TERRA INNOVATUM SOLO™

WHITE PAPER

Transportation and Logistics for SOLO Research and Test Reactor deployment

(Non-Proprietary)

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None.

STANDARD TERMS, ACRONYMS, AND DEFINITIONS

For convenience Table 1 and Table 2 provide the definitions of common terms used in this section.

Table 1 - Definitions

Term	Definition
Import	Import to the United States
Individual shipment	a shipment consisting of one lot of freight tendered to a carrier by one consignor at one place at one time for delivery to one consignee on one bill of lading. This lot may consist of: (1) Only one item or (2) A number of containers all listed on the same set of shipping documents. This one lot of freight or "distinct" shipment can be transported on the same carrier with other distinct shipments containing the same items as long as each shipment is covered by separate sets of shipping documents.
License	a general or specific export or import license issued pursuant to this part
Licensee	a person authorized by a specific or a general license to export or import nuclear equipment or material pursuant to this part
Low-enriched uranium	uranium enriched below 20 percent in the isotope uranium-235
Graphite	Nuclear grade graphite for nuclear end use
Nuclear grade graphite for nuclear end use	graphite having a purity level better than (i.e., less than) 5 parts per million boron equivalent, as measured according to ASTM standard C1233-98 and intended for use in a nuclear reactor. (Nuclear grade graphite for non- nuclear end use is regulated by the Department of Commerce.)
Nuclear reactor	an apparatus, other than an atomic weapon or nuclear explosive device, designed or used to sustain nuclear fission in a self-supporting chain reaction
Packaging	one or more receptacles and wrappers and their contents, excluding any special nuclear material, source material or byproduct material, but including absorbent material, spacing structures, thermal insulation, radiation shielding, devices for cooling and for absorbing mechanical shock, external fittings, neutron moderators, non fissile neutron absorbers and other supplementary equipment

Table 2 – Acronyms

Term	Definition
CFR	Code of Federal Regulations
DOT	Department of Transportation
EPA	Environmental Protection Agency
FOAK	First-Of-A-Kind
FSAR	Final Safety Analysis Report
HALEU	High-Assay, Low-Enriched Uranium
IAEA	International Atomic Energy Agency
IMDG	International Maritime Dangerous Goods
IMO	International Maritime Organization
LEU	Low-Enriched Uranium
NEI	Nuclear Energy Institute
NEPA	National Environmental Policy Act
NRC	Nuclear Regulatory Commission
PHMSA	Pipeline and Hazardous Materials Safety Administration
QA	Quality Assurance
REP	Regulatory Engagement Plan
RG	Regulatory Guide
RSF	Required Safety Function
RTR	Research Test Reactor
SAR	Safety Analysis Report
SSR	Safety Standard Series
SSG	Specific Safety Guide

EXECUTIVE SUMMARY

Terra Innovatum is pursuing a construction permit and operating license for the SOLO RTR microreactor as a non-power RTR under Title 10 CFR Part 50, following the NUREG-1537 regulatory framework. To date, Terra Innovatum has engaged with the U.S. NRC through pre-application activities, as outlined in the previously submitted REP [1].

As detailed in the REP, Terra Innovatum is preparing white papers and several topical reports to support the licensing process. This white paper is developed to receive NRC guidance on the scope of NRC reviews to be secured and the eventual required engagements approval as part of the construction permit and operating license application for the SOLO RTR microreactor.

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Purpose and Scope

The initiative aims to evaluate the legal and regulatory frameworks governing:

- [[.]]
- [[.]]
- The risk analysis methodologies applicable throughout the transport and logistics chain.

Transport operations encompass all activities from packaging design and maintenance to loading, carriage, in-transit storage, unloading, and receipt at the final destination. The approach adheres to the US and International Atomic Energy Agency (IAEA) graded standards for routine, normal, and accident conditions of transport.

Regulatory Compliance

Key U.S. regulations include:

- 10 CFR Part 110 (Export and Import of Nuclear Equipment and Material)
- 10 CFR Part 71 (Packaging and Transportation of Radioactive Material)
- 10 CFR Part 20.1906 (Procedures for Receiving and Opening Packages)

Terra Innovatum seeks NRC feedback on the adequacy of its risk identification and compliance processes, the need for specific licensing, and recommended procedures for package handling at [[ ]] sites.

