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Guide to Deployment Process and Operational Procedures used by NRENs, covering the whole life span of a fibre route

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LIST OF ACRONYMS AND ABBREVIATIONS

BER	Bit Error Rate
CLONETS	CLOck NETwork Services: Strategy and innovation for clock services over optical-fibre networks Project
CPO	Checked for Proper Operation
CRS	Checked in Regular Service
DWDM	Dense Wavelength Division Multiplexing
GIT	Guaranteed Intervention Time
GRT	Guaranteed Recovery Time
IRU	Indefeasible Right of Use
LLD	Low Level Design
NAT	Network Acceptance Test
NE	Network Element
NOC	Network Operational Centre
NREN	National Research and Education Network
NSOC	Network Service Operational Centre
OTDR	Optical Time Domain Reflectometry
POC	Proof of Concept
PoP	Point of Presence
QOS	Quality Of Service
SPOF	Single Point Of Failures

LIST OF PROJECT PARTNER ACRONYMS

AGH / AGH-UST	Akademia Górniczo-Hutnicza im. Stanisława Staszica w Krakowie, Cracow, Poland
CESNET	CESNET, zájmové sdružení právnických osob, Prague, Czech Republic
CNRS*	Centre National de la Recherche Scientifique, Paris, France
INRIM	Istituto Nazionale di Ricerca Metrologica, Turin, Italy
GARR#	Gruppo per l'Armonizzazione delle Reti della Ricerca, Rome, Italy
Menlo	Menlo Systems GmbH, Martinsried, Germany
Muquans	Muquans, Talence, France
NPL	National Physical Laboratory, Teddington, United Kingdom
OBSPARIS¶	Observatoire de Paris, Paris, France
OPTOKON	OPTOKON a.s., Jihlava, Czech Republic
Piktime Systems	Piktime Systems sp z o.o., Poznan, Poland
PSNC	Instytut Chemii Bioorganicznej Polskiej Akademii Nauk – Poznańskie Centrum Superkomputerowo-Sieciowe, Poznan, Poland
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UCL	University College London, London, United Kingdom
UP13	Université Paris 13, Villetaneuse, France
UPT AV CR (ISI)	Ustav Pristrojove Techniky AV, v.v.i., Brno, Czech Republic

* linked third party to OBSPARIS; # third party to INRIM; ¶ coordinator

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[3] http://ec.europa.eu/growth/single-market/public-procurement/rules-implementation_en

[4] http://europa.eu/youreurope/business/public-tenders/rules-procedures/index_en.htm

[5] "Background and Recommendations on Indefeasible Rights of Use", http://eblackcu.net/portal/archive/files/executive-summary-iru-document-20110513---final_be895a000a.pdf

EXECUTIVE SUMMARY

The deliverable D1.4 reviews the deployment process of optical fibre links followed by NRENs (National Research and Education Networks) and the operational procedures during their lifetime. The backbones of the NRENs' fibre networks are in constant evolution, as the NRENs are continuously aiming to improve the speed, reliability and security of their networks. Therefore the NRENs are regularly increasing their data bandwidth, deploying new fibre links or removing obsolete ones.

Because, the network deployment process is long and involves many in-depth studies from different (e.g. legal, technical, financial) departments of the NREN, a lot of foresight is needed. It includes the awarding of public contracts (9 months), a deployment phase (up to 1 year) and requires verification tests of operation (3 months). Therefore, generally 2 years before the end of a fibre link contract, the renewal of the fibre link is investigated and, if applicable, either the deployment or decommissioning process is started.

In order to implement new services in NREN backbones, for example a time and frequency transfer, it is important to have a good understanding of the deployment process (from planning to commissioning) and the operational procedures (e.g. supervision, planned maintenance, reaction to faults etc.) followed by NRENs. In this document, we present the general procedure and the main steps involved in the deployment of an optical fibre link within the NREN's architecture:

- Phase 1: Planning the deployment (Section II);
- Phase 2: Commissioning the optical link (Section III);
- Phase 3: Maintaining the link in an optimal operating condition (Section IV);
- Phase 4: Decommissioning the link (Section V);

and illustrate the steps with flowcharts.

I. INTRODUCTION

A National Research and Education Network (NREN) is a specialised Internet service provider to the research and educational communities within a country. NRENs provide connectivity and services to higher education establishments (typically universities) and research institutes, but also support schools, further education colleges, libraries and other public institutes. In some cases, services are provided to government and healthcare sectors as well [1]. There usually is only one recognised NREN in each country, although some countries have separate networking organisations for different research and educational sectors. In larger countries, it is also common to have separate regional or metropolitan networks, which are interconnected by the NREN.

Research and education establishments were amongst the first users of computer networks, and have therefore played an important role in the development of the Internet. They have traditionally been early adopters of new technologies (new Internet protocols like IPv6 and IP multicast and new architectures client/server and Cloud computing), and continue to play an important role in the establishment of new services.

