Guideline TNO Technology Watch

RVO TechWatch – WP4: Methods and Tooling

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Introduction

This document serves as a guideline for conducting TNO technology watch. The document provides an overview and general description of the steps of a technology watch. In addition, it offers tips for the use of supporting tooling.

This guideline will contribute to improving the quality of TNO technology watch by conducting them in a consistent manner. Please note that this guideline only serves as a tool and that any technology watch always requires (partial) customisation.

This guideline is the result of Work Package 4: Methods and Tooling of RVO Technology Outlook 2023. It is a living document, which means that there will constantly be innovative methods and innovations in the way TNO conducts technology watch that should be included in this document.

Questions? Feel free to contact Sacha de Wolf (sacha.dewolf@tno.nl).



Reading guide

This document starts by describing the *why* and importance of technology watch. After that, different variations of technology research are explained in the *what*. Then the *how* of a technology watch is discussed, including the different phases of a technology watch based on the objective, approach, result and roles. To get an idea of the different variants of a technology watch, examples of TNO technology watch research are given. The document concludes with a bibliography and appendices, in which various tools for conducting a technology survey are described.

Navigate to:

Why
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Why?
The importance of technology watch

Foresight studies into emerging, potentially disruptive technologies have been on the rise in recent years. Although the concept of *foresight* (looking ahead to the future) is not new, the importance attached to identifying and interpreting trends (technological or otherwise) seems to have increased. This is partly due to the increasing complexity, uncertainty and degree of change in the world around us (Kohler, 2021). It is precisely this degree of uncertainty that underlines the importance of foresight. NATO, the EU, but also individual countries, among others, are not only trying to identify new developments (watch), but also to assess their value (assessment).

TNO endorses this importance of continuous foresight and assessment, especially in the field of technological developments. For example, TNO has been conducting ongoing technology watch for the Ministry of Defence since 2014. In general, but certainly for organisations in the Defence and Security domain, it is important to be able to anticipate technological developments. On the one hand, this anticipation can provide opportunities and seize them, and on the other hand, organisations can better prepare for new threats. We call this the anticipation function: making an inventory of future (technological) developments and also interpreting and analysing this information (Bastings & Lassche, 2020). Foresight and assessment can be done at a strategic, operational and tactical level.

What?

Various forms of technology watch (1/3)

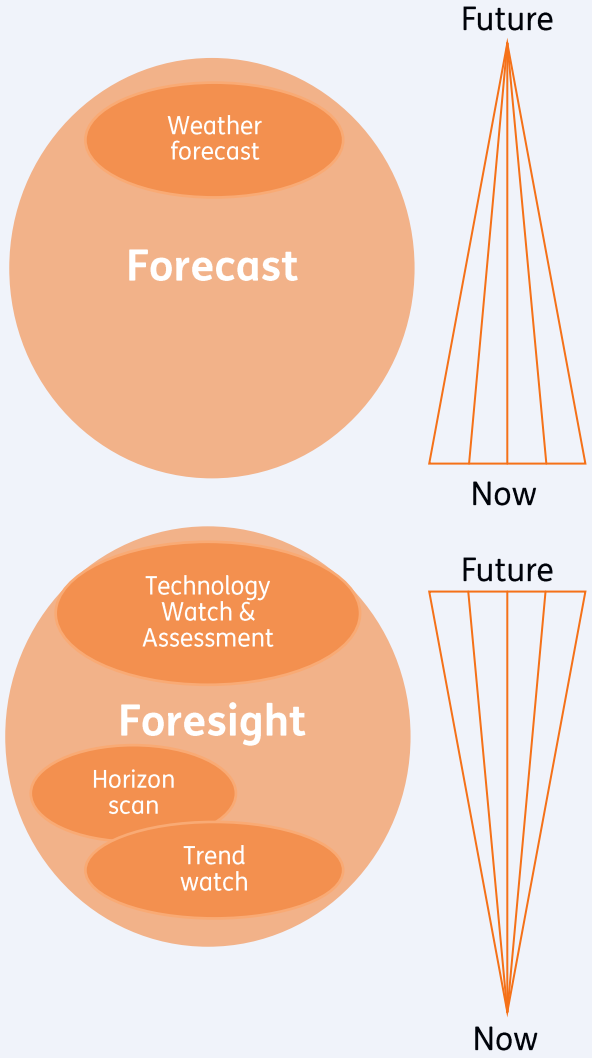
Partly due to the increased awareness of foresight at all levels (strategic, operational & tactical,) and in various sectors, different terminology is often used interchangeably, without an unambiguous definition. To ensure consistency, we at TNO use the following definitions of the most common terms within foresight studies. See on the right a visual overview of the distinction between forecast and foresight and the types of technology watch described below.