Transport and Logistics

- **Assembly Location:** [[

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- **Shipping Route:** [

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- **Final Delivery:** [

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Risk Assessment

A comprehensive risk assessment will address:

- Incident-free and accident scenarios for each transport phase
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- Use of established codes such as RADTRAN 6 for dose and accident risk calculations.
- Evaluation of both radiological and non-radiological risks, including worker exposure, accident probabilities, and public safety impacts.
- Consideration of previously approved or foreign-certified packaging designs to streamline regulatory acceptance.

Import Licensing and Regulatory Engagement

The import process will be evaluated under 10 CFR 110.43, ensuring the shipment does not threaten public health, safety, or national security. Terra Innovatum will present analyses to demonstrate compliance and is open to NRC recommendations regarding the licensing pathway and procedural requirements.

TABLE OF CONTENTS

1 INTRODUCTION

1.1 PURPOSE

SOLO RTR is expected to be produced in a factory and assembled on-site. [
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Terra Innovatum industrial strategy consists in using contract manufacturing model to assemble SOLO core across various industrial facilities [[.]]

SOLO RTR [[.]]

This paper is looking at evaluating the legal framework applicable to:

- [[.]]
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]
- the risk analysis framework applicable at the various steps of the transport and logistical process.

1.2 SCOPE

Transport comprises all operations and conditions associated with and involved in the movement of radioactive material, including the design, manufacture, maintenance and repair of packaging, the preparation, consignment, loading and carriage, including in-transit storage; and the unloading and receipt at final destination of loads of radioactive material and packages. A graded approach is applied to the performance standards in the IAEA Regulations, characterized by the following three general severity levels:

- routine conditions of transport (in incident-free conditions);
- normal conditions of transport (including minor mishaps); and
- accident conditions of transport.

1.3 APPLICABLE REGULATIONS AND REGULATORY GUIDANCE

10 CFR part 110 Export and import of nuclear equipment and material

10 CFR part 71 Packaging and Transportation of Radioactive Material

10 CFR part 20.1906 Procedure for receiving and opening packages

1.4 REQUESTS FOR NRC

Terra Innovatum is providing this white paper to the NRC to facilitate discussions regarding the SOLO RTR FOAK related transport and logistical operations.

Specifically, Terra Innovatum has the following goals for submitting this white paper and is requesting the following from NRC:

- To keep NRC informed of the process Terra Innovatum is following to identify and evaluate risks and maintain compliance with the international and US regulatory requirements.
- Based on the review of the contents of this white paper, and subsequent pre-application discussions, Terra Innovatum is requesting NRC feedback and observations on the approach and information discussed herein.

In addition, Terra Innovatum is looking for feedback from NRC on the following specific questions:

- Does NRC find the process described herein an acceptable way to identify risks related to the transport operations ?

- Does NRC find the process described herein an acceptable way to manage compliance with NRC regulatory requirements ?
- [[

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- Does NRC recommend to comply with 10 CFR 20.1906 procedures for receiving and opening packages at the construction site of the SOLO FOAK RTR ?
- Does NRC recommend to comply with operating controls and procedures defined in 10 CFR 71.85 and 10 CFR 71.87 at loading point [[ ] ?
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- [[

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2 PROPOSED ACTIONS

2.1 BACKGROUND

The cross borders transport of radioactive material is regulated by several levels (International, Regional, Countries, …) of instruments, laws and regulations including notably:

- IAEA SSR-6 Regulations for the safe transport of radioactive material.
- IAEA SSG-26 Advisory material for the IAEA regulations for the safe transport of radioactive material.
- IMDG code by the IMO
- European regulations including Euratom treaty.
- Title 10 of the CFR.
- Title 49 of the CFR.

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2.2 FOAK CORE REACTOR ASSEMBLED [[ ]]

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The engagements with regional and national regulatory bodies will be considered to ensure compliance notably with:

- European Agreement concerning the International Carriage of Dangerous Goods by Road.
- IMDG Code.
- Convention on the Physical Protection of Nuclear Material.
- Regulation 1493/93/Euratom of 8 June 1993 on shipments of radioactive substances between Members Sates.
- Directive 96/29/Euratom of 13 May 1996 laying down basic safety standards for the protection of the health of workers and the general public against the dangers arising from ionizing radiation.

2.3 SHIPPING BETWEEN [[ ]]

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The engagements with Federal, States and local regulatory bodies will be considered to ensure compliance notably with the safety and security regulations and directives of:

- The U.S. Department of Energy.
- The U.S. Department of Transportation.
- The U.S. Environmental Protection Agency.
- The US. Nuclear Regulatory Commission.