As part of the CLONETS project, they are valuable partners in studying the deployment of revolutionary CLOck NETwork Services, i.e. metrological time and frequency services generated by atomic clocks [2]. In order to implement these new services in NREN backbones, scientific equipment dedicated to metrological services needs to be deployed. Therefore scientists need to have a good understanding of the way NRENs deploy the optical layer of their architecture. In this document we present the general procedure and the main steps involved in such a deployment:

- Phase 1: Planning the deployment;
- Phase 2: Commissioning the optical link;
- Phase 3: Maintaining the link in an optimal operating condition;
- Phase 4: Decommissioning the link

II. PLANNING THE DEPLOYMENT

II.A Fibre network design

There is a worldwide demand for faster, more reliable and safer telecommunication networks. This growing need has kept rising for many years and pushes NRENs to rapidly respond. Their network's backbone is therefore in constant evolution. NRENs increase their data bandwidth or deploy new fibre links (optical fibres connecting two extremity sites) to strengthen the network or, on the contrary, remove fibre links, for instance at the end of a specific project.

II.A.1 Renewal of a fibre link

Generally two years before the end of every fibre contract, the NREN's legal department and network operating teams discuss whether a fibre link should be renewed or not, depending on the demand and overall network performances. This brainstorming occurs early in the process as renting fibres is expensive and a public competition has to be published in agreement with national and European market rules [3]. Anticipation is the key, as the process is long; it includes the awarding of public contracts (9 months), a deployment phase (up to 1 year) and requires verification tests of operation (3 months). It may even be advised to additionally run a preliminary market study of fibre stakeholders, in order to maximise the incoming public market (timing, existence of alternative fibre links, etc).

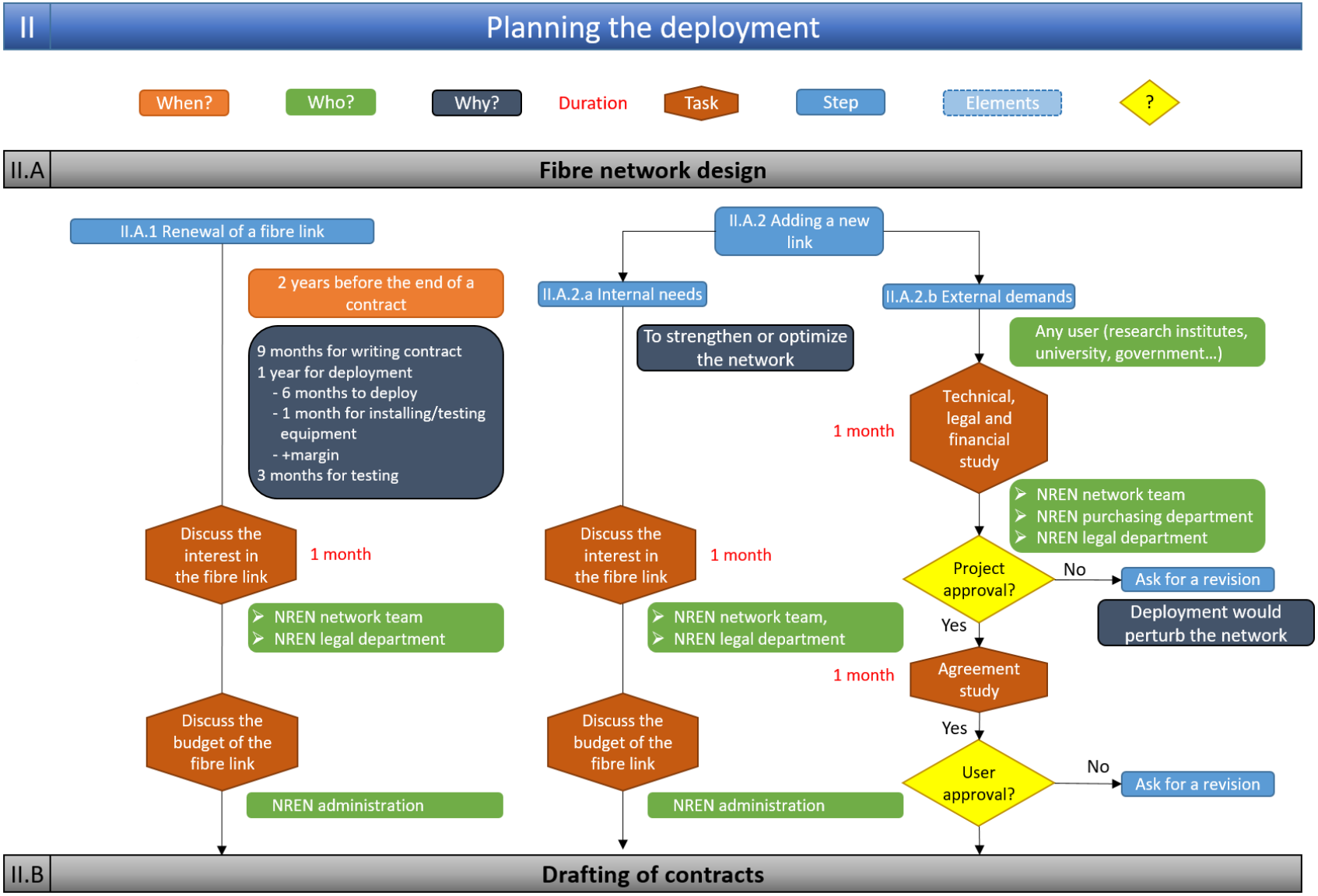

Figure 1. Planning the deployment: Fibre network design.