Forecast

Forecast is about actually predicting the future, based on data from the present and the past. Consider, for example, the English term 'weather forecast'. Data from the past is extrapolated or modelled in order to construct the future. Often a closed choice is used (an event will or will not occur), or it is stated that a certain quantitative value will be achieved (for example, how big the shortage of technically skilled personnel will be in 2025) (Kohler, 2021).

Foresight

Foresight means exploring possible futures (often in scenarios), without looking for definitive answers about the future. Foresight attempts to give organisations resilience by providing insight into what certain choices and consequences might look like in the future. The term foresight is an umbrella term within which various activities can be encompassed. A typical foresight process consists of a data collection process, and an interpretation process in which signals and patterns are processed. The process can be data-driven or expert-based. Depending on this, developed future scenarios, for example, contain some form of assumptions or predictions (Cadet et al, 2022).



What?

Various forms of technology watch (2/3)

Within TNO, we focus mainly on foresight, which includes several types of technology watch. These are described below.

Trend watch

A trend study looks at long-term developments that could develop further in the future. It's about extrapolating existing trends and looking at what realistic extremes are. While it can provide valuable insights, a trend watch does not focus on identifying potential unexpected events. A trend watch therefore has a monitoring function rather than a long-term signalling function (Kohler, 2021).

Technology watch

A technology watch is aimed at identifying technological developments and new applications of technology that may have an impact on an organisation, a field of study, or a domain (Peters & Thönissen, 2019).

Horizon scanning

Horizon scanning involves identifying different types of trends and developments (Peters & Thönissen, 2019) that are relevant to an organisation, a field or a domain. Horizon scanning is about analysing data to recognise trends (Schubert, 2021), looking for 'weak signals' (Kohler, 2021). Consider, for example, the identification of geopolitical change (new rulers, new geopolitical relationships) and technological changes that could eventually lead to new (types of) digital attacks (Cadet et al, 2022).

What?

Various forms of technology watch (3/3)

Technology assessment

Technology assessment involves evaluating opportunities and threats of technological trends, developments and applications for an organisation, a field of study, or a domain (Peters & Thönissen, 2019). The field has its origins in the public sector, where it serves as a method to improve (strategic) decision-making processes. In this context, the aim of a technology watch is to inform policymakers by assessing the short- and long-term impact of new technological applications within various domains (such as societal or economic) (Tran & Daim, 2008).