2.4 TRANSPORT BETWEEN [[ ]AND FIRST-OF-A-KIND ASSEMBLY SITE

The final selection of the site for the assembly of the First-Of-A-Kind remains to be confirmed. To that effect, the transport modalities (roads, rail, waterway) remain to be confirmed.

The engagements with Federal, States and local regulatory bodies will be considered to ensure compliance notably with the safety and security regulations and directives of:

- The U.S. Department of Energy.
- The U.S. Department of Transportation.
- The U.S. Environmental Protection Agency.
- The US. Nuclear Regulatory Commission.

3 IMPORT LICENSING CRITERIA ASSESSMENT

10 CFR 110.43 refers to the criteria applicable to the import licensing criteria:

"*The review of license applications for imports requiring a specific license under this part is governed by the following criteria:*

(a) The proposed import is not inimical to the common defense and security.

(b) The proposed import does not constitute an unreasonable risk to the public health and safety.

(c) Any applicable requirements of subpart A of part 51 of this chapter are satisfied."

[[ ]] is considered as covered by 10 CFR 110.43, we are planning to present an analysis:

- Confirming that the proposed import is not inimical to the common defense and security.
- Confirming that the proposed import does not constitute an unreasonable risk to the public health and safety.

4 OPTION TO UTILIZE A PREVIOUSLY APPROVED PACKAGE

It is our intention to evaluate the possibility to use a previously approved package design (as per 10 CFR 71.19) and/or a foreign approved package design (as per 10 CFR 71.21).

5 RISK ASSESSMENT APPROACH FOR TRANSPORT AND LOGISTICS

This section presents how we anticipate estimating both incident-free and accident risks associated with transportation in support of [[
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The risks assessment methodology will cover:

- [[

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This section also presents the methodology considered to estimate the potential impacts from severe radiological accidents for the shipments and discusses the results in terms of individual risk.

5.1 DESCRIPTION OF TRANSPORTATION ACTIVITIES

The following activities will be evaluated:

- [[

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Air transport has not been considered for these shipments, primarily because of the weight of [[
]] which would eventually make it uneconomical. Additionally, there are proven solutions to manage land and sea operations for fresh fuel. Previous NEPA evaluations have demonstrated that ocean transport is safe and would involve minimal environmental impacts (Figure 1).

[[

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5.2 RISKS ASSOCIATED WITH LOADING OF THE PACKAGE AT THE FACTORY

The company or its subcontractors would apply the procedures for preparing and loading packages as defined in 10 CFR 71.85 (Preliminary determinations) and §71.87 (Routine determinations).

The risk of both incident-free operations and potential site accidents will need to be analyzed.

The risk from incident-free loading operations would be estimated assuming that the number of personnel and length of time required for cask handling and inspection will be comparable to the same as those used in the existing fresh fuel assemblies transport, UF6 transport and spent fuel casks.

The potential for cask handling accidents during loading operations would need to be considered. No package handling accidents at loading site would be postulated that would involve situations more hazardous than those for which the packages were designed.

The non radiological risk of site operations will also be estimated using packages-handling information and fatality accident frequency statistics.

5.3 RISKS ASSOCIATED WITH INCIDENT-FREE MARITIME TRANSPORTATION

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5.4 RISKS ASSOCIATED WITH [[ ]]

This risk analysis will capture the potential impacts of a severe accident that involves [[
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The risk analysis for a [[ ]] under 10 CFR Part 71 employs a systematic evaluation of accident environments, containment integrity, and radiological consequences.

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5.5 RISKS ASSOCIATED WITH [[ ]]

The risk of both incident-free operations and potential [[ ]] accidents will need to be analyzed.

The risk from incident-free [[ ]] operations would be estimated assuming that the number of personnel and length of time required for cask handling and inspection will be comparable to the same as those used in the existing UF6 transport and spent fuel casks.

The potential for cask handling accidents during [[ ]] operations would need to be considered. No cask handling accidents [[ ]] would be postulated that would involve situations more hazardous than those for which the casks were designed.

The non radiological risk of [[ ]] operations will also be estimated using cask-handling information and fatality accident frequency statistics.

5.6 RISKS ASSOCIATED WITH TRUCK TRANSPORTATION IN THE USA

We are planning to evaluate the risks of incident-free transportation as well as accidents for all overland shipments using notably the RADTRAN 6 code (or similar code).

[[
]]for incident-free transportation risk, the RADTRAN 6 (or similar code) code would be used to calculate the dose and corresponding risk based on the external dose rate from the shipping vehicle, the transportation route and the population density along the route. However, for fresh fuel the dose rate should be negligible.