II.A.2 Adding a new link

II.A.2.a Internal needs

A backbone is a really complex structure. Different kinds of topologies are implemented based on the amount of data traffic delivered to end-users 24/7/365. Several levels of protections are deployed to prevent any discontinuity in the traffic flow and ensure that any failure or incident on a fibre link, forcing data to be rerouted, is taken care of by the rest of the network. Therefore, the strengthening and the optimisation of the backbone by deploying new optical links is a constant concern for telecommunication networks guaranteeing a resilient quality of service.

II.A.2.b External demands

Every NREN is a close stakeholder to research and education and as well as to new scientific development. They provide the scientific community with their expertise in operating a wide telecommunication network. They act as a catalyst, for example by enabling the realisation of tests under real network conditions or by connecting distant research infrastructures.

II.A.2.b.i Technical study

After a new demand has been submitted to an NREN, the network's engineering team leads a technical review evaluating its feasibility. This study is usually concluded within a month and includes exchanges between all involved parties. It also aims to determine if the technical specifications asked are consistent with the demand.

II.A.2.b.ii Legal and financial agreement

At the same time, the NREN's legal and purchasing departments set up an appropriate agreement framing the user's demand. Various legal restrictions in different countries should be kept in mind. An international connection may be an additional challenge in a legal agreement. It is important that these discussions are led in parallel, so that no unnecessary work is done. For example, if adjustments required for the project threaten the network integrity, there is no need for an in depth administrative and financial analysis. On the other side, if the estimated budget is too expensive or if no contractual framework for the user exists, a technical study is pointless. Finally, once all parties have agreed on the legal, technical and financial aspects and the agreement has been signed by the user, the NREN can start working on a dedicated contract with fibre and optical network equipment providers.

II.B Drafting of contracts

At this point, there are two options. Either the NREN asks for a turnkey project managed by a telecommunication operator (the easiest but expensive solution), or the NREN controls the implementation of the network and has project ownership.

We point out that a telecommunication network may prefer to finance the deployment of new fibre links itself, in which case it owns its network and therefore does not require fibre contract at all.

Only private operators with a huge financial capacity are able to employ this economic strategy. Therefore, we describe the more common cases, in which the NRENs have fibre contracts and a good control over the deployment.

