

Signature Research on Spent Fuel and Nuclear Materials at the National Nuclear Laboratory, United Kingdom – 10361

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ABSTRACT

The UK's National Nuclear Laboratory (NNL) is establishing a number of Signature Research Areas which will support the future needs of the UK Nuclear Industry.

Management of spent fuel and nuclear materials (i.e. separated plutonium and uranium) is at the heart of the nuclear fuel cycle, whether it is open or closed. Expanding knowledge through research is required for many aspects of the fuel cycle: safe and efficient operation of nuclear fuel cycle facilities; safe and responsible fissile material management; and security of radioactive and fissile materials. Such research is fundamental to the UK as a nuclear nation and so it is core to the NNL. In light of this, one of the NNL's Signature Research Areas is focussed on spent fuel and nuclear materials management.

The NNL has unique expertise both nationally and internationally in enhancing existing fuel cycles and advancing future fuel cycles. Through the Signature Research Area, the NNL will advance its work and build its profile in the fields of spent fuel and nuclear materials, in support of the UK nuclear industry and overseas initiatives.

The NNL's Signature Research Area for Spent Fuel and Nuclear Materials focuses on:

- Supporting policy and ongoing operations
- Building a skill base that supports UK regulators, UK Site License Companies and industry as a whole
- Expanding NNL research in spent fuel and nuclear material
- Underpinning decision making on strategic options for disposition (storage, re-use/recycle of materials, immobilisation/encapsulation for disposal)

Initial NNL analysis within this Signature Research Area has identified the need for targeted and integrated R&D for all disposition choices, as well as throughout the lifetime of the chosen strategy. At the NNL, we believe we have a major role to play in establishing the UK R&D requirements as part of an integrated national programme. In recognition of this, we have launched the NNL Signature Research Programme for Spent Fuel and Nuclear Materials, which through collaboration with other leading organisations in the nuclear community, will build momentum on a UK based research initiative.

INTRODUCTION

Core to the NNL's mission is provision of independent, authoritative advice on nuclear issues. In order to facilitate success in this mission, the NNL has established four Signature Research Areas to build scientific reputation and to serve as platforms for collaboration with national and international research institutes.

The Signature Research Areas cover the following topics:

- Spent Fuel and Nuclear Materials
- Fuel and Reactors
- Legacy Waste and Decommissioning
- Waste Processing, storage and disposal

The four Signature Research Areas encompass activities which are of strategic significance to both the NNL and the UK nuclear industry as a whole, with the intention that the NNL should be renowned for its expertise and capabilities. Collectively the Signature Research Areas already encompass the majority of the civil nuclear fuel cycle and consideration is being given to the establishment of a fifth Signature Research Area encompassing security and activities related to Chemical, Biological, Radiation and Nuclear (CBRN) incidents.

In each Signature Research Area the NNL currently undertakes work for customers, including both specific research and a range of technical support activities. The objective now is to play an expanded, more strategic role, contributing to the growth of the NNL business and effecting a transition to a recognised and trusted source of expertise and knowledge, building new capabilities and enhancing existing ones.

Although work is currently underway in all of the Signature Research Areas, this paper concentrates on one: that of spent fuel and nuclear materials.

SPENT FUEL AND NUCLEAR MATERIALS RESEARCH

Spent nuclear fuel, separated plutonium (Pu) and separated uranium (U) have unique behaviours and properties that require special and sound management: they can present a hazard to human life and the environment, yet they can also be harnessed to produce energy securely and sustainably.

In the UK and worldwide, there are thousands of tonnes of these materials held in safe storage awaiting a decision being made or a technology to be developed, so they can be finally put to use or disposed of as stable, safe wastefoms. Inaction will be detrimental to all future operations involving these materials and the integrity of the packages and facilities which currently house them due to the materials' present unconsolidated nature.