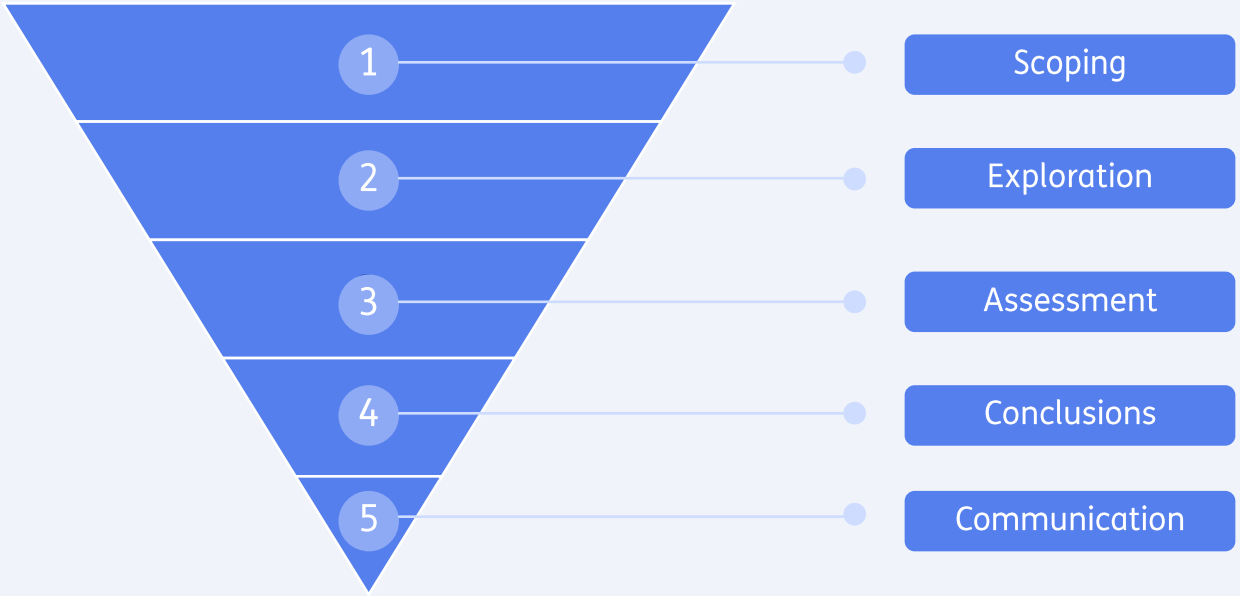
Technological trends are often inextricably linked to trends in other domains, such as political, economic and social trends. In addition, technology watch exercises will almost always be linked to a technology assessment. Merely an overview of trends and developments provides little interpretation and guidance to an organisation. The importance often lies in estimating the value and impact of technological developments specific to an organisation, field or domain.

The aforementioned terms are often used interchangeably. In this guideline, we use the term technology watch to refer to a watch and assessment, as these are often inextricably linked.

How?

Introduction – Phases of a technology watch

The next section takes a closer look at how a technology watch and assessment is carried out within TNO. For each step, the goal, the approach, the roles and (intended) results are described. In addition, tips are given for the use of supporting tooling. Below is a visualisation of the different phases of a technology watch and assessment.



How?

Scoping | Exploration | Assessment | Conclusions | Communication

Phases of a technology watch (1/5)

Objective

Determining the (provisional) objective, scope and research questions of the technology watch together with the client.

Approach

The focus and scope are determined in dialogue with the client. This can be done on the basis of the following key questions:

- What exactly is the theme and the framing (what is it not)?
- What does the client want to achieve with this technology watch?
- What are the goals of the client within the theme (dot on the horizon) and when have these goals been achieved?
- What are the thematic underlying (social) phenomena and trends?
- On what criteria does the client want to assess the technologies (effectiveness, interoperability, feasibility, sustainability, etc.)?

Based on the answers to these key questions, a research question can be formulated. This research question can focus on the general impact of a technological development or more specifically on the opportunities and/or threats of a technological development (see Appendix I for sample research questions linked to the underlying purpose of the technology watch). It is also necessary to determine the level of abstraction at which the research is carried out: technology area (quantum technology or artificial intelligence), applications of different technology areas (quantum computing or adversarial AI), or applications within a singular technology area (quantum computing for medical diagnostics)

Supporting tooling & tips

- ASPI technology tracker provides a quick overview of technological developments in various countries. It is also possible to compare two countries or regions in different areas of technology. This tracker is useful as a source of inspiration at the beginning of a technology watch.

By whom?

TNO will carry out this step in close consultation with the client. As input, (TNO) experts or the end users of the results can be consulted.