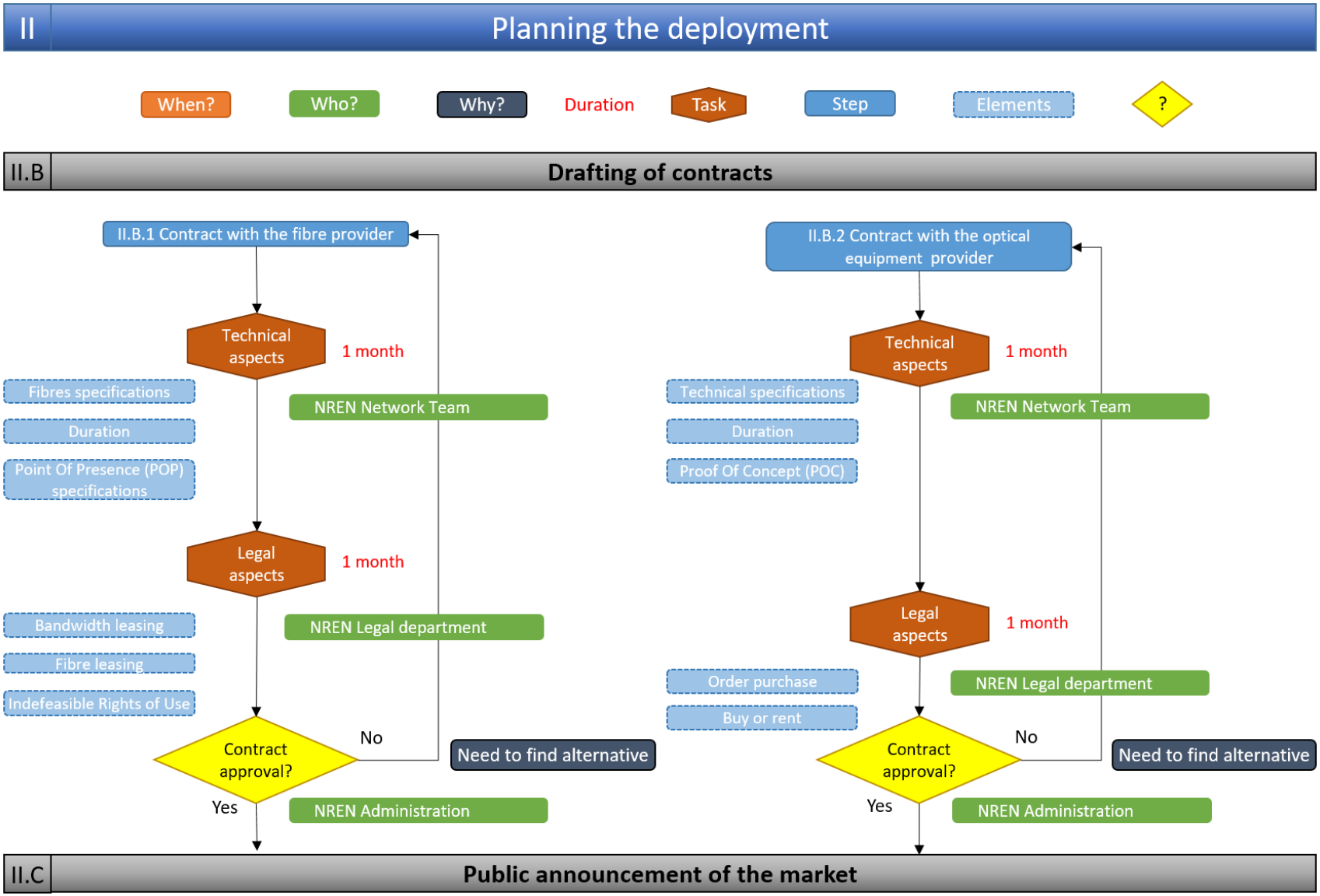

Figure 2. Planning the deployment: Drafting of contracts.

Type of contract	Description	Duration	Financial aspects	Legal aspects	Technical aspects
IRU (Indefeasible Right of Use) *Backbone fibres*	This type of contract is strongly associated with telecommunication networks as fibre cable owners do not normally sell their fibres but offer IRUs. An IRU is a permanent contractual agreement between the owners of a communication system (fibre optical provider in our case) and a customer of that system. The word "indefeasible" means "not capable of being annulled, or voided, or undone". The customer buys the exclusive use of one or more fibres in a fibre optic cable.	IRU contracts are almost always long term (between 10 and 30 years).	This contract obligates the purchaser to pay a portion of the operating and cable maintenance costs, including any costs that incurred for the repair of the cable after a mishap. There is a large up-front payment, i.e. a fibre access fee.	IRUs imply rights and obligations of co-ownership during the contract.	An IRU contract defines detailed technical and performance specifications for the IRU fibres. It can include dark fibre acceptance and testing procedures, the description of the dark fibre's physical route, operating specifications for the dark fibre infrastructure (renting of Point of Presence (PoP) shelters where amplifiers are deployed*), performance specifications (attenuation, chromatic dispersion, polarization mode dispersion, optical return loss…), maintenance and restoration terms. These terms must be valid for the full duration of the IRU contract.
Fibre leasing *Urgent need or a rather short term project*	This type of contract is a simpler version of an IRU. A fibre leasing purchaser will use his own optical equipment to illuminate the fibre. This contract occurs if IRU contracts are not possible or if the link is needed only for a few years, e.g. until a more significant public procedure for IRU fibres is awarded.	Based on the demand	This structure gives the fibre provider a steady income stream (yearly, bi-annual, monthly…), without any large up-front payment.	The purchaser has no ownership responsibility.	As for an IRU, this contract defines detailed technical and performance specifications for the purchased fibres. These terms must be valid for the full duration of the contract
Bandwidth leasing *Low data traffic link*	This type of contract is the least flexible for the NREN, which only pays for a fixed bandwidth. They have the advantage to be easy and quick to set up and mostly occur on an urgent or low data rate demand or when no IRU or fibre leasing is possible.	Based on the demand	This structure gives the fibre provider a steady income stream (yearly, bi-annual, monthly…), without any large up-front payment.	The NREN will use the provider's optical equipment	Only specifications on the Quality Of Service (QOS) are set out in this type of contract.

***** The NREN may also ask the fibre provider about technical aspects of the PoP shelters (e.g. shelves, where the equipment will be deployed, may be provided, a secured and easy access to the shelter, a secured power supply, etc.).

Table 1. Type of contracts with fibre providers (non-exhaustive list).

II.B.1 Contract with the fibre provider

It is common for NRENs to use one of the three following types of contracts:

- IRU (Indefeasible Right of Use) [5];
- fibre leasing;
- bandwidth leasing.

Several aspects of these contracts are compared in Table 1, whereby the list is by no means exhaustive.

II.B.2 Contract with the optical equipment provider

During the whole duration of the contract, the scope of the agreement with an optical equipment provider may include:

- every study on the optical transport required for the operation of the network;
- the supply of all optical equipment and its software;
- the supply of any complementary materials (optical fibres, shelves, supervising equipment, etc.);
- the deployment of this equipment;
- the migration of services from old optical equipment to new equipment;
- the removal of optical equipment that is no longer needed;
- the maintenance of all equipment deployed during the running contract in an optimal condition;
- the upgrade to any mentioned technology (flex grid, statistical multiplexing, coherent technology, etc.);
- the training of the NREN's network engineering team to use their technology.

An agreement with an optical equipment provider can last from 2 to 6 years. NRENs mostly own their optical equipment to simplify maintenance procedures and contracts, however, in some cases they may prefer to rent it.

Writing the contract is a long process that requires a close interaction between the network engineering team and the legal department. An estimated 2 to 3 months of work are needed before a final version of the document is approved and can be published.

II.C Public announcement of the market

The market is then published on an online platform as a competitive public market. There are several types, which are briefly described in this section. It is important to keep in mind that these procedures vary from country to country depending on national laws or other internal regulations. All the procedures can be found in [4] and abide by European Law concerning public market procedures.