In a world where uncertainty is inherent and a "leave it for the next generation to solve" culture is becoming increasingly untenable, decisions for the nuclear industry have to be made using the best data at hand. Internationally, there are few mature technologies and, given the unique properties of the materials, only a limited understanding of their characteristics which can support a government's or a utility's decision on management of their spent nuclear fuel and separated plutonium and uranium. Although research and development does not replace difficult decisions with absolute answers, it will always yield information that informs and helps the decision makers.

The commitment to continue nuclear power generation in the UK for at least the next 50 years is driving the need for a decision to deal with not only legacy material but also the future arisings.

The UK is considering the options for managing spent nuclear fuel and special nuclear materials, but can the best option be identified without the best data?

It is the National Nuclear Laboratory's position that the UK needs a coherent and integrated Research and Development programme on the management or disposition of spent nuclear fuel and separated plutonium and uranium. At the NNL, we believe we have a major role to play in establishing this UK R&D programme, but that crucially it needs to involve partners from industry and academia to fulfil the UK's needs.

The UK's challenges are similar, if not the same as those faced by many other nuclear nations: thus the NNL believe that collaboration with international partners is of key importance. Learning from available international experience can prevent wasted time and effort replicating research already undertaken, and will lead to collation of relevant data for all countries considering spent fuel and nuclear materials disposition.

R&D has always played a key part in the UK nuclear industry and in deciding the fate of nuclear materials. The NNL believe that targeted R&D is needed for all disposition choices and throughout the lifetime of the chosen strategy. The NNL has unique expertise both nationally and internationally in enhancing existing fuel cycles and advancing future fuel cycles, thus effective and advancing research by the NNL can have a clear impact on the UK nuclear industry.

On a wider scale, research on the management of spent fuel and nuclear materials also aligns with key fields of international nuclear interest, such as the safe and efficient operation of nuclear fuel cycle facilities, the safe and responsible management of fissile material and the security of radioactive and fissile materials. The fundamental issues surrounding spent fuel and nuclear materials disposition are pertinent to all countries with either an active or historic nuclear programme.

Understanding Disposition

For each of the three material groups under consideration (spent fuel, separated plutonium and separated uranium), three overarching disposition options exist:

- Re-use/recycle of materials
- Immobilisation/encapsulation for disposal
- Storage (a holding position which avoids foreclosure of options but ultimately leads to one of the other disposition options)

However, there are genuine uncertainties about how to handle these materials and the implications of a disposition decision that goes beyond the current storage regime. These uncertainties stem from immature technology, limited knowledge of the material properties and hazards, and how they change with time. Furthermore, the disposition of spent fuel, separated plutonium and separated uranium is interlinked and potentially complex. A single strategy is unlikely to offer a complete solution for the entire inventory due to diverse material characteristics, unconsolidated capabilities and low technical maturity.

Disposition is not just a question of understanding the material and the technical feasibility of deploying a strategy. The “best” disposition decision is also influenced by the varied range of values placed on it by the numerous stakeholder groups. For example, environmental lobbyists may value disposal of the material as quickly and as safely as possible, economists may seek the lowest cost option and nuclear energy advocates may prefer a strategy maximising the reuse of available resources.

It is clear that the selection of the preferred management option must account for safety, environmental impact, security and safeguards, and societal and economic impacts.

UK R&D Needs

NNL analysis has resulted in an integrated and targeted vision of the UK’s R&D needs in the areas of spent fuel and separated plutonium and uranium. As a result, the NNL propose an R&D programme for the UK, the initial representation of which is presented below and is available for consultation and collaboration in order to further refine the details.

For the three disposition routes for spent fuel and nuclear materials (disposal, storage and re-use) the R&D requirements can be considered in four logical stages:

Determine – The understanding of the chemical and physical properties of the material in question through characterisation

Develop – The development and evaluation of the material package for disposal, storage or re-use, together with the inherent scientific and engineering requirements

Decide – Assessment of disposition possibilities identified in the previous stage against the known technical information as well as environmental, social and economic factors to down select to credible market options

Deploy – Design, build and implement the chosen credible option

Within each of these stages, there exist a number of activities specific to the chosen disposition route, all of which require dedicated R&D in order to fully understand their impacts and influences on that disposition route. Only by understanding and validating the required steps of a potential disposition strategy can its credibility be ascertained.

