Spent Nuclear fuel Characterisation and Evolution Until Disposal (SFC)

Overview

2021-02-03 • Peter Jansson, Uppsala University

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Outline

- The context - EURAD
- Overview of SFC
- ∀ four tasks: Scopes and objectives
- The users' group

The context - EURAD

- **Implementation of a JOINT strategic programme of research and knowledge management activities at the European level.**
- **Support the implementation of the Waste Directive in EU member states (across varying degree of advancement)**
- **Gathering of:**
  - WMO's
  - TSO'
  - RE's
- **Consortium of 51 organisations in 23 EU member states.**
- **7 WP's with R&D - main activities**
- **2 WP's on strategic studies**
- **3 WP's on knowledge management**
- **Interaction with CSO's**

More info:
https://ejp-eurad.eu

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Overview of SFC - Objectives

- **To produce experimentally verified procedures to reliably determine the nuclide content in SNF, including realistic uncertainties, by developing:**
  - characterization techniques
  - uncertainty quantification
- **To understand the performance of SNF during prolonged storage, transport and emplacement in a deep geological repository by:**
  - enhancing the capability for safety analysis of relevant operations
- **To understand the behaviour of SNF and ageing effects under normal and postulated accident scenarios until disposal:**
  - in order to identify relevant or typical bounding cases
  - to contribute to operational safety for SNF handling at packaging facilities.
- **To contribute to education, training and building of competence in the subject.**

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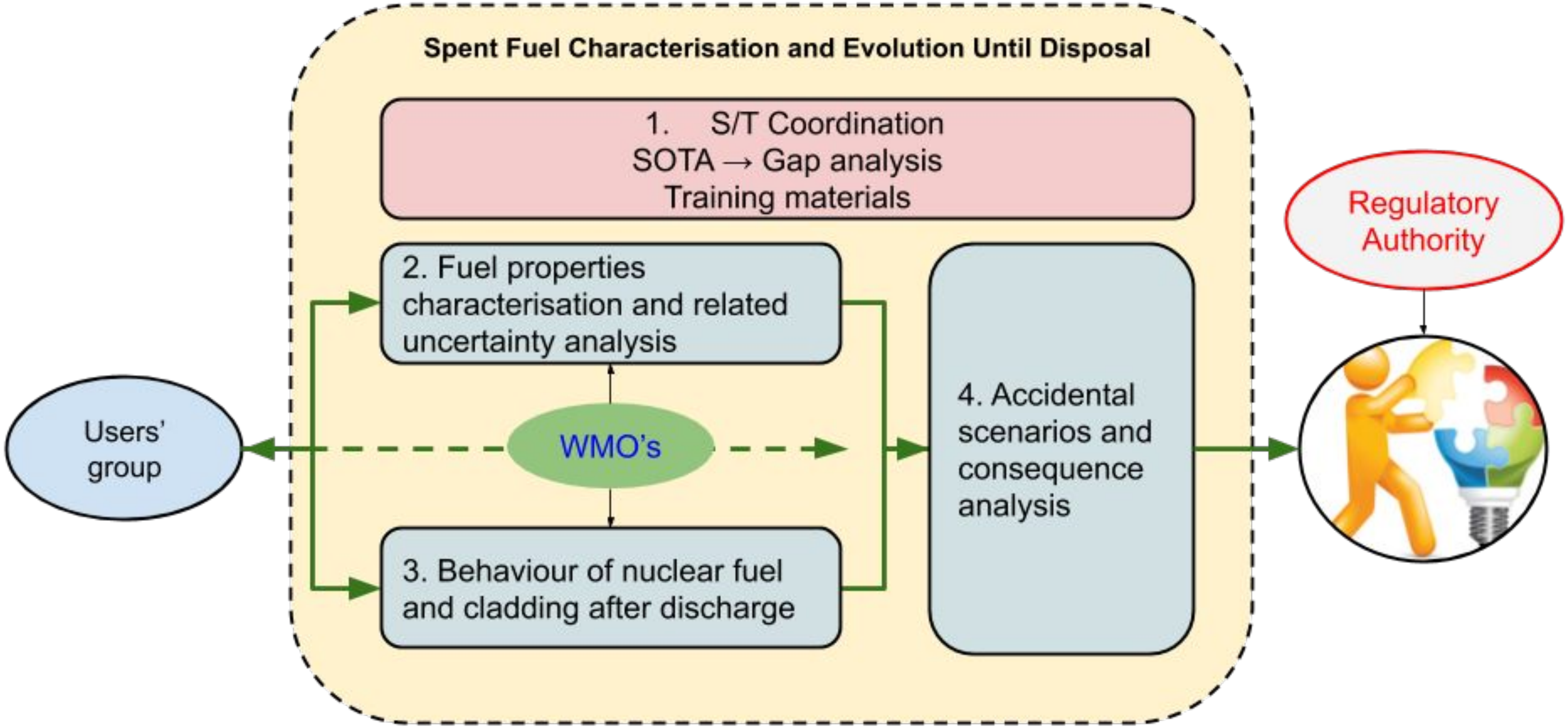
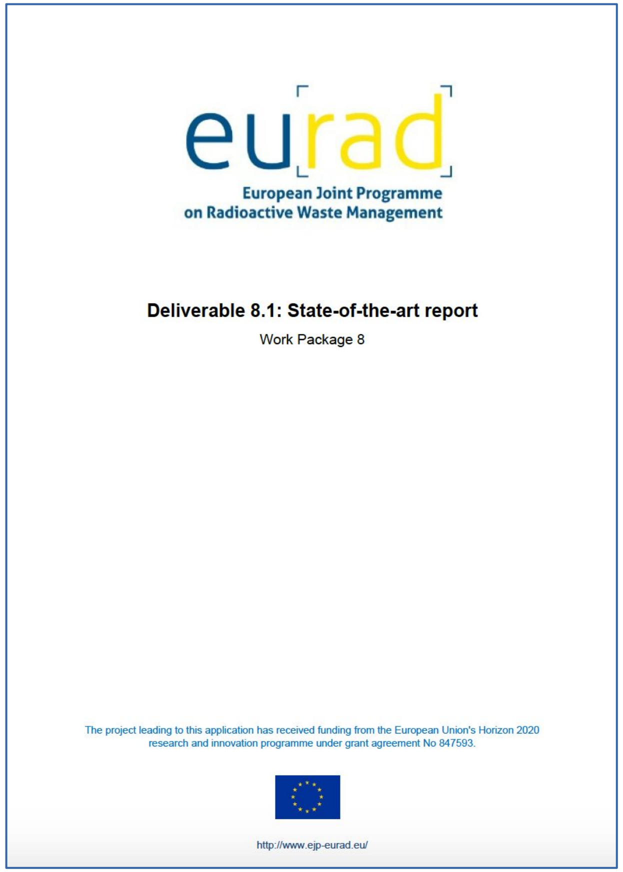
Overview of SFC - The four tasks



