Functional Interactions Among Safety, Security, and Safeguards (3S) for International Transport of Nuclear and Other Radioactive Material—Conflicts and Synergies

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ABSTRACT
In recent years, the need to achieve a better understanding of the interactions, interfaces, synergies, and potential conflicts among the three disciplines related to the transport of nuclear and other radioactive material—safety, security, and safeguards (3S)—has become increasingly recognized. Specifically, since the 9/11 terrorist attacks, there has been growing and significant emphasis worldwide on the need for enhanced security during the transport of nuclear and other radioactive material. Commensurate with this growing concern, it has been recognized that steps are needed to ensure that enhanced security during transport does not conflict with transport safety and transport safeguards and that the three work together to the greatest extent possible. In the United States, over the past decade, a series of training courses on transport security for nuclear and other radioactive material have been convened. These courses, which focus on both international transport and U.S. domestic transport, have been held at Argonne National Laboratory, under the auspices of the U.S. Department of Energy Packaging Certification Program (PCP). Recently, they have included addressing the interactions among transport 3S for shipments occurring within the United States. In preparation for a future training course focusing on international transport security, the assessment of transport 3S has been expanded to address the potential synergies and conflicts of 3S in the context of international requirements and measures.

Enhancing the understanding of these synergies and conflicts leads to potential benefits, including in the areas of regulatory compliance, design, operations, and economics during transport. Through a better understanding of the 3S interactions, steps can be taken to maximize the synergies and to minimize the conflicts. In the United States alone, significant potential cost savings could be derived for the 16 ongoing nuclear-material-related cleanup programs being performed by the U.S. Department of Energy, for which the entire life-cycle cost is forecast to be over U.S. $400 billion, with a significant portion of those costs projected to be related to transport.

In this paper, we show the principles and methodology that have been developed to address the 3S disciplines for international transport of nuclear and other radioactive material and apply them to International Atomic Energy Agency guidance, recommendations, and requirements documents for 3S. We identify synergies and conflicts that may exist for 3S during international transport and discuss how synergies can be enhanced and how conflicts might be resolved.

INTRODUCTION
Transport of nuclear and other radioactive material is an integral part of both the commercial nuclear fuel cycle and nuclear defense activities. Globally, about 20 million consignments of radioactive material are transported each year on public roads, railways, and ships. Around 5% of these are nuclear-fuel-cycle-related.[1] The total cumulative amount of used nuclear fuel that has been discharged worldwide is more than 400,000 tonnes of heavy metal (tHM), of which more than 100,000 tHM have been reprocessed. Thus, about 300,000 tHM are stored at or away from reactors in wet and dry storage facilities, awaiting recycling or disposal in a repository.[2]

In the U.S. alone, more than 3 million packages of radioactive materials are shipped each year by road, rail, air, or water.[3] Transport of nuclear waste is also required for cleaning up U.S. nuclear defense sites, and the bill for the entire life-cycle cleanup of those sites could be over $400 billion.[4] In 2019, the DOE reported that the Defense Environmental Cleanup will require expenditures of more than $250 billion at the remaining 16 sites to complete its ongoing mission.[5] The National Nuclear Security Administration estimates that up to four future shipments per week to the Waste Isolation Pilot Plant in New Mexico will be made during the dilution and disposal of 34 metric tons of weapons-usable plutonium.[6]

Safety, security, and safeguards (3S) are required for nuclear materials at facility sites and during transportation. All stakeholders, including designers, operators, carriers, shippers, and government authorities, could potentially benefit from synergies in the integration of the three disciplines. One reason why integrating 3S is both a necessity and a challenge is that when one of the three becomes a primary concern, the other two are affected and can produce new issues if conflicts are not addressed. The challenge has been characterized as demonstrating that "3S can provide more with less."[7]

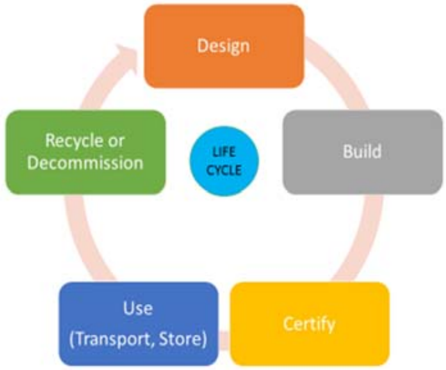
Historically, the emphasis has been on safety at facilities and during transport. Internationally [8] and domestically [9, 10], transport security has been given almost equal priority following the 11 September 2001 terrorist attacks in the U.S. But implementation of nuclear safety cannot be isolated from implementation of nuclear safeguards and nuclear security.[11] As more nuclear material has been put into use by more countries, national systems for material control and accounting (MCA) and international safeguards have received greater attention.[1] The interactions of the three disciplines—safety, security, and safeguards—have come to the attention of experts.