For accident transportation risk, RADTRAN 6 (or similar code) will also use states-specific accident rates and a conditional accident frequency-severity relationship that considers the route conditions (urban, suburban, rural).

The non radiological accident risks (fatalities resulting from potential transportation accidents) will also be calculated using RADTRAN 6 (or similar code).

We are planning to use the accident severity classification of NUREG-0170 [1].

An important determinant in transportation risk is the route, including its length, the states through which the route passes, and the population along the route. Representative routes for each of the shipments will selected notably using an adequate code (ex: WebTRAGIS). This code and other tools would allow to identify routes consistent with current routing practices and applicable routing regulations and guidelines, and identifies the population living within 0.5 mi of the route using 2000 U.S. Bureau of Census data.

5.7 RISKS ASSOCIATED WITH RECEIVING AND OPENING THE PACKAGE

Upon delivery of the package, the company would apply the procedures for receiving and opening packages as defined in 10 CFR 20.1906.

The risk of both incident-free operations and potential site accidents will need to be analyzed.

The risk from incident-free site operations would be estimated assuming that the number of personnel and length of time required for cask handling and inspection will be comparable to the same as those used in the existing fresh fuel assemblies transport, UF6 transport and spent fuel casks.

The potential for cask handling accidents during site operations would need to be considered. No cask handling accidents at assembly site would be postulated that would involve situations more hazardous than those for which the casks were designed.

The non radiological risk of site operations would also be estimated using cask-handling information and fatality accident frequency statistics.

5.8 COMPARISON OF IMPACTS

We plan to present a comparison of the potential human health risk for transportation of materials for SOLO nuclear core assembly and fabrication.

It will notably compare the potential impacts of selecting [[
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6 APPLICATION OF A RISK INFORMED METHODOLOGY FOR TRANSPORT ACTIVITIES IN THE US IF EXEMPTIONS REQUESTS WERE REQUIRED

In the case that we would identify the need to secure exemptions from the dose rate and containment criteria, we are considering leveraging on the determination made by the US NRC staff that a risk-informed methodology is appropriate for use in developing the safety basis for a Title 10 of the Code of Federal Regulations (CFR) Part 71 "Packaging and Transportation of Radioactive Material," application for a transportable microreactor similar to the U.S. Department of Defense Project Pele design [2].

DoD's Strategic Capabilities Office (SCO) tasked Pacific Northwest National Laboratory (PNNL) with developing the methodology to support potential exemption requests that may be necessary for demonstrating compliance with NRC's transportation regulations. SCO determined that the application for the transportation package would likely need to include exemption requests from the dose rate and containment criteria after evaluation of the tests for hypothetical accident conditions in 10 CFR Part 71 , "Packaging and Transportation of Radioactive Material."

The risk-informed methodology would consist of risk evaluation guidelines (F-C plots) and the systematic process to develop a demonstration probabilistic risk assessment (PRA). The risk evaluation guidelines would allow to assess the likelihood of bounding representative accidents and determines their radiological consequences and total effective dose equivalent to workers and the public. Additionally, the risk-informed methodology would describe the process to evaluate sensitivity analyses, sources of modeling uncertainty, defense in depth, and safety margins as part of the PRA.

The goal of the risk-informed methodology would be to inform the package design (or selection of an existing design previously approved by the NRC or of a foreign approved package) relative to the risk significance of containment and shielding features and to identify the need for compensatory measures during transportation.

7 REFERENCES

[1] Regulatory Engagement Plan Revision, LTR-TINN-25-007, Revision 1, June 2025.

[2] NRC (U.S. Nuclear Regulatory Commission), 1977, Final Environmental Statement on the Transportation of Radioactive Material by Air and Other Modes," vol. 1, NUREG-0170, Office of Standards Development, Washington, DC, December.

[3] U.S. NRC SECY-24-0062: Risk-Informed Methodology for a Future Transportable Triso-Based Micro-Reactor Package Application

8 APPENDIX

8.1 OTHER APPLICABLE FEDERAL REGULATIONS: DEPARTMENT OF TRANSPORTATION

- DOT 49 CFR subtitle B Chapter 1 Subchapter C part 173 subpart 1 Class 7:
    - 49 CFR subtitle B Other regulations relating to transportation
        - Chapter 1 Pipeline and Hazardous Materials Safety Administration DOT
            - Subchapter C Hazardous Materials Regulations
                - part 173 Shippers – General Requirements for shipments and packaging
                - Subpart I class 7 radioactive Materials
- DOT regulations in 49 CFR parts 107, 171 through 180, and 390 through 397, appropriate to the mode of transport

8.2 [[ ]]

The risks of incident-free transportation as well as accidents for all overland shipments will be calculated using the RADTRAN 6 code (or a similar code).