Result

A document in which the objective, scope and research question are clearly laid down.

How?

Scoping | Exploration | Assessment | Conclusions | Communication

Phases of a technology watch (2/5)

Objective

Carrying out an inventory of selected sources within the chosen scope and making an initial selection of relevant technological developments on the basis of this.

Approach

- Collection of Information

In the first instance, TNO material such as the Future Innovations Radar and TNO reports can be looked at, as well as public sources, such as academic publications, news reports and public trend reports. In addition, material from the client can be looked at and the possible questioning of (TNO) experts.

- Organising information

For the sake of accessibility, the researcher writes a concise summary of the technological development(s) using a format (see Appendix II for an example). Which topics are included depends on the scope and research question (step 1). The overview of this is a *long-list* of relevant technology areas.

Based on the previously determined scope, a selection of the most relevant technology areas for the client must be made with the help of experts. This can be done through a workshop where experts provide input for the *short-list* or by having a short-list drawn up by the project team validated.

Supporting tooling & tips

- Future Innovations Radar
- Databases such as Google Scholar, Scopus, ScienceDirect etc.
- The Lens, database of scientific articles and patents.
- Factiva, database of news articles.
- ConnectedPapers, a tool to map relevant articles based on a core paper.
- ASReview*, a tool for accelerated scanning of relevant articles
- For trend reports, think of the WEF, DCDC and the NIC, for example.

By whom?

In this step, the TNO project team will act as a facilitator between the substantive, possibly technical (TNO) experts and the possible experts internal to the client.

Result

A *short-list* of technological developments for the next step; assessment.

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How?

Phases of a technology watch (3/5)

Objective

Determining the relevance of the selected technological developments based on pre-defined criteria in the scoping phase (e.g. *impact*; expected contribution of the technology to the organisation, *opportunities*; what improvement can this technology offer, *threat*; what threat does this technology pose to the organisation?).

Approach

Depending on the goal and scope of the project, there are different methods that can be applied in the assessment phase. Some methods are explained below, see Appendix III for an overview of TNO experts per method and the following slide for a brief explanation per method*.

- MARVEL: a semi-quantitative method to map system-dynamic dependencies.
- Scenario analysis: a method that allows possible future scenarios to be drawn up and/or analysed using the results of a horizon scan or a trend analysis that are captured in, for example, a morphological box or the Shell matrix.
- Modelling & Simulation: modelling or simulating the future by, for example, *disruptive technology assessment game.*
- Delphi: experts are questioned anonymously by means of a survey and receive the statistical representation of the response of the entire group. This process repeats itself to eventually arrive at an expert consensus.

Supporting tooling & tips

- Bibliometrix, for the analysis of bibliometric data.
- AtlasTI, for the qualitative coding of sources and converting them into quantitative data.
- Futurescraper, Delphi survey tool.

By whom?

The TNO project team will facilitate the assessment step by offering TNO's experts and/or the client the opportunity to have the technological developments assessed.

Result

A report (format in consultation with the client) with the assessment of the technology areas in the *short-list* based on the predetermined criteria.

* For the online version, click on the method's link to read an in-depth article or report on that method, or go to FOGUS via the link on page 17.

How?

Phases of a technology watch (3/5)

Marvel

Marvel is suitable for problems that (1) can be described in causal relationships; (2) that is expected to contain feedback loops; (3) that are likely to exhibit dynamic behaviour; (4) which are about evaluating interventions; (5) for which there are general ideas about the strength and speed of causal relations; (6) for which only an initial insight into time behaviour is acceptable; and (7) for which understanding the relative strength of identified impact loops is desired.

Scenario analysis

Scenario analysis uses information from previously conducted horizon scans or trend analyses to indicate the possible impact of strategic choices or important trends by sketching a future world based on plausible developments. It is a suitable method if (1) complex information needs to be presented to a customer in a simple way; (2) if awareness about the impact of strategic choices should be promoted; (3) if creative results are needed that bypass everyday thinking; and (4) if focus should be placed on the factors that strongly determine how a situation can develop. Scenarios themselves are rarely an end in themselves, but often function as a tool or first step for the development of other activities.