Task 1: S/T coordination, State-of-the-art and training material

Objectives:

- To provide efficient management and administration of the work package-
- Developing/updating State-of-the-art, performing WP-specific gap analysis.
- Developing training materials as an input to KM.
- Collecting data from tasks 2-4.
- Collecting experience from the project to guide efforts in a possible future 2nd wave of the programme.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European Joint Programme
on Radioactive Waste Management

Deliverable 8.1: State-of-the-art report

Work Package 8

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Subtasks in task 1

Subtask 1.1 – S/T coordination

- WP operational management and performance monitoring
- WP information and communication management

Subtask 1.2 – State-of-the-art and Gap analysis

- Current state-of-the-art: The current state-of-the-art of nuclear fuel characterisation and evolution of its properties will be summarized in a state-of-the-art report
- Updated state-of-the-art: At the end of the project, the report describing state-of-the-art will be complemented with text on how state-of-the-art has been improved by contributions from the project

Subtask 1.3 – Training materials

- Training material is to be developed during the project in close link with KM Training/Mobility WP.

Task 2: Fuel properties characterisation and related uncertainty analysis

Objectives:

- **To produce experimentally verified procedures to estimate reliable source terms of spent nuclear fuel (SNF), including realistic uncertainties**
- **The main source terms of interest:**
  - gamma-ray and neutron emission rate spectra
  - decay heat
  - inventory of specific nuclides

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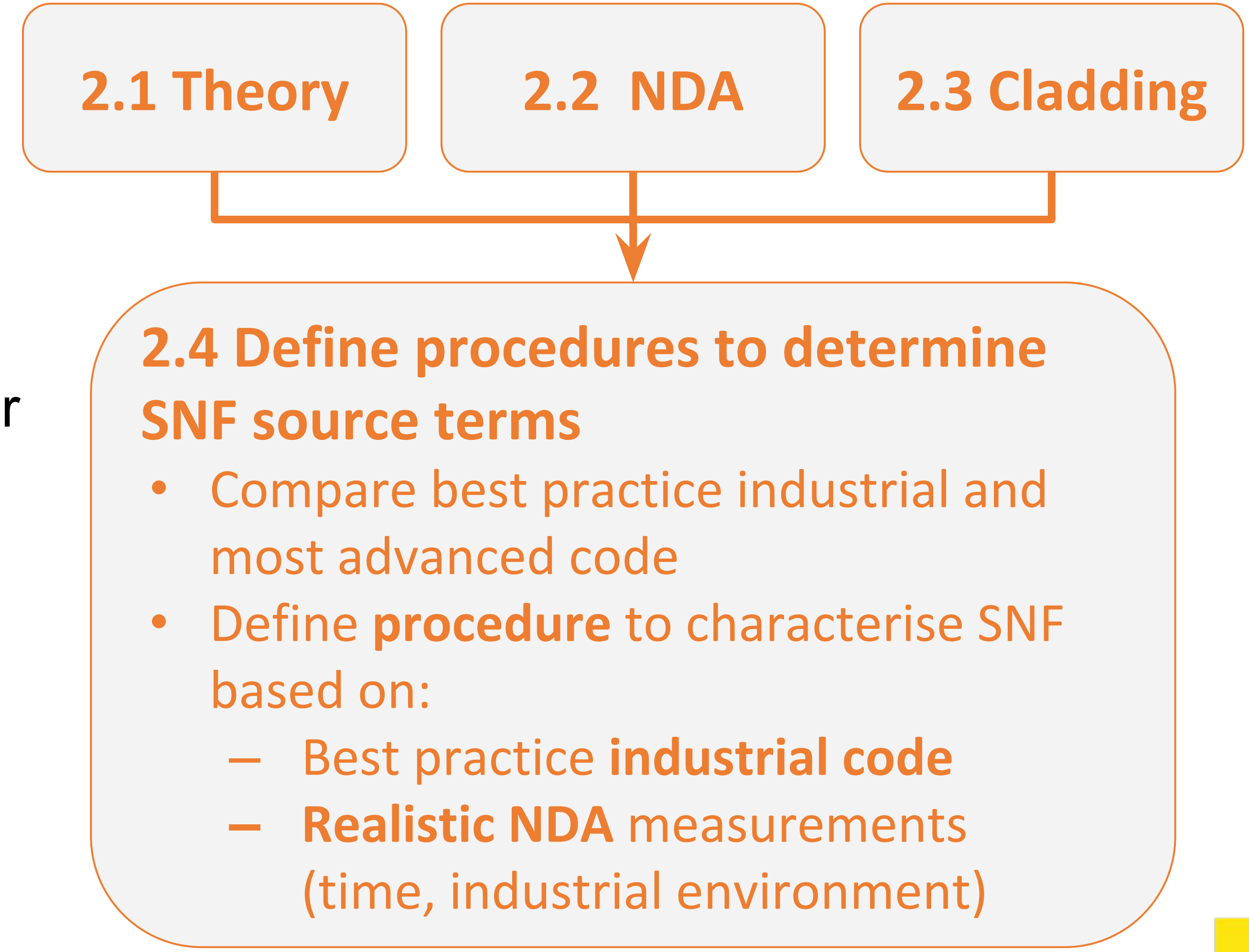
Subtasks in task 2

Subtask 2.1: Theoretical study of SNF source terms

Subtask 2.2: Develop, improve and demonstrate NDA methods/systems for SNF characterisation

Subtask 2.3: Determine the inventory of activation and fission products in cladding material

Subtask 2.4: Define and verify procedures to determine the source terms of SNF assemblies with realistic confidence limits