II.C.1 Open procedure

In an open procedure any business can submit a tender. The minimum time limit for submission of tenders is 35 days from the publication date of the contract notice. If a prior information notice has been published, this time limit can be reduced to 15 days.

II.C.2 Restricted procedure

Any business may ask to participate in a restricted procedure, but only those who are pre-selected will be invited to submit a tender. The time limit to request participation is 37 days from the publication of the contract notice. The Public Authority then selects at least 5 candidates with the required capabilities, who then have 40 days to submit a tender. This time limit can be reduced to 36 days, if a prior information notice has been published. In urgent cases the Public Authority may set a time limit of 15 days for participation requests (if the notice is sent electronically, this can be reduced to 10 days) and 10 days for the submission of the tenders.

II.C.3 Negotiated procedure

In a negotiated procedure the Public Authority invites at least 3 businesses with whom it will negotiate the terms of the contract. Most contracting authorities use this procedure only in a limited number of cases, for example for supplies intended exclusively for research or testing purposes. The contracting authorities in sectors such as water, energy, transport or postal services may use it as a standard procedure. The time limit to receive requests for participation is 37 days from the publication of the contract notice. This can be reduced to 15 days in urgent cases, or 10 days if the notice is sent electronically.

II.C.4 Competitive dialogue

This procedure is often used for complex contracts such as large infrastructure projects where the Public Authority cannot define the technical specifications at the start. After the publication of the contract notice, interested businesses have 37 days to request participation. The Public Authority must invite at least 3 candidates to a dialogue in which the final technical, legal and economic aspects are defined. After this dialogue, candidates submit their final tenders.

II.D Evaluation of tenders

Public Authorities use different criteria when evaluating tenders, each of them granting a certain amount of points. Generally, there are two main criteria (price offered, technical pertinence) with sub criteria (maintenance, technical performances, environmental aspects, etc.). Each applicant is informed of the different weights given to the different criteria (i.e. price, technical characteristics and environmental aspects). Public Authorities only start evaluating tenders after the expiration of the submission deadline. As these are high budget markets, NREN prefer using competitive dialogue procedures (Section II.C.4). Several rounds of discussion are organized and businesses have the opportunity to modify their tender to be as competitive as possible. Every round can last up to 15 days and will require the NREN to re-evaluate the businesses' tenders.

The Public Authority may also ask for a "Proof of Concept" (POC) to test the provider's procedure. This test may affect the evaluation of the submitted tender.

II.E Official publication of the market holder

The business that submitted the best compliant tender is officially designated as the "Holder" of the market. Companies that have submitted a tender, have the right to be informed of the statement as soon as possible independent of whether they have won the contract. If they have not been selected, they are entitled to a detailed explanation for the rejection and can ask for an appeal within 15 days. This period is called a "standstill". The Public Authority must observe strict confidentiality regarding the exchange and storage of their data.