Modelling & Simulation

Modelling & simulation can be used to create domain-specific knowledge models or simulations of situations or possible futures based on causal reasoning. This can be suitable if a (cautious) prediction needs to be made about the development of a technology, or the impact of a trend or technological development. It is important to accurately determine values and the corresponding weight in the model.

Delphi

Delphi aims to bring together participants with different opinions, expertise and experience into a common vision. It is particularly suitable for surveys that last a longer period of time because the intention is that the participants, based on their knowledge, fill in a survey with questions several times over a certain period of time in order to reach a consensus together. This makes Delphi suitable for a large group of participants, but the interpretation of the results can take a long time.

How?

Phases of a technology watch (4/5)

Objective

Answering the research question by linking the analysis results (retrieved in the exploration and assessment step) back to the scope.

Approach

When analysing the research results, the original purpose of the study (established in step 1; scoping) should be taken into account. Depending on this, the conclusion will be an advice, a prioritisation of technology areas or a value assessment. In doing so, explicit attention should also be paid to conclusions that were not expected in advance.

As part of the conclusion, there should always be a recommendation for follow-up. This can be internal work at the client to do something with the insights and/or a further deepening of the research results (such as a technology roadmap). This can be interesting because:

- there may not have been an in-depth investigation due to limitations in the scope, but this is interesting;
- technology watch activities should actually take place continuously because technological developments are taking place at an ever-increasing pace;
- There may be a need to investigate and/or prioritise mitigations.

Supporting tooling & tips

- The Lens, for the bibliometric analysis and visualisations that the tool provides based on the dataset.
- Bibliometrix, for the bibliometric analysis and visualisations that the tool provides based on the dataset.
- AtlasTI, for analysis based on the coding of originally qualitative data.

By whom?

The TNO project team will jointly analyse the research results and write the conclusions. Because the TNO project team is probably deeply involved in the matter, it may be useful to explain the conclusion to a suitable TNO colleague outside the project team in order to get it in focus.

Result

A report (format in consultation with the client, such as a memo, report or PowerPoint) in which the research question is answered.

How?

Scoping > Exploration > Assessment > Conclusions > **Communication**

Phases of a technology watch (5/5)

Objective

Making the research results transparent and (visually) presentable.

Approach

Ideally, this step should be discussed with the client early in the research project in order to manage expectations and meet the requirements. In order to be able to share the entire investigation, a report must be drawn up. The format must be coordinated with the client, for example a report, presentation, or visual (radar) model. This document documents in a detailed and accessible manner the purpose of the research, the scope, the research methods used, the research results, the conclusion (answering the research question), the reflection including lessons learned, and possible follow-up steps. The use of visuals is recommended to promote clarity.

Usually, the research results are also presented. The presentation serves to convey the results to the client in a relatively short time. Use visuals in your presentation to show the most important results at a glance. After giving the presentation, room for discussion is necessary to be able to answer questions from the client.

Supporting tooling & tips

- Make sure the report/memo is finished on time so that reviewers have enough time to look at it critically.
- Make sure the presentation is concise, refer to the report for more information.
- Have visuals in both the report and the presentation to see the most important results at a glance. Think, for example, of a map, a time axis or graphs.

By whom?

The TNO project team will write the report, have it reviewed and present the results to the client

Result

A combination of, for example, a report and a presentation in which the research results are shown.