3S INFRASTRUCTURE

While the principles and applications of the transport 3S disciplines are well understood individually, the three generally have not been addressed collectively. Many published papers address two of the 3S requirements as pairs: safety and security, security and safeguards, or safeguards and safety. Some of these pairwise relationships lead to conflicts, and others lead to synergies. Determining interactions and seeking integration of 3S lead to a methodology and an infrastructure that provide the most effective and efficient design and operation for handling, storage, transfer, and shipment of nuclear material packages.

Figure 1(a) depicts the life cycle for packaging of nuclear and other radioactive material. Figure 1(b) depicts the separate disciplines of safety, security, and safeguards, their 2S paired interactions, and the 3S combined for nuclear packaging.

[1] In this paper, the term "safeguards" refers to international safeguards applied to national systems of material control and accounting (MCA) for nuclear material.



(a)

(b)

Figure 1. (a) Life cycle of packaging of nuclear and other radioactive material, and (b) 3S interactions, 2S interactions, and 1S for nuclear packaging

2S AND 3S INTERNATIONAL GUIDANCE

In a resolution enacted at the International Atomic Energy Agency (IAEA) 2002 General Conference, the IAEA adopted an integrated approach that includes physical protection and material accounting for transport of nuclear and other radioactive material, and recommended that security system designers consult with safety experts.[12]

The most frequent approach for interactions of the three disciplines has been to address safety and security only, sometimes including MCA in security. At the IAEA 2018 General Conference, a resolution was enacted that acknowledged the distinctions between safety and security, affirmed the importance of addressing their interfaces, and encouraged the IAEA to ensure the consistency of the terminology.[13]

Recently, the IAEA fostered a series of consultants' meetings which looked at how best to interface transport safety and transport security for both nuclear and other radioactive material.[14]

It is also common to address the 2S interactions between security and MCA, but not their interactions with safety. For example, for security purposes, detailed information about the transport of nuclear material should be protected as sensitive information until the movement is complete; however, this protection should not conflict with notification requirements for MCA.[15]

Other 2S pairings do not address one of the 3S disciplines:

- Recognized interactions between security and safety should address interactions with MCA. For example, it is recognized that nuclear security and safety considerations for transport of nuclear material should work in concert. In assessing the potential for sabotage, the safety features of the package and conveyance and the nuclear security measures to prevent unauthorized removal should work in concert. Facilities can benefit from a safety and security culture built and maintained for the management of safety/security interfaces.[16]
- Recognized interactions between physical protection and MCA should address interactions with safety. An in-depth defense of materials should take into account the ability of the physical protection system

and the MCA system to protect against both insider and external threats. These two disciplines together should also deter and detect the protracted theft of nuclear material by an insider.[17]

When building the capacity for nuclear security, there will be direct interfaces with nuclear safety and nuclear safeguards. In 2S interactions, basic capabilities may be the same; for example, using equipment to detect and identify nuclear and other radioactive material. Multiple professional competencies, based on education and experience, may be maintained by staff. It is most effective and efficient if the management system, procedures, and personnel take maximum advantage of shared capabilities, equipment, and resources and work together to achieve goals.[18]

A recent IAEA publication addressed interactions between nuclear MCA and nuclear security (2S) in production, processing, use, storage and movement. (Nuclear MCA should continue during off-site movement of nuclear material.) Using the appropriate administrative and technical measures ensures that nuclear material is not misused or removed without proper authorization. Control of nuclear material should be coordinated among all organizational units involved. Physical protection measures and MCA measures should be coordinated and should complement each other, and the same technical measures may serve both disciplines. The operator should assess and manage the interfaces to prevent adverse effects, and activities should be mutually supportive, to the extent possible.[19]

The IAEA Safety Standards Series documents have addressed both safety and security by noting that safety measures and security measures must be designed and implemented in an integrated manner so that one set of measures does not compromise the other.[20, 21] This series on safety measures further provides advisory material to help a consignor provide evidence that measures to meet requirements for safeguards and physical protection are complied with.[22] This series also extends to 3S interactions in "Principal Technical Requirement No. 8, Interfaces of Safety with Security and Safeguards," which states that 3S measures should be designed and implemented in an integrated manner so they do not compromise one another.[23]

The IAEA Nuclear Security Series documents have previously noted that for new nuclear facilities, site selection and design should take physical protection into account as early as possible and address the interface between physical protection, safety, and MCA to avoid conflicts and to ensure that all three elements support each other. More specifically, the safety features of the design of the transport package, container, and conveyance should be taken into account when deciding what additional physical protection measures are needed to protect the material against sabotage.[8] Subsequent reports in this series further noted the importance of addressing all 3S disciplines.[24, 25, 26]

There are interfaces among safety, security, and safeguards, including MCA, which should be coordinated during each phase of development of a nuclear power program, taking into account related requirements for each. In particular, the management system has a key role to play in reinforcing the interfaces and taking into account their commonalities and differences. For new facility site selection and design, 3S interfaces should be considered as early as possible to avoid any conflicts and to ensure complementarity.