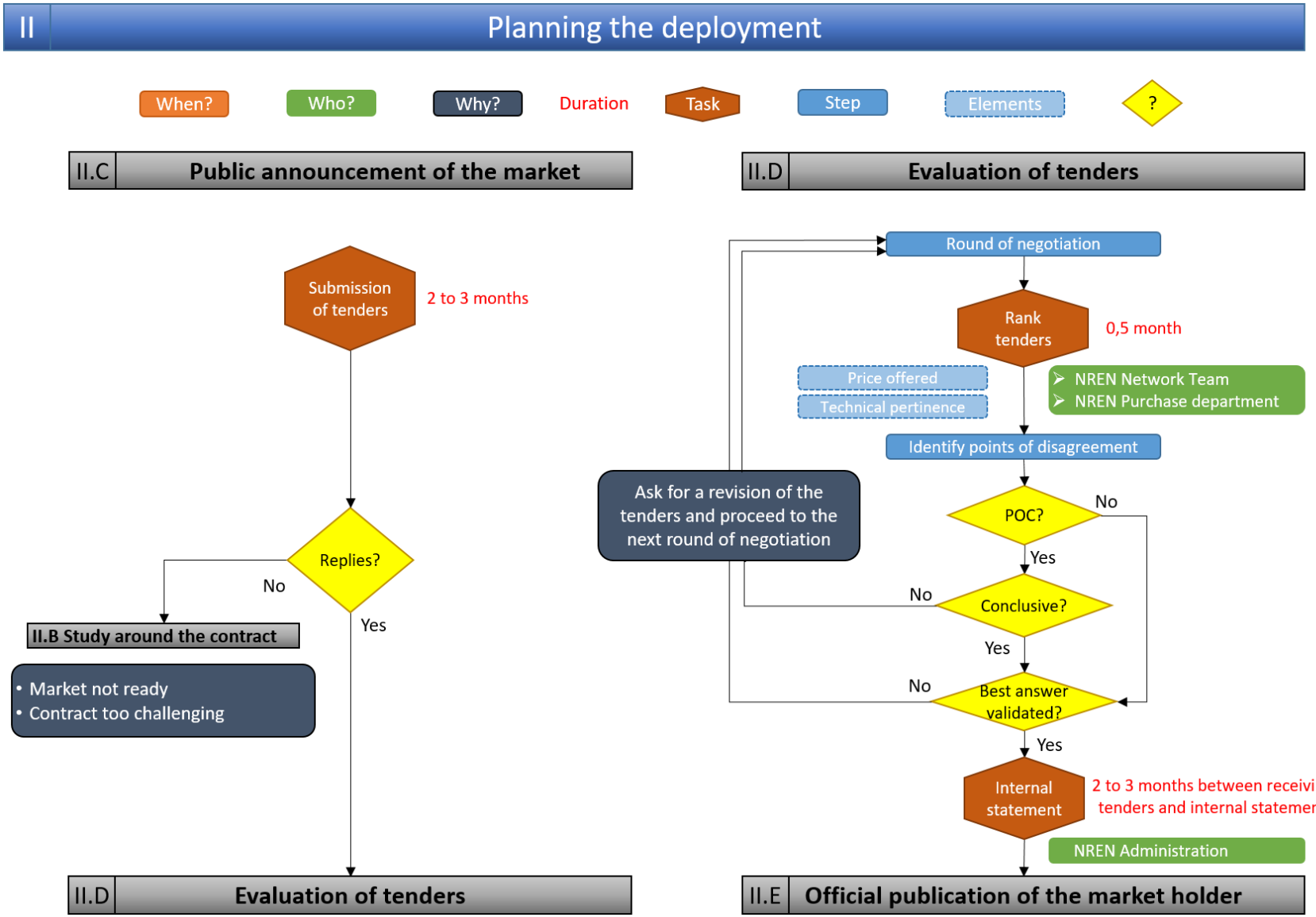

Figure 3. Planning the deployment: Public announcement of the market and Evaluation of tenders.

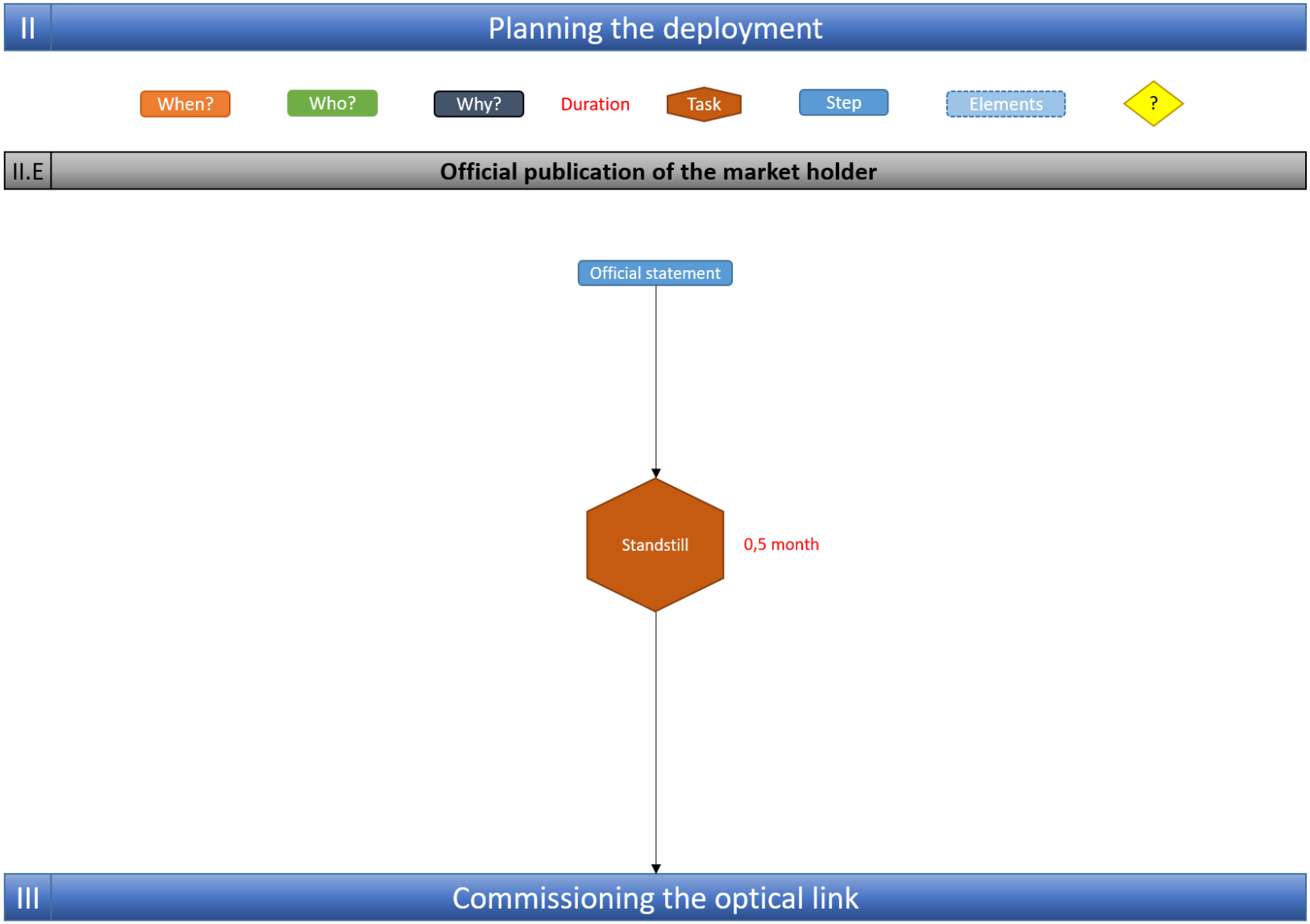

Figure 4. Planning the deployment: Official publication of the market holder.