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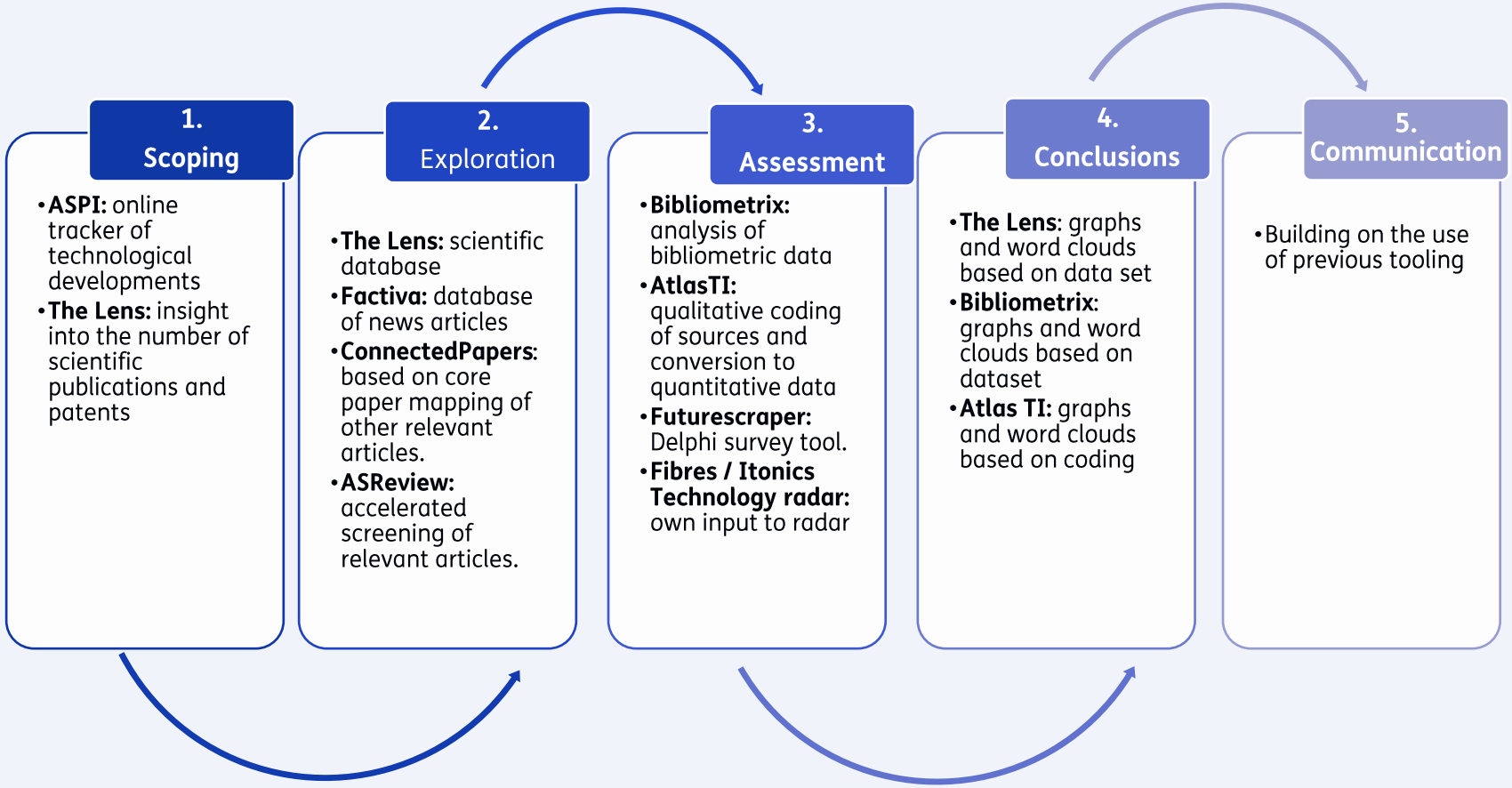
With what?

Supporting tooling

Within RVO TechWatch WP4: Methods and Tooling, research has been conducted into different types of tools and their functionalities for the purpose of carrying out a more efficient technology watch and assessment.

A distinction is made between; databases, tooling for analysing data, tooling for collecting and structuring sources, online trackers, online scrapers, tooling for horizon scanning/foresighting and survey tools.