Consignors and carriers of nuclear and other radioactive material should develop an integrated transport security plan. Safety during transport of nuclear and other radioactive material relies primarily on the performance of packages. It is the consignor's responsibility to ensure the appropriate selection of the packaging and the mode of transport.[27]

Focusing on safety, some IAEA standards recognize the importance of integrating 3S disciplines at the national authority level.[28, 29] U.S. Nuclear Regulatory Commission (NRC) national regulations 10CFR73.55 and 10CFR73.58 address the safety and security (2S) interface at nuclear power reactors, including a review of the security program and audit of the safety and security interface. For the transport of spent nuclear fuel, 10CFR73.38(b) sets a performance objective for personnel such that they do not constitute an unreasonable risk to public health and safety or the common defense and security. Under 10CFR73.38(c)(ii), when potential conflicts are identified, the licensee must notify licensee personnel and take actions to maintain safety and security.[10]

In addition, the NRC provides guidance for management of the 2S safety/security interface by nuclear power plant licensees, an important element for achieving the objectives of both safety and security. The licensee should address activities, including the handling, storage, and preparation for transport of spent nuclear fuel, that could compete or conflict. Procedures should be reviewed and should provide a means for resolving conflicting or competing safety and security interests. The licensee should also provide training to managers involved in the process of facilitating the interface between safety and security.[30]

Recognizing the need to achieve a better understanding of the interactions and interfaces among all 3S disciplines related to nuclear power, Argonne National Laboratory has developed a training series on Nuclear and Other Radioactive Materials Transport Security, which includes a module on how to address the interactions of safety, security, and safeguards to meet national and international requirements.[31, 32]

3S OBJECTIVES AND RISKS

A new paradigm is needed that addresses potential conflicts and synergies, starting with reconciliation of the objectives and risks for the three disciplines. Totally independent 3S systems are likely to introduce conflicts and duplication. It is therefore important that the objectives for the 3S disciplines be compatible and mutually supportive. Before defining an approach or methodology for analyzing 3S interrelationships, it is essential to identify a working definition of the corresponding threats and objectives.

The three main aspects of nuclear law for 3S are [33]:

- Safety: Preventing unintended conditions or events leading to radioactive releases from authorized use
- Security: Preventing intentional misuse of nuclear or other radioactive materials
- Safeguards: Preventing activities that could lead to the acquisition of nuclear weapons

These three aspects independently address the following three corresponding risks:

- Safety risk: Accident due to system failure, human error, or natural disaster.
- Security risk: Terrorism due to sabotage, external attack, or inside malicious act.
- Safeguards risk: Diversion or misuse of nuclear material for non-peaceful purposes.

Based on these risks, the objectives become:

- Safety: Protect people and the environment from radiation.
- Security: Protect nuclear and other radioactive materials and facilities from malevolent people.
- Safeguards: Protect people and the environment from malevolent people.

Collectively, the overall objective is protection of human life, health and the environment. Each of the 3S disciplines must be designed and implemented in an integrated manner so that the collective and individual objectives are harmonized.

PRINCIPLES FOR A SYSTEMATIC METHODOLOGY TO DETERMINE 3S INTERACTIONS

Given these three risks, the corresponding objectives, and a collective overall objective, a set of basic principles and a systematic methodology for determining 3S interactions are needed for identifying 3S conflicts and synergies. Two basic principles for determining conflicts and synergies are based on the need for two types of access for the 3S disciplines:

1. *Access to nuclear material information*: All three disciplines (safety, security, and safeguards) require access to nuclear material information on occasion. Sharing this information to the extent possible (rather than collecting and compartmentalizing it) can lead to synergies that result in greater effectiveness and efficiency for each discipline. However, conflicts can occur over sharing information because of its sensitivity, particularly that related to proprietary information or physical security regarding quantity, type, location, and transport of nuclear material.

2. *Access to nuclear material*: All three disciplines also require access to nuclear material on occasion. Synergies can occur when access to nuclear material for purposes of measurement or inspection (for example, for safety and safeguards) is shared. On the other hand, conflicts can occur when safety and security disciplines restrict or control physical access to nuclear material, but safeguards require access to verify nuclear material.

A SYSTEMATIC METHODOLOGY FOR DETERMINING 3S INTERACTIONS

This methodology was originally presented in the context of international safeguards requirements INFCIRC/153 and INFCIRC/540, and then compared to U.S. domestic transport safety and security requirements to determine potential conflicts and synergies.[34] Later, this approach was presented starting with 10CFR71 [35], with subsequent comparison to domestic security and MCA requirements.[36] A good example to enhance 3S is the smart-drum technology developed by Argonne for the DOE PCP to monitor the "state of health" of radioactive and other hazardous materials during transport and storage.[37]

The approach presented here extends the use of this methodology to international requirements and measures for transport safety, security, and safeguards. It starts with identifying international transport safety requirements and measures, and then compares each generally to international requirements and measures for transport security and transport safeguards to determine potential conflicts and synergies.

