Ongoing updates, drift prevention, change control	NEI 08-09 Sections 4.4 & 4.5; RG 5.71 B.1.6
Supply Chain & Procurement Controls	Vendor screening, firmware validation, secure sourcing	NEI 08-09 Section 4.1; RG 5.71 B.1.18
System Decommissioning	Secure removal of digital assets, sanitization of data	NIST SP 800-88; NEI 08-09 Section 4.6
Lifecycle Integration	Cybersecurity embedded throughout system lifecycle	10 CFR 73.54(a)(1); RG 5.71 Section C.3

# SOLO Personnel reliability, Insider threat mitigation and emergency response interface

The Trustworthiness and Reliability (T&R) applicable criteria to SOLO MMR are going to be implemented to ensure that individuals granted access to safeguards information (SGI), special nuclear material (SNM), or critical systems and areas at SOLO reactor are properly vetted and pose no undue risk to nuclear security.

The purpose of SOLO T&R determinations is to:

- Prevent insider threats
- Ensure only trustworthy and reliable individuals are granted unescorted access to Protected Areas, Vital Areas, or SGI
- Meet the regulatory requirements under 10 CFR Part 73 and 10 CFR Part 74

Element	Description
Background Check	Verification of identity, SOLO employment history, education, and criminal background.
Criminal History Review	Review of criminal history information obtained from FBI and state databases.
Behavioral Observation	Continuous monitoring by supervisors and peers for behavioral changes or red flags.
Access Authorization Program	Individuals must be part of an NRC-compliant access authorization program under 10 CFR 73.56.
Psychological Assessment	May include psychological testing or interviews as part of a Personnel Assurance Program (PAP), especially at higher category sites.
Drug and Alcohol Testing	Screening to individuals that must have access to the facility : periodically
Security Training	Individuals will complete training on security responsibilities, SGI handling, and reporting suspicious behavior.

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Regulation / Guidance	Relevance
10 CFR 73.56	Access Authorization Program requirements for nuclear facilities.
10 CFR 73.21 & 73.22	Safeguards Information protection and access restrictions.
NUREG-0800 (SRP), Ch. 13.1	Staff qualifications and training standards.
Regulatory Guide 5.66	Guidance for T&R evaluations for SGI access.
NRC Order EA-02-261	Security orders post-9/11 implementing interim compensatory measures.
NEI 03-01 (Rev. 3)	Template for access authorization program

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# SOLO Material Control and Accounting (MC&A) Guidelines

The MC&A program applied to SOLO will meet the requirements of 10 CFR Part 74 Subparts B & C. Given the LEU fuel, SOLO is not subject to the heightened requirements of Subparts D–E.

Let's remember that SOLO Microreactor is loaded with Fuel based on LEU that is retained within the reactor for a lifecycle forecasted to 15 years. During this period, no actions to replace the fuel are possible, and the fuel is sealed within the core structure which is in turn contained into the Integrated Radiological Containment.

However, the reactor has been conceived with access for Testing and R/D activities. This will be used only for radioisotopes production and no Fissile material or SNM will be inserted. The presence of the ex-core SOLO Real Time Core Monitoring (RTCM) will detect immediately and in real-time any variation of the gamma-neutron emissions generated by such materials

# SOLO Material Control and Accounting (MC&A) Guidelines

The SOLO MMR will not have any specific variation of the inventory of nuclear material referred to the fuel rods (embedded and sealed within the core and with no access) but any possible variation may be eventually related to the experimental activities that will be executed and for which we expect to eventually produce the Reporting and Inventory as well as the Measurements and Verifications but will not be anyhow Fissile or SNM material.

**Reporting and Inventory:** SOLO MC&A reports will be submitted via the NMMSS

- Form 741: Fuel receipts reported within 10 days may not be applicable
- Form 742: Annual material balance (required without Fuel movements)
- Form 742C: Physical inventory listing submitted post inventory

**Regulatory Basis:** The SOLO MC&A program is designed to meet requirements set in: 10 CFR Part 73; ANSI N15.8-2009 (R2022); NUREG/CR-5734, “MC&A System Evaluation Guide”; DOE/NRC NMMSS Reporting Requirements; ANSI N15.36-2021 (on NDA methodology to measure fissile materials)

For the Topical Report, would the Staff prefer to structure it as the example shown in the following slide?

# Example of one-to-one response to 10 CFR73 requirements

§ 73.40 Physical protection: General requirements at fixed sites.

*Each licensee shall provide physical protection at a fixed site, or contiguous sites where licensed activities are conducted, against radiological sabotage, or against theft of special nuclear material, or against both, in accordance with the applicable sections of this Part for each specific class of facility or material license. If applicable, the licensee shall establish and maintain physical security in accordance with security plans approved by the Nuclear Regulatory Commission.*

SOLO Addressing requirements of § 73.40

- SOLO fuel and the moderator is placed inside the IRC (pressurized vessel not accessible from the outside).
- a thick concrete structure (Monolith) surrounds the IRC aimed at protecting the environment from the reactor and the reactor from the environment.
- The fuel is not moved from the reactor because the fuel cycle is as long as 15 years.
- Physical security plan will be set in accordance with RG 5.59 (part II – SNM low strategic significance)

Thank you!

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