Figure 1, below, summarises the R&D activities required in the UK in order to successfully identify a satisfactory disposition route. It can be seen that there are no timescales on the diagram and as such it is not a typical Gantt Chart. This is due to the fact that different areas have different urgencies and it was not considered appropriate to show timescales on this representation. Future work will define more detailed programmes for meeting these R&D requirements. The lack of timescales also acknowledges the iterative nature of R&D: new ideas or options may become apparent during the course of research work, which require repetition of previous activities.

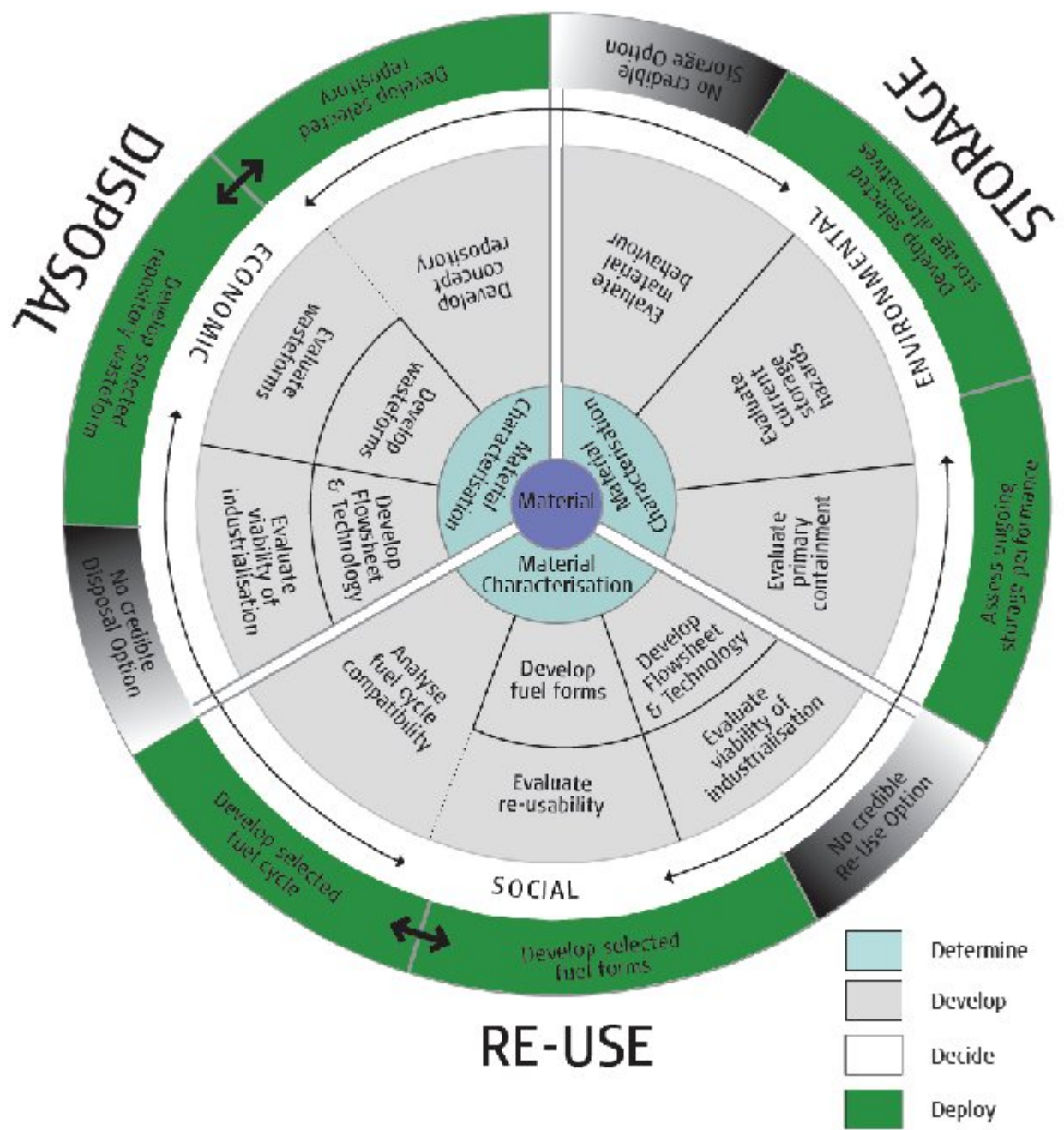


Fig. 1. Diagram showing the R&D tasks required to inform disposition in the UK

THE NNL'S SIGNATURE RESEARCH AREA & PROGRAMME

Against this background of the overall UK R&D requirements, the NNL has established its Spent Fuel and Nuclear Materials Signature Research Area, with an underlying strategy to:

- Support policy and ongoing operations
- Build a skill base and NNL capability in SF and NM that supports UK regulators and industry as a whole
- To establish the NNL position on disposition and associated research
- Underpin decision making on strategic options for disposition

Key to realising this strategy is the formation of a Signature Research Programme for Spent Fuel and Nuclear Materials, which forms a key part of the overall UK R&D programme and will endeavour to underpin informed decisions in the disposition of spent fuel and nuclear materials disposition.

It is the NNL's vision that our programme will achieve a significant advance in knowledge of the disposition routes for spent fuel, separated plutonium and separated uranium, in support of the UK's nuclear clean up, new reactor build missions and the global nuclear renaissance. The NNL will perform targeted research to yield up-to-date and substantiating data and structured analyses of disposition decisions, underpinning knowledge and potential outcomes. With this goal in mind, we will deploy our own world class skills and laboratory facilities.

It is the belief of the NNL that we cannot and should not progress UK research and development for spent fuel and nuclear materials alone. We recognise that collaboration and partnering with universities and industry will maximise opportunities for generating new data and advancing knowledge.