The international requirements and measures used in this methodology are given in the following documents:

For transport safety:
- IAEA SSR-6 (Rev. 1) (2018 edition) [Recommendations] [21];

For transport security:
- The Convention on the Physical Protection of Nuclear Material (CPPNM) [40] and
- The Amendment to the CPPNM [39];

For transport safeguards:
- IAEA INFCIRC/153 (Corrected) [Negotiating Basis for Safeguards Agreements] [40] and
- IAEA INFCIRC/540 [Model Protocol Additional to Safeguards Agreements] [41].

Table I shows the results of applying the two principles and associated methodology, starting with the set of international transport safety requirements and measures, and then generally comparing these to international requirements and measures for transport security and safeguards to identify potential conflicts (C) and synergies (S). Table I provides insight on where conflicts need to be avoided and where synergies can be realized. This insight then can be applied to transport and storage of packages of nuclear material.

Some requirements and measures entail only a minor 3S consideration (denoted by N/A for "none apparent"). The more specific a requirement is, the clearer the degree of conflict or synergy. A key factor for each 3S discipline is the technology (equipment and procedures) used for purposes of safety, security, or safeguards.

Determining the potential for conflicts and synergies at this level has a subjective element, which makes it all the more important that international transport experts in each of the 3S disciplines apply this methodology jointly. Note that a similar but less subjective table, representing a more complex application, could be generated by comparing specific articles of each of the three sets of international requirements and measures to determine the more specific nature of conflicts and synergies.

Table I. Interactions Leading to Potential 3S Conflicts (C) and Synergies (S) under Requirements and Measures for International Transportation of Nuclear Material
(N/A means none apparent)

Safety Requirements/Measures	Security	Safeguards	Comments
Topic 1: Basis of Requirements in International Regulatory Documents			
SSR-6/§101: <u>Basis of Requirements</u> – Background and basis for SSR-6: SSR-6 (Rev. 1) (2018): This IAEA Specific Safety Standards Requirements document establishes standards of safety for the control of the radiation, criticality, and thermal hazards to people, property and the environment that are associated with the transport of radioactive material, including the transport of fissile (nuclear) material These standards are made mandatory through actions by international and regional modal authorities and by individual IAEA Member States.	N/A	N/A	The CPPNM and Amendment and the IAEA Safeguards Agreement (based on INFCIRC/153 and INFCIRC/540) are legally binding upon signature by a State.
Topic 2: Sources of Recommendations/Guidance in International 3S Regulatory Documents			
SSR-6/§102: SSR-6 is supplemented by multiple safety guides.	N/A	S	The IAEA has been careful to avoid conflicts when developing requirements and recommendations.
Topic 3: Definitions in the International 3S Regulatory Documents			
SSR-6/§§206, 210, 212: <u>Definitions of Carrier, Consignee and Consignor.</u> **SSR-6/§207:** <u>Definition of Competent Authority.</u> **SSR-6/§§211 and 237:** <u>Definitions of Consignment and Shipment.</u>	C/S	S	Definitions generally are consistent, but a potential conflict exists for the terms "fissile material" (safety) and "nuclear material" (security and safeguards).

Safety Requirements/Measures	Security	Safeguards	Comments
Topic 4: Objectives/Purposes/Goals of the International 3S Regulatory Documents			
SSR-6/Foreword: A comprehensive set of high-quality standards under regular review is a key element of a stable and sustainable global transport safety regime. **SSR-6/§104:** The objective of SSR-6 includes establishing requirements to ensure safety and to protect people, property, and the environment from harmful effects of ionizing radiation during transport of radioactive material. This objective is achieved by: (a) containment of radioactive contents, (b) control of external dose rates, (c) prevention of criticality, and (d) prevention of damage caused by heat.	S	S	The individual and collective objectives are consistent for protection of persons, property, and the environment.
Topic 5: Responsibilities for Applying Provisions of the 3S Regulatory Documents			
SSR-6/§103: Responsibility for transport safety actions is not assigned in SSR-6. Since responsibility may vary according to the laws and customs of different countries (Member States) and international conventions and agreements, each government has the prerogative to assign responsibilities.	S	S	There may be none or multiple State Authorities for a single discipline.
Topic 6: Compliance with the International 3S Regulatory Documents with Respect to the Need for Appropriate Cultures and Regimes			
SSR-6/Foreword: <u>Regime</u> – A comprehensive set of high-quality standards under regular review is a key element of a stable and sustainable global transport safety regime. **SSR-6/Foreword:** <u>Culture</u> – The IAEA's safety services include, for the safe transport of radioactive material, having a sound safety culture in organizations. **SSR-6/§105:** <u>Management systems</u> – Confidence in compliance with SSR-6 is achieved through management systems and compliance assurance.	S	S	Though "safeguards culture" is not explicitly defined, management cultures exist for all 3S.
Topic 7: Applying a Graded Approach in the International 3S Regulatory Provisions			
SSR-6/§104: SSR-6 provides recommended transport safety requirements that follow a <u>graded approach</u> and which are directed toward the protection of people, property, and the environment from the harmful effects of ionizing radiation during the transport of fissile (nuclear) material. Protection is achieved by requiring: (a) Containment of the radioactive contents; (b) Control of external dose rate; (c) Prevention of criticality; and (d) Prevention of damage caused by heat.	S	S	Graded approaches are explicitly identified for safety and security. The safeguards graded approach is implicit in safeguards requirements.