The visualisation on the right shows which tools can be used in each step of a technology watch and assessment.



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Technology watchs within TNO

Some examples

Future Innovations Radar



Since 2014, TNO has been carrying out a continuous technology watch on behalf of the Ministry of Defence. The aim of this watch is to gain insight into possible technological innovations and to analyse the impact (opportunities and threats) of these innovations. The technologies are described by TNO, NLR and MARIN experts in the Future Innovations Radar. The estimated impact is then interpreted by domain experts from the Ministry of Defence.

Want to know more? Visit the Innovation Radar here.

Strategic Alert



As part of the Strategic Monitor of the Clingendael Institute and the Hague Centre for Strategic Studies, TNO has been asked to write a Strategic Alert. The purpose of this Strategic Alert was to identify important technological developments within two technology areas and to indicate the impact of these developments on national security.

Want to know more? Read the Strategic Alert Quantum Technology and Biotechnology here.

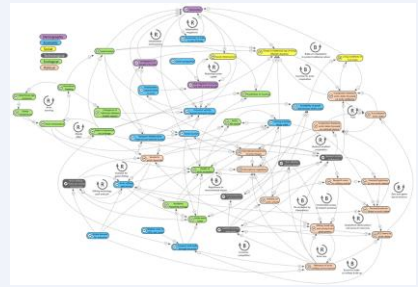
FOGUS



Commissioned by the National Cyber Security Centre (NCSC), TNO has developed a *Foresight Guide for Selecting methods* (FOGUS). This guide supports the user in selecting and familiarising themselves with the wide variety of foresight methods. The tool describes a range of methods commonly used in foresight activities and assists the user in selecting relevant methods by providing standardised features.

Want to know more? See here the link to FOGUS.

Integrated Strategic Foresight



Within the Risk Exploratory Research Programme of the Ministry of Defence, TNO has conducted a study into Integrated Strategic Foresight (ISF). Within this project, it was investigated to what extent the methodology based on Complex Systems Modelling is workable and offers added value for strategic future studies.

Want to know more? Read the internal memo here.

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Attachments

I. Appendix I: Example research questions to support step 1; Scoping

II. Appendix II: Example template describing technology as support of step 2; watch

III. Appendix III: TNO experts per method to support step 3; Assessment

Appendix II: Example template describing technology as support of step 2; exploration

[Technology Area]	
[Description]	
Relevant actor [Which key actors are at the forefront of the technology? (sharpening in the field of sub-technology), Type of actors; countries, companies, NGOs, (knowledge) institutes, criminal networks]	**Related technology fields**
Areas of application/sub-areas/sub-technologies (incl. TRL/CML) - A, TRL 4 - B - C - Etc.	
[Scope A] [Description: state of the art and future applications, major technological breakthroughs, timeline of development, links to other technology areas and added value through concrete application: - Process improvement, operational improvement - Possible future opportunities - Possible future threats	
[Scope B] [Description: state of the art and future applications, major technological breakthroughs, timeline of development, links to other technology areas and added value through concrete application: - Making the processes better/faster - Possible future opportunities - Possible future threats	
[Scope C] [Description: state of the art and future applications, major technological breakthroughs, timeline of development, links to other technology areas and added value through concrete application: - Making the processes better/faster - Possible future opportunities - Possible future threats	

Appendix III: TNO experts per method to support step 3; Assessment

Method	TNO-experts*
Marvel	• Eefje Smits-Clijsen • Guido Veldhuis • Peter van Scheepstal • Rob van Waas • Bas Keijser
Technology Roadmapping	• Imelda van de Voorde • Deborah Lassche • Clara Peters • Thijs van Engelen • Marcel-Paul Hasberg
Scenario Analysis	• Ingrid Bastings • Carolina van Weerd • Deborah Lassche • Peter van Scheepstal
Delphi	• Carolina van Weerd • Ingrid Bastings • Thijs van Engelen • Peter van Scheepstal