NNL plans to collaborate with a number of organisations, such as universities, other National Laboratories and industry. Our overall research strategy will include activities that will be carried out in these collaborative organisations, with NNL involvement, to complement the NNL based research. NNL will actively interact with partners and users to ensure that the Signature Research programme involves credible, targeted R&D and utilises all available expertise in the field. Engagement of stakeholders and understanding of societal concerns will play a significant role in the analysis of disposition scenarios and decisions.

As part of the NNL's objective to re-invest profits for the benefit of the UK nuclear industry, the majority of the Signature Research Programme will be self-funded. The intention is to use internal investment to develop products and services aligned to these areas and to develop or demonstrate our capability and expertise.

Programme Structure

In order to provide the most useful and credible data, the programme has been designed to be flexible such that it can respond effectively to new data or research findings.

Priority areas for spent fuel and separated plutonium and uranium that will significantly increase knowledge and underpin decisions have been identified, and these address the following important topics:

- Stored material properties, behaviour and package performance
- Wasteform and immobilisation technology development
- Fuel cycle assessment and support to UK reactor licensing
- Disposability and repository performance
- Analysis of existing knowledge gaps
- Technology development and engineering

Figures 2, 3 and 4 highlight the areas of the overall UK R&D programme in which the NNL is undertaking work as part of its Signature Research Programme.

Spent Fuel R&D

Signature Research on spent fuel disposition covers all four of the strategic stages (Determine, Develop, Decide and Deploy). Key tasks include the development of proliferation resistant reprocessing flowsheets and technologies, engineering substantiations of spent fuel treatment facilities and examinations of irradiated metal and oxide fuel.