Safety Requirements/Measures	Security	Safeguards	Comments
The graded approach is applied for fissile (nuclear) material transport to: (a) Contents limits for packages and conveyances; (b) Performance standards that are applied to package designs depending upon the hazard posed by the fissile (nuclear) material contents; (c) The design and operation of packages; (d) Requirements applied to administrative controls; and (e) Planning and preparing for emergency response. **SSR-6/§106:** The graded approach is applied in SSR-6, which is characterized by three levels of transport operations: (a) Routine conditions (incident-free), (b) Normal conditions (minor mishaps), and (c) Accident conditions.			
Topic 8: Applying the Defense-in-Depth Concept in the International 3S Regulatory Provisions			
IAEA Safety Glossary (2016 Revision): Defense in depth is explicitly defined. Although the IAEA transport safety documents are silent on defense in depth, that topic is implicitly applied throughout the transport safety regulations through the application of multiple, overlapping and complementary safety measures as specified in SSR-6.	S	S	Safety and security documents address defense in depth. Safeguards documents apply defense in depth without explicitly defining the concept.
Topic 9: Activities Addressed in, and Mandatory Compliance with, Relevant International 3S Transport Regulatory Documents			
SSR-6/§106: Compliance with international transport safety regulatory documents – SSR-6 applies to the transport of radioactive material by all modes on land (road and rail), water (inland waterways and maritime), and air; and during all operations and conditions, including design, manufacture, maintenance and repair of packaging, preparation, consigning, loading, storage, shipping, unloading, and receiving.	S	S	Compliance with safety standards is legally mandatory when they are adopted. Compliance with security and safeguards requirements is legally binding when they are signed.
Topic 10: Activities/Functions Not Addressed in the International 3S Transport Regulatory Documents			
SSR-6/§108: Controls for transport security are not addressed – SSR-6 does not specify controls such as routing or physical protection instituted for other reasons. **SSR-6/§107:** Some radioactive (fissile) materials are excluded from transport safety regulatory controls.	S	S	Safety, security, and safeguards documents are mutually exclusive; hence, they avoid conflict.

Safety Requirements/Measures	Security	Safeguards	Comments
Topic 11: Provisions for Ensuring Safety, Security and/or Safeguards Interfaces in the International 3S Transport Regulatory Documents			
SSR-6/Introduction: Measures for transport safety and security should be coordinated – Safety measures and security measures have in common the aim of protecting human life and health and the environment. Safety measures and security measures must be designed and implemented in an integrated manner so that security measures do not compromise safety and safety measures do not compromise security. **SSR-6/§109:** Measures for transport security – Measures should be taken to ensure that radioactive material is secure in transport to prevent theft or damage.	C/S	C/S	The safety, security, and safeguards documents each recognize the existence of potential conflicts and the need to take measures to avoid conflicts.
Topic 12: Training Provisions in the International 3S Transport Regulatory Documents			
SSR-6/§311: Radiation training – Workers shall receive radiation protection training. **SSR-6/§312:** Regulatory training – Persons engaged in transport of fissile material shall receive training on transport safety regulations. **SSR-6/§§313, 315:** Worker training – Persons directly involved in transport of fissile material shall receive training in awareness, functions, and safety. **SSR-6/§314:** Training records shall be maintained. **SSG-6/§§311.1–315.1:** Radiation training – Only appropriately trained persons should be engaged in transport of fissile material.	S	N/A	Training for safety and security is mutually consistent. The safeguards documents do not address training for the State or the IAEA.
Topic 13: Radiation Protection in the International 3S Transport Regulatory Documents			
SSR-6/§302: A radiation protection programme shall be established. **SSR-6/§301:** Radiation doses to persons shall be below the relevant dose limits. **SSR-6/§303:** Occupational radiation protection measures shall follow a graded approach. **SSR-6/§§307, 308:** Periodic radiation dose assessments shall be arranged. **SSR-6/§§617, 648, 659:** Strict controls on radiation levels external to a package are imposed.	S	S	Safety, security, and safeguards documents are consistent regarding the need for radiation protection.
Topic 14: Radiological Emergencies, Preparedness and Response in the International 3S Transport Regulatory Documents			
IAEA Safety Glossary: Definition of an Emergency. **SSR-6/§304:** Radiological Emergency – National and international provisions shall be observed.	S	S	Emergency planning for safety, contingency planning for security, and safeguards activities during radiological