III. COMMISSIONING THE OPTICAL LINK

As every NREN operates differently, elements within fibre/optical equipment contracts can be different (schedule, procedures, deliverables…). The commissioning can be roughly differentiated into 3 categories:

- Turnkey project: The Fibre provider controls every step of the deployment, testing and operation.
- Half-way contract: If the NREN has provided a full description of its need (technical specifications, Single Point of Failures (SPOF), scheduling constraints), the first interactions with fibre provider only occur after the fibre is delivered and fully deployed.
- Controlled contract: Some NRENs prefer this type of arrangement. Both parties have regular exchanges and the NREN has a good overview of deployment progress.

The flowchart in Figure 5 describes the third type of contract for both the deployment of a fibre and that of optical equipment.

III.A Deployment of the fibre

The realisation of the deployment of the fibre has 3 main steps (depending on the type of contract):

- Phase 1: Kick-off meeting
- Phase 2: Deployment
- Phase 3: Testing phase

A validation at the end of each phase is necessary before next phase can start. At the end of phase 3, the equipment is checked for regular service and the fibre link is considered operational.

III.A.1 Kick-off meeting

Once the market has officially been awarded, the Holder will appoint a project manager to deploy the fibre. At the kick-off meeting, he presents a precise schedule as well as a technical solution. A kick-off meeting is not mandatory, if in the process all parameters have been agreed on in advance. However, this meeting ensures that every parameter concerning the deployment will indeed be respected. Fibres are not always readily deployed and some engineering may be needed to ensure the fibre pathway characteristics comply with the contract. Deployments may face issues that force fibre road paths to be modified. If so, the project manager will submit and discuss these modifications. Amendments and agreements can be made, but contractual commitments remain (scheduled deadline, technical characteristics, etc.)

III.A.2 Project monitoring

III.A.2.a CPO: Checked for Proper Operation

After the deployment is completed (fibre and shelters), the Holder leads a measurement campaign (Optical Time Domain Reflectometry (OTDR) and optical budget of the fibre link) as specified in the contract. The results are compiled in a test report and submitted to the NREN. The delivery of the fibre triggers the next phase, the so-called Checked for Proper Operation (CPO) phase. The NREN optical engineers evaluate the report within two weeks and either accept it or ask for adjustments. If adjustments are necessary, the fibre provider has two weeks to implement modifications and submit a new test report. This is repeated until an agreement is found. Once everything has been approved, the project can move to the next phase.