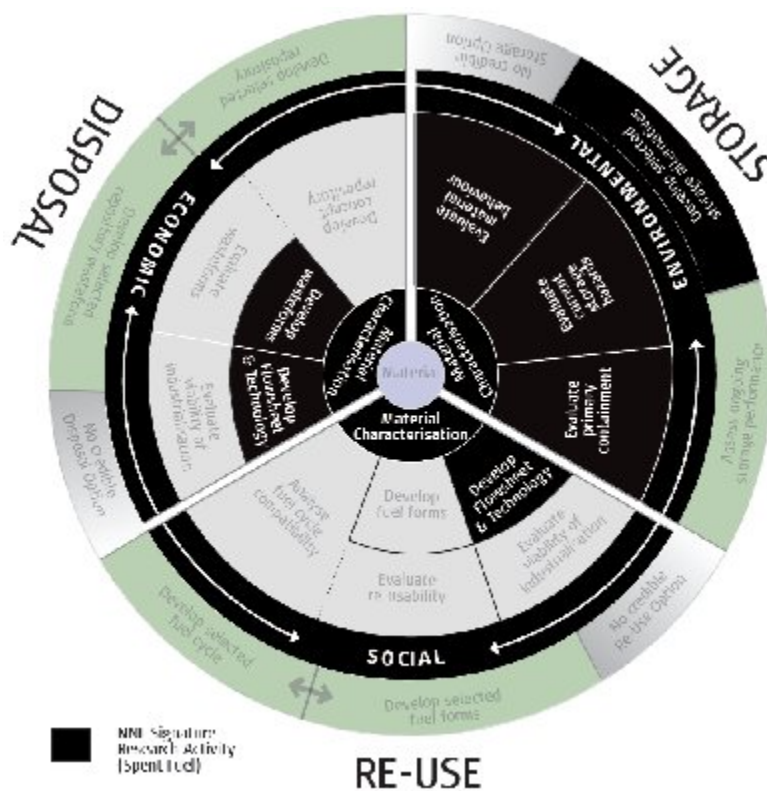


Fig. 2. NNL R&D activities for spent fuel in the context of the overall UK disposition research effort

Plutonium R&D

Signature Research on plutonium disposition covers all four of the strategic stages (Determine, Develop, Decide and Deploy), with key activities investigating the manufacture and use of MOx fuel, as well as different options for storage and ultimate disposal of plutonium.

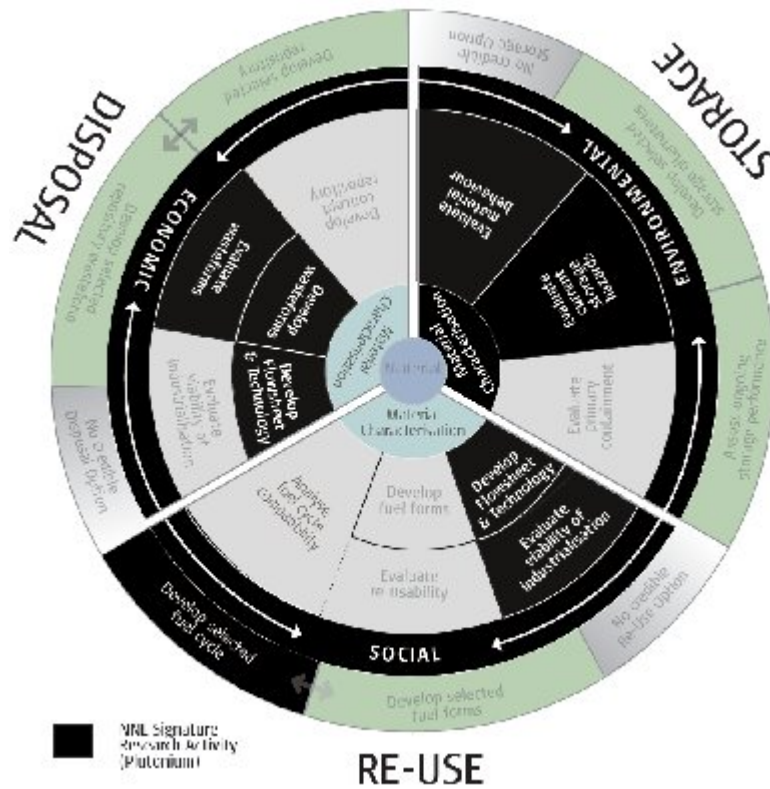


Fig. 3. NNL R&D activities for plutonium in the context of the overall UK disposition research effort

Uranium R&D

Of the four strategic stages, Signature Research on uranium disposition focuses on Develop and Decide type R&D. The tasks cover both laboratory and desk-based activities, including the continued development of tools for the use of reprocessed uranium and investigation of encapsulation options and processes.