Safety Requirements/Measures	Security	Safeguards	Comments
SSR-6/§304: Nuclear or radiological doses to persons – *Consignors* and *carriers* shall establish arrangements for preparedness and response. **SSR-6/§305:** Emergency preparedness and response – Arrangements shall be based on the graded approach and shall consider the identified hazards and their potential consequences.			emergencies are consistent.
Topic 15: Transport Operational Controls in the International 3S Regulatory Documents			
SSR-6/§§517–522: Controls for IF packages. **SSR-6/§§244, 523–524A, 573, 575, 579 and Table 10:** Controls on external dose rates. **SSR-6/§§218, 525–528, 567–569, 686 and Table 11:** Controls on criticality safety. **SSR-6/§§529–543:** Controls on marking, labeling and placarding. **SSR-6/§§545–561, 584–588:** Controls on consignors and carriers. **SSR-6/§§562–570:** Controls on segregation, storage and stowage of fissile (nuclear) material in transit. **SSR-6/§582:** Controls on customs operations. **SSR-6/§583:** Controls on undeliverable packages.	C/S	C/S	Certain operational measures are required for each 3S discipline. However, the availability and communication of certain operational information may cause conflicts.
Topic 16: Management System: Compliance Assurance, Quality Assurance and Quality Control in the International 3S Transport Regulatory Documents			
SSR-6/§228: Management systems. **SSR-6/§306:** Management systems. **SSR-6/§§307 and 308:** Compliance. **SSR-6/§§501–503:** Ensuring proper controls on packagings. **SSR-6/§§504 and 505:** Compliance with package contents. **SSR-6/§309:** Non-compliance – In the event of non-compliance, the appropriate organization shall inform, mitigate, investigate, remedy, and communicate the non-compliance. **SSR-6/§§310 and 434:** Special Arrangements.	C/S	C/S	A high level of assurance is required for each 3S discipline. However, the 3S documents do not address the same quality and compliance program features for each 3S discipline.
Topic 17: Measures and Controls Based on Characteristics, Radioactivity, Mass-levels, and Risks in the International 3S Transport Regulatory Documents			
SSR-6/§401 and Tables 1 and 3: Controls with UN Numbering. **SSR-6/§§402–407 and Tables 2 and 4:** Controls on form of radioactivity. **SSR-6/§§408–420 and Table 1:** Controls on Material Classification. **SSR-6/§§421–420, 813, 832 and Table 4:** Controls on Package Classification.	C/S	C/S	Measures for each 3S discipline are based on material characteristics, which are categorized differently for each material and discipline.

Safety Requirements/Measures	Security	Safeguards	Comments
Topic 18: Operational Controls, Transport Control Centres in the International 3S Transport Regulatory Documents			
SSR-6/§§501–503: Controls on packagings. **SSR-6/§§530–537, 547:** Controls through communications with markings of packages. **SSR-6/§§538–542, 547:** Controls through communications with labeling of packages. **SSR-6/§§543–544, 547, 561, 571, 572:** Controls through communications with placarding. **SSR-6/§§546–553, 561:** Controls through communications with documentation on a consignment. **SSR-6/§§554–556:** Controls through communications with carriers. **SSR-6/§§557–560:** Controls through communications with competent authorities. **SSR-6/§§802, 805–807, 814–816, 825–826, 829–831:** Competent authority's controls.	C/S	C/S	Much of the information relevant for each 3S discipline is the same. However, some of the information needs to be readily available, but some of it may be sensitive.
Topic 19: Materials Control and Accountability in the International 3S Transport Documents			
MCA provisions are not included in the transport safety regulations.	C/S	C/S	Safety documents do not address MCA. Security and safeguards documents address MCA.
Topic 20: Roles of Competent Authorities: Approvals and Oversight in the International 3S Transport Regulatory Documents			
SSR-6/§§802, 805–807, 814–816: Competent authorities issue multilateral approvals of package designs and excepted fissile (nuclear) material. **SSR-6/§§825–826, 829–831:** Competent authorities issue multilateral approvals of shipments of fissile (nuclear) material. **SSR-6/§§832–839:** Competent authorities issue certification of competent-authority approval. **SSR-6/§840:** Competent authorities may issue validation certificates.	C/S	C/S	National authorities play an important enforcement role. There may be none or multiple authorities for a single discipline.
Topic 21: Controlling Contamination, Leakage and Subcriticality of Nuclear Material in the International 3S Transport Regulatory Documents			
SSR-6/§§508–509, 513–514: Controls on contamination. **SSR-6/§§511–513:** Controls on leakage. **SSR-6/§§617, 648, 659:** Controls on release of fissile (nuclear) material. **SSR-6/§632:** Controls on release of uranium hexafluoride. **SSR-6/§§673, 674:** Controls on criticality safety in the event of release of fissile (nuclear) material.	C/S	C/S	Control of material is essential for all 3S. The IAEA is required to respect safety and security measures when carrying out safeguards requirements for verification.