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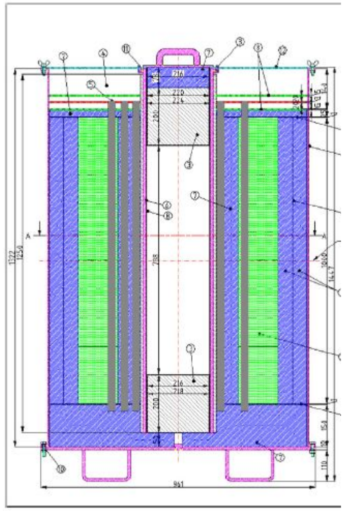
Subtask 2.1: Theoretical study of SNF source terms (Theory)

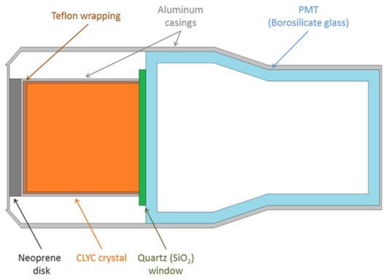
1. Select representative assemblies
2. Calculated quantities:
   isotopic concentrations, decay heat, gamma/neutron emissions
3. Cooling time:
   up to 10^5 years
4. Perform calculations
   (nominal and uncertainties / sensitivities / biases)

Subtask 2.2: Develop, improve and demonstrate NDA methods/systems for SNF characterisation (NDA)

1. **NDA techniques to characterise small samples as an alternative to radiochemical analysis**
   - Finalise design and construction of an improved neutron counter including transfer container
   - Finalise design transfer container for NRTA measurements of the SNF REGAL sample



2. **NDA techniques/method to characterise fuel assemblies**
   - Continue study of the CLAB calorimeter performance
   - New neutron detection systems (DDSI and DDA) for SNF characterisation



3. **Study new detectors**
   - Continue MC simulations of CLYC detectors
4. **Radiochemical analysis of a set of BWR samples**
   - Finalised June 2021

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Subtask 2.3: Calculate and determine experimentally the inventory of activation and FP in cladding (Cladding)

Objectives:

- Dedicated experiments to determine the radionuclide inventories in Zircaloy samples, irradiated in a PWR.
- Zircaloy cladding samples surrounding fuel pellets (UO2 and MOX) as well as Zircaloy from plenum of a UO2 fuel rod segment will be used.
- CIEMAT, SURAO(CTU), KIT, LEI, NAGRA and VTT will calculate the inventories and compare their results to measured inventories.

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Subtask 2.4: Define and verify procedures to determine source terms of SNF with realistic confidence limits

2.4.1 Preparation of data from SKB-50 for simulation with "sophisticated" and "best practice industry" codes. If budget and time schedule allow data from SFCOMPO will be added [M13-M24].

2.4.2 Calculations and results for "best practice industry" code [M24-M36].

2.4.3 Calculations and results for "sophisticated" code [M30-M42].

2.4.4 Evaluation of results from 2.4.2 and 2.4.3 and documentation for part of report D8.6 [M36-M42].

2.4.5 Creation of correlation schemes between conventional fuel history parameters and source term strengths [M13-M36].

2.4.6 Documentation of correlation schemes for part of report D8.7 [M36-M48].

2.4.7 Formulation of procedure to estimate the SNF source terms including realistic uncertainty margins based on theoretical calculations with "best-practice industry" code and NDA measurements which can be routinely performed for part of report D8.7 [M36-M48].

2.4.8 Workshop to present results of Task [M48].

Activities just starting.

Task 3: Behaviour of nuclear fuel and cladding after discharge

Objectives:

To understand and describe numerically the behaviour of

- **spent nuclear fuel (SNF)**
- **irradiated cladding**
- **fuel/cladding chemical interaction (FCCI) and**
- **ageing effect under conditions of extended interim storage, transportation and emplacement in a final disposal system.**

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Subtasks in task 3

Subtask 3.1: Thermo-mechanical-chemical properties of SNF rods and cladding

- Thermo-mechanical-chemical properties of unirradiated and irradiated samples of spent nuclear fuel rod segments and cladding.

Subtask 3.2: Behaviour of SNF pellets under interim storage conditions

- Influence of oxygen and fission products on microstructure of UO2 fuel and He within the UO2 matrix.