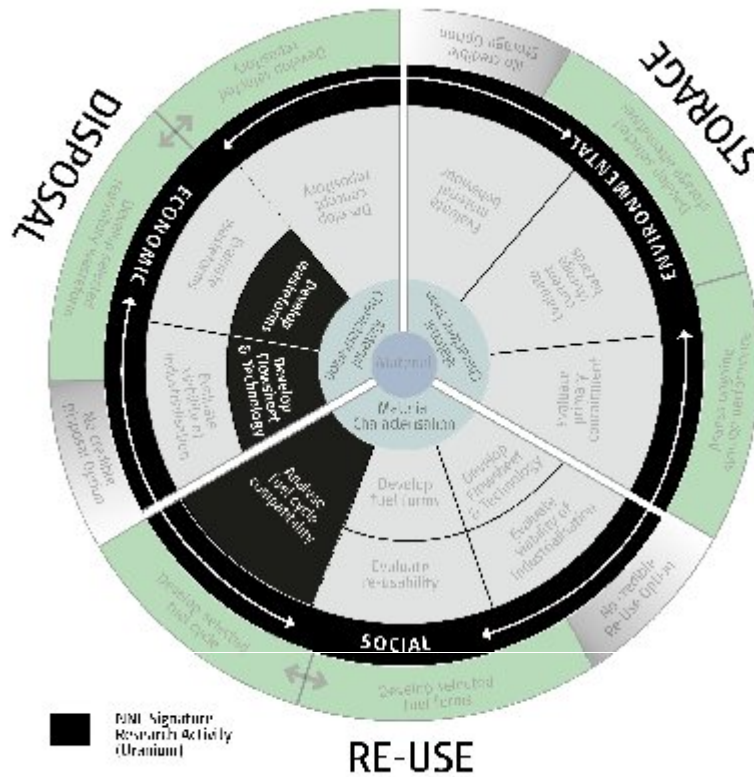


Fig. 4. NNL R&D activities for uranium in the context of the overall UK disposition research effort

Strategic R&D

In addition to the tasks outlined above, there are also overarching strategic research activities, which cut across spent fuel and separated plutonium and uranium disposition research. This R&D will obtain data and establish a decision-making methodology and capability – a vital asset to allow informed and accurate decisions to be made.

The strategic activities fall into the following broad categories:

- Strategic optioneering such as analysis of scenarios, estimating costs, optimisation
- Acquisition of fundamental chemical data, e.g. kinetics, thermodynamics
- Validation of process models
- Engineering assessments
- Support to stakeholder engagement

A decision-making toolkit is being developed to consolidate the gathered data and research findings, and allow the implications of different decisions and scenarios to be investigated.

PROGRESS TO DATE

At the conclusion of the programme's first year, there are a number of successes to report.

A UK disposition R&D programme has been drawn up by the NNL for consultation. In response to this programme, a bounded Signature Research Area has been established, within which a number of specific research tasks will be carried out.

Work on these tasks has already commenced, with notable achievements including the identification of feed materials and final disposition options. These options, and the research required to underpin them, are undergoing further investigation. Their discussion and endorsement at seminars attended by UK academics and industrial representatives is planned to take place this summer.

The decision analysis approach and criteria, and related database have been established and existing information (from both the public domain and previous NNL research) has started to be gathered and used to populate the database.

Interaction with UK industry and universities has taken place, resulting, for example, in the initiation of two NNL-funded research PhDs.

SUMMARY

The formation of the NNL's Signature Research Areas and the establishment of the Spent Fuel and Nuclear Materials Signature Research Programme an important step for the nuclear industry and research community, which ultimately seeks to advance knowledge and understanding of the disposition of these materials.

The NNL is proud of its achievements to date and is excited about research that is scheduled to take place in the near future, as well as about the formation of research relationships in the UK and worldwide.