Safety Requirements/Measures	Security	Safeguards	Comments
SSG-26/§510.2: Controls on leakage from damaged packages.			
Topic 22: Controls for Small Quantities of Nuclear Material in the International 3S Transport Regulatory Documents			
SSR-6/§§516–519: Controls for excepted package. **SSR-6/§§417, 606, 622, 636, 619–621:** Controls on excepted fissile (nuclear) material.	C/S	C/S	All 3S address measures for small quantities, but these measures may vary.
Topic 23: Physical Controls of Nuclear Material in the International 3S Transport Regulatory Documents			
SSR-6/§§607–621, 623–672: Controls on packaging of fissile (nuclear) material for transport. **SSR-6/§637:** Control to indicate package seal integrity during transport. **SSR-6/§§564, 576, 638, 809, 836, 838:** Controls on package retention/stowage during transport and storage during transport. **SSR-6/§§673–685:** Specific controls on transport and packaging of fissile (nuclear) material. **SSR-6/Sections 6 and 7:** Controls on tests for fissile (nuclear) material packages.	C/S	C/S	Physical control of material by a State is mutually beneficial for all 3S disciplines. Each State has sole responsibility for material for which there may be variations in 3S measures among the States.
Topic 24: Inspection Requirements in the International 3S Transport Regulatory Documents			
SSR-6/§302: Program documents shall be available for inspection by the relevant competent authority. **SSR-6/§306:** The manufacturer, *consignor* or user of fissile (nuclear) material transport packages shall provide facilities for inspection during manufacture and use of these packages. **SSR-6/§503:** Before each shipment, compliance shall be ensured by inspection or testing. **SSR-6/§582:** Where customs inspections are required, inspections shall be carried out only where adequate control of radiation exposure is provided. **SSR-6/§713:** Specimens used to demonstrate compliance shall be inspected before the testing.	C/S	C/S	IAEA conducts safeguards inspections based on an internationally accepted standard that is legally binding. Safety and security requirements may vary from State to State, as there is no requirement for inspection by an independent international body.
Topic 25: Administrative Requirements and Controls in the International 3S Transport Regulatory Documents			
SSR-6/§501: Before packaging is used, conformance with design specifications is confirmed. **SSR-6/§§502, 503:** Before shipment, conformance with certificate of compliance is ensured. **SSR-6/§§525, 526, 566, 567:** Criticality safety index (CSI) determination. **SSR-6/§§530–553, 571:** Package, freight container, and vehicle marking.	C/S	C/S	Administrative controls are widely standardized in safeguards documents and include measures to ensure consistency with safety and security. However, practices may vary from State to State depending on

Safety Requirements/Measures	Security	Safeguards	Comments
SSR-6/§§554–555: The consignor shall provide transport documents to the carrier. **SSR-6/§557:** Before shipment, competent-authority certificates are submitted to the competent authorities of each country where the shipment is transported. **SSR-6/§558:** Before shipment, the competent authority of each country is notified. **SSR-6/§§568, 569:** Storage in transit of groups of packages is limited by the sum of CSIs.			circumstances, particularly regarding availability and sensitivity of information and the manner by which a State applies IAEA safety and security regulatory documents.
Topic 26: Application of Relevant Regulations for Subsidiary Hazards Associated with the Other Classes of Dangerous Goods in the International 3S Transport Regulatory Documents			
SSR-6/§110 Scope: <u>Measures for addressing subsidiary hazards of fissile (nuclear) material in transport.</u> **SSR-6/§§506–507**: <u>Measures for segregating fissile (nuclear) material from other dangerous goods.</u> **SSR-6/§§110, 507, 618**: <u>Measures for addressing other dangerous properties of fissile (nuclear) material in transport.</u>	N/A	N/A	Only safety documents address hazards associated with other classes of dangerous goods.
Topic 27: Basic Structure of the International 3S Transport Regulatory Documents			
SSR-6/§111: SSR-6 consists of eight sections: I. Introduction II. Definitions III. General Provisions IV. Activity Limits and Classification V. Requirements and Control for Transport VI. Requirements for Radioactive Material and for Packagings and Packages VII. Test Procedures VIII. Approvals and Administrative Requirements It also contains three Annexes: • Summary of Approval and Prior Notification Requirements • Conversion Factors and Prefixes • Summary of Consignments Requiring Exclusive Use	C/S	C/S	The structures of the documents for safety, security, and safeguards differ, but the contents of the documents address the same principles for protecting persons, property, and the environment.