Subtask 3.3: Pellet-cladding interaction

- Chemical and structural / crystallographic properties of simulated fuel pellets and irradiated fuel pellets at the cladding/fuel interface

Subtask 3.1: Thermo-mechanical-chemical properties of the SNF rods and cladding

Work plan & objectives:

- Quantification of the effects of hydrogen load, hydride distribution and reorientation as well as mechanical loading
- Evaluation of validity and significance of laboratory tests outside of hot cells
- Physicochemical and fracture mechanical properties of claddings

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Subtask 3.2 Behaviour of SNF pellets under interim storage conditions

Work plan & objectives:

- New insights on the ageing and degradation mechanisms of the SNF (e.g. He build-up, oxidation of the SNF, influence of the various fission products, etc.)
- Potential evolution of the SNF in case of mal operation conditions (e.g. moisture, aqueous dissolution of the UO2 matrix, corrosion of the SNF, etc.)

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Subtask 3.3: Pellet-cladding interaction

Work plan & objectives:

- Chemical effects of activation and fission products on the cladding integrity, and activity release considerations under dry storage and subsequent transportation conditions
- Analyses of pellet/cladding interactions performed using non-irradiated UO2 fuel, high burn-up UO2 fuel and MOX fuel irradiated in commercial PWR
- Morphological and chemical/spectroscopic analyses of the fuel/cladding interfaces and claddings
- High energy resolution XAS (X-ray absorption spectroscopy) analyses of radionuclide speciation at the interface of fuel types and claddings

Task 4: Accident scenario and consequence analysis

Objectives

- To study SNF behaviour under accident conditions which may lead to a potential loss of confinement during storage, transport and predisposal activities.
- To perform criticality safety analysis for credible transport accident scenarios after long-term storage (including fuel rod failure and in-cask fuel distribution).
- To determine the accumulated dose in materials relevant for moderation and/or shielding.

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Task 4: Accident scenario and consequence analysis

Remarks

- Tight bond with Tasks 2 & 3 (empirical correlations and models).
- Vision on developing concepts of mitigation of accident consequences.
- Phenomena cited: radial hydride reorientation; fuel oxidation (clad barrier failure assumed).

Subtask 4.1:
Accident scenario for fuel under dry interim storage conditions.

Subtask 4.2:
Consequence analysis of accident scenarios

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Subtask 4.1: Accident scenario for fuel under dry interim storage conditions.

Objectives

- Synthetic analysis of identified potential accident scenarios during long-term dry storage, transportation and handling of SFAs.
- Support National Programs in relation of a safe management of SNF in back-end activities.

Approach and deliverables

- Identification and analysis of potential accident scenarios for fuel assembly damage and fuel material release during fuel handling
- Assessment of fuel performances for a postulated accident scenario under storage conditions: re-criticality, integrity under mechanical loads and container degradation studies

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Subtask 4.2: Consequence analysis of accident scenarios

Objectives

- Study of SNF behavior under accident conditions, which may or will lead to loss of confinement during storage, transport and pre-disposal activities.
- Support National Programs in relation of a safe management of SNF in back-end activities.

Approach and deliverables

- Analysis of the conditions of the state-of-emergency radioactive wastes packages contained SNF, FCM or HLW/LLW generated due to ChNPP accident

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The users' group - Open for interested parties

- Analytical Research Bureau for NPP Safety (ARB-NPPS)
- Chalmers University of Technology, Department of Chemistry and Chemical Engineering
- Czech Radioactive Waste Repository Authority (SÚRAO)
- Electric Power Research Institute (EPRI)
- Energorisk LLC
- Framatome GmbH
- Gesellschaft für Anlagen- und Reaktorsicherheit (GRS)
- Institute for Energy Technology (IFE)
- International Atomic Energy Agency (IAEA)
- Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA)
- Kernkraftwerk Gösgen-Däniken AG
- Kharkov Institute of Physics and Technology
- Laboratoire de Physique Atomique et Technologies Associée (SUBATECH)
- Lawrence Livermore National Laboratory (LLNL)
- National Nuclear Laboratory (NNL)
- Nuclear research and consultancy Group (NRG)
- Oak Ridge National Laboratory (ORNL)
- OECD NEA Data Bank
- Pacific Northwest National Laboratory (PNNL)
- POSIVA
- Radioactive Waste Management (RWM)
- Spectra Tech
- Studsvik Nuclear AB
- Swedish Radiation Safety Authority (SSM)
- The Research Centre Rez (CV Rez)
- Tokyo Institute of Technology
- TS Enercon
- Teollisuuden Voima Oyj (TVO)
- University of Sheffield (USFD)

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