For incident-free transportation risk, the RADTRAN 6 code (or similar code) will be used to calculate the dose and corresponding risk based on the external dose rate from the shipping vehicle, the transportation route and the population density along the route.

For accident transportation risk, RADTRAN 6 (or similar code) will use country-specific accident rates and a conditional accident frequency-severity relationship that considers the route conditions (urban, suburban, rural).

The non radiological accident risks (fatalities resulting from potential transportation accidents) will also be calculated using RADTRAN 6 (or similar code).

8.3 GLOBAL COMMONS DESCRIPTION

The Atlantic Ocean is a critical global commons and the second-largest of Earth's four oceans, spanning 32 million square miles in an "S" shape from the Arctic to Antarctic regions between the Americas and Europe/Africa. With an average depth of 11,810 feet, its surface temperatures range from 32°F in polar zones to 82°F near equatorial regions (corrected from original 1°F, as equatorial waters typically exceed 77°F). The Atlantic supports vast economic activity, including some of the world's most productive fisheries on continental shelves off the British Isles, Iceland, Canada, and the northeastern U.S. Key commercial species such as herring, cod, haddock, mackerel, and tuna contribute to annual catches of millions of tons, while shellfish like scallops, clams, and menhaden support industries ranging from bait to omega-3 supplements. Beyond fisheries, the Atlantic's mineral resources include actively mined deposits of tin, iron ore, titanium, and rare-earth-bearing monazite, alongside polymetallic nodules on the seabed. The continental slopes harbor major petroleum reserves, with extensive fossil fuel extraction already underway, particularly in the Gulf of Mexico and North Sea. As the most heavily traveled ocean, it facilitates 20% of global maritime trade, with ports like New York and Rotterdam serving as hubs for transatlantic commerce and energy corridors.

The Mediterranean sea is a global commons area potentially impacted by the proposed action. The Mediterranean Sea is a semi-enclosed sea bordered by Europe, Africa, and Asia, connecting to the Atlantic Ocean through the 14-km-wide Strait of Gibraltar. It spans approximately 970,000 square miles (2.5 million km²) with an average depth of 4,900 feet (1,500 meters) and reaches its deepest point at 16,762 feet (5,109 meters) in the Calypso Deep. Surface water temperatures range from 54°F (12°C) in cooler northern regions to 82°F (28°C) in eastern and southern areas. The Mediterranean Sea is a vital economic hub, generating

significant revenue across multiple sectors. It contributes approximately $450 billion annually to the regional economy, making it one of the most economically productive marine areas in the world. Tourism is the dominant sector, accounting for 92% of the sea's economic output, with millions of visitors drawn to its coastal cities, islands, and cultural heritage sites each year. The Mediterranean is also home to an important fishing industry, valued at over $3 billion annually, with key species such as anchovies, sardines, and bluefin tuna supporting livelihoods across coastal communities. However, overfishing has placed 80% of fish stocks under threat, underscoring the need for sustainable practices to maintain this critical economic resource. The sea also plays a crucial role in global trade and transportation. It serves as a major shipping corridor connecting Europe, Asia, and Africa, with approximately 20% of global maritime traffic passing through its waters. Ports such as Marseille, Genoa, and Piraeus are vital logistical hubs for international commerce.

Additionally, the Mediterranean is rich in energy resources, including offshore oil and gas reserves that contribute to regional energy production and economic stability. These industries collectively make the Mediterranean an indispensable driver of economic activity and growth for the surrounding nations.

The approach will consist in evaluating the impacts – if any - of accidents on the social, economic and economic components of the global commons.

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8.5 SABOTAGE OR TERRORIST ATTACK RISKS

The assessment of potential acts of sabotage or terrorists attacks during transport will be conducted.

Safety features of transportation casks that provide containment, shielding, and thermal protection also provide protection against sabotage. [[

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Terra Innovatum will also continue to examine the protections built into its transportation system. Terra Innovatum would modify its methods and systems as appropriate based on the results of this examination to reduce the potential for sabotage or terrorist attack to be successful.

It is likely that companies with extensive experience [

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8.6 SAFEGUARD RISK MANAGEMENT APPROACH ON [[ ]]

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