EXAMPLES OF SYNERGIES AND CONFLICTS FOR NUCLEAR MATERIAL TRANSPORT

Below are examples of potential 3S synergy opportunities and conflict risks, using the IAEA SSR-6 safety document as the baseline for comparing safety requirements to security and safeguards requirements.

- Application for license — Where licensing regulations require submittal of information to the national authority for all 3S disciplines, there may be duplication of submitted information. This is an opportunity for achieving 3S synergy by sharing information and avoiding duplication of effort.
- Information — Availability, integrity, and confidentiality of information (e.g., transport plans, records and reports) are important to each 3S discipline. Protection of sensitive information is necessary. Only

non-sensitive information should be shared generally, and sharing of sensitive information must be restricted to those who have a demonstrated need to know. Sharing safety information may lead to conflicts with safeguards and security.

- Package design — Robust design, testing, and manufacture can synergistically support 3S with shared information. Design for safety and security required to physically control access to packaged material may conflict with access required to verify package design or material for safeguards. Where design information is needed for each of the 3S disciplines, synergies may be realized when package design allows physical access for all 3S disciplines to avoid duplication of effort.
- Design changes — The potential for 3S conflict is increased when design changes are made for only one discipline. Review of design changes jointly for 3S disciplines can be synergistic.
- Certificate of Compliance for Package Design — Package design information is relevant to all 3S disciplines. Synergies may be gained by sharing design information rather than duplicating it for each discipline, keeping in mind sensitivity of information.
- Transport conveyance — The type of transport conveyance is more relevant for potential safety and security conflicts and synergies than for safeguards.
- Package tie-downs — Tie-downs for transport can be synergistic for safety and security. Conflict with safeguards is low, since access is required before shipment and after receipt, but not during transport.
- Loading and unloading of a package — There may be conflicts with safeguards access for shipments or receipts if security and safety considerations limit access at these times.
- Inspection — Safety and security may conflict with safeguards when access to packaged material is needed for safeguards inspections. Joint inspection of a package and its contents, joint use of surveillance and seals, and information sharing can be 3S synergistic by reducing multiple independent accesses and duplication of information such as material type, amount, and location.
- Unattended monitoring — Continuous monitoring during storage while in transit and stopping of the transport conveyance for rest, refueling or border crossing can be synergistic for all 3S disciplines if the monitoring is properly coordinated, and when information and use of surveillance by personnel or technical means and the use of sealing equipment are shared.
- Seals — Joint use of seals for ensuring the integrity of the contents of a package can be 3S synergistic.
- Records and reports — Records and reports for packages, nuclear material, and inspections can be 3S synergistic when the information is shared and not independently duplicated.
- Advance notification — Advance notification is synergistic when non-sensitive information is shared.
- Transportation security plan — Transportation plans for both safety and security can benefit from joint 3S review regarding design and handling procedures to identify potential 3S conflicts and beneficial synergies.
- Accident/emergency planning and response — In the event of an accident or incident during transport, all 3S disciplines come into play for the emergency response teams. A safe, secure design synergistically helps reduce potential damage to the package and theft of the contents and helps preserve the integrity of the nuclear material and related data for safeguard purposes. Sharing of physical access control and information can be 3S synergistic during an emergency.

- Training — Training is essential for each of the 3S disciplines. Cross-training in 3S can be synergistic when 3S disciplines are addressed jointly, rather than separately, which can lead to conflicts.
- Quality assurance program — QA procedures and quality control for design, manufacture, handling, shipping, storing, and inspection are 3S synergistically beneficial.

CONCLUSIONS AND RECOMMENDATIONS

1. A more detailed and comprehensive assessment of international 3S interactions for specific requirements and measures is warranted and is being undertaken by Argonne National Laboratory using an expanded suite of international transport safety, security, and safeguards regulatory documents.
2. The 3S approach is valuable for meeting the combined objectives for safety, security, and safeguards.
3. The methodology presented in this paper is most effectively applied early in the planning and design phases for transporting packages of nuclear and other radioactive material; and also can be effectively applied when new requirements, recommendations, or guidance for safety, security, or safeguards are issued.
4. The benefits of the 3S approach apply to all stakeholders, including designers, manufacturers, carriers, consignors, and government regulators.
5. Retrofitting and modifications can be avoided by jointly and systematically addressing 3S disciplines.
6. Certain functions must remain independent and non-conflicting, but where possible, benefits from synergies can be gained when access to material or access to information can be shared.
7. Training and technology demonstration of the 3S approach, such as the Argonne National Laboratory Transport Security training courses, help identify 3S conflicts and synergies.

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