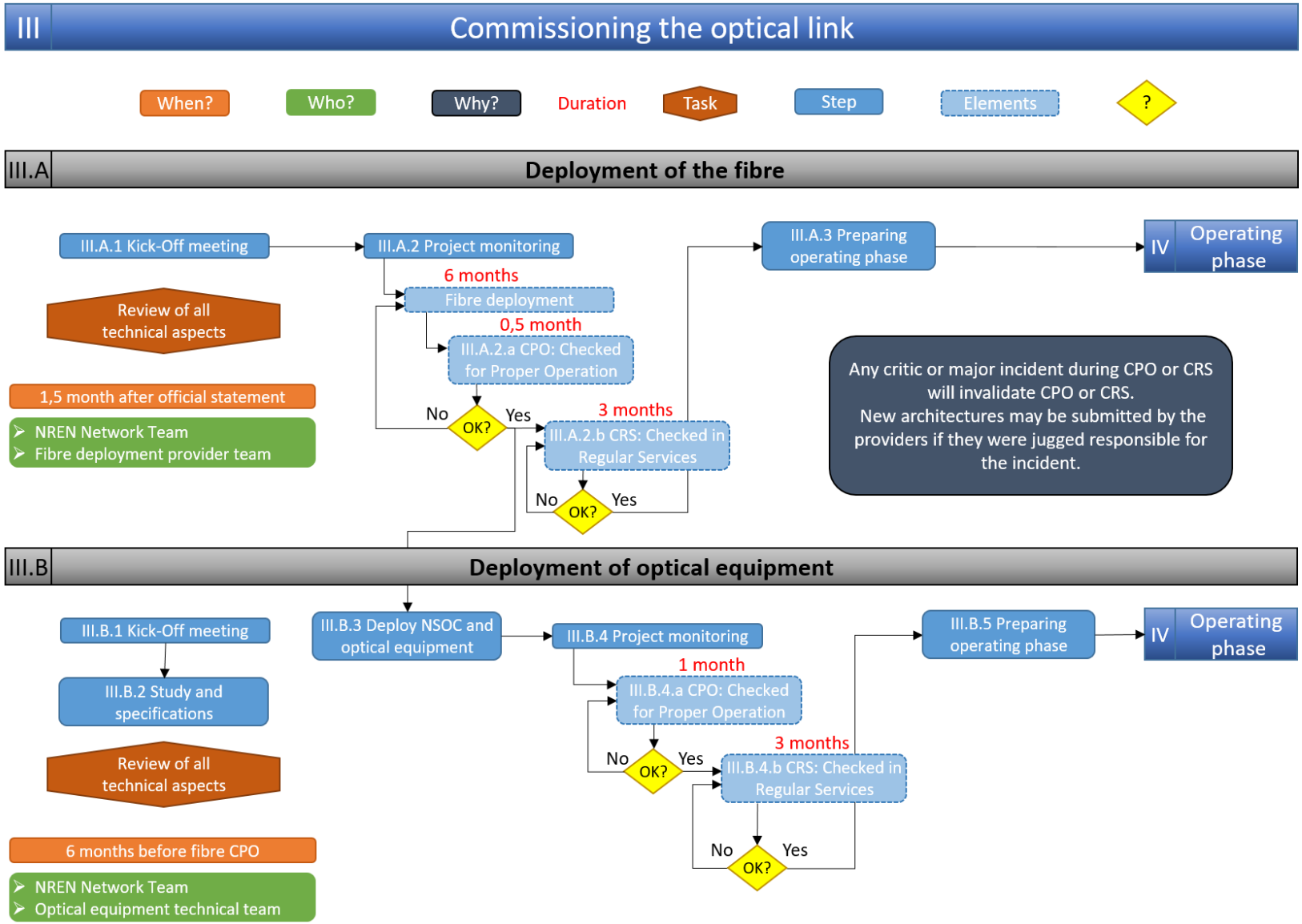

Figure 5. Commissioning the optical link: Deployment of the fibre and Deployment of optical equipment

III.A.2.b CRS: Checked in Regular Service

After the CPO has been approved, the NREN then tests the link under real conditions. The Checked in Regular Service (CRS) phase aims to verify the stability of the performance and a good functionality of the deployed equipment over a time period that ranges from one month up to three months. Real data traffic now propagates through the link. At the end of the observation period:

- If the verification has been approved, the link can be set in "operating" mode
- If not, the NREN will ask for a referral/adjournment with a restart of the observation period

III.A.3 Preparing the operational phase

At the end of the CRS phase, the link is considered to be operational. All information related to the deployment is collected and sent to the Network Service Operational Centre (NSOC) who then is responsible for maintaining the link in an optimal operating condition.

III.B Deployment of optical equipment

The realisation of the deployment of optical equipment has 4 main steps (depending on the type of contract):

- Phase 1: Kick-off meeting
- Phase 2: Study and specification
- Phase 3: Deployment
- Phase 4: Testing phase

Again, a validation at the end of each phase is necessary before the next phase can start. At the end of phase 4, the equipment is checked for regular service and the link is considered operational.

III.B.1 Kick-off meeting

As for optical fibre deployment, once the market has officially been awarded, the Holder of optical equipment contract will appoint a project manager who will coordinate the deployment of both optical and supervising equipment, as well as the management of the test phases.

III.B.2 Study and specification

This phase consists in studying the characteristics of the fibre (based on the information provided in the fibre contract) and the list of services the NREN wants to implement (metrological links for instance require additional equipment and will therefore add losses). The Holder elaborates an optimised optical network architecture (a "Low Level Design" (LLD)) specifying the type of equipment that should be deployed, any technical constraints, the power needed, etc.

> The NREN may ask for a POC, for instance, to test whether the migration of services between the existing architecture and the Holder's architecture or whether the deployment of any new Network Elements (NEs) can be done without any troubleshooting.

As soon as possible, the Holder visit every sites where equipment is to be deployed and confirms whether or not it is possible to install the new optical equipment. We highly recommend to carefully list all the services needed as adding any new equipment after the deployment is completed will disrupt the optimised architecture.

III.B.3 Deployment of NSOC and equipment

When the CPO analysis on the fibre part begins, the real characteristics of the fibre link are sent to the optical equipment supplier for a possible adjustment of the LLD. The optical provider then starts deploying and configuring the equipment (both for the optical and supervision part) as agreed in the LLD. A Network Acceptance Test (NAT) is written by the optical provider and includes measurements on the quality of the optical link such as:

- Power redundancy tests;
- Dense Wavelength Division Multiplexing (DWDM) optical infrastructure/network topology;
- tests of migrated services (Bit Error Rate (BER) stats, jitter, etc.);
- optical characteristics (attenuations, round trip delay, etc.).

III.B.4 Project monitoring

III.B.4.a CPO: Checked for Proper Operation

So far only virtual data traffic is sent in the fibre. The NREN has to check whether every NE is well configured and to validate the Quality Of Service (QOS) of the optical transmission based on the NAT. The NREN also checks whether the supervision is well integrated in the NSOC control map. This phase lasts up to a month.

III.B.4.b CRS: Checked in Regular Service

After the CPO has been approved, the NREN then tests the link under real conditions. The CRS phase aims to verify the stability of the performance and a good functionality of the deployed equipment over a time period that ranges from one month up to three months. Real data traffic now propagates through the link. At the end of the observation period:

- If the verification has been approved, the link can be set in “operating” mode.
- If not, the NREN will ask for a referral/adjournment with a restart of the observation period.

III.B.5 Preparing the operational phase

At the end of the CRS phase, the link is considered to be operational. All information related to the deployment is collected and sent to the NSOC who then is responsible for maintaining the link in an optimal operating condition.

III.C Particular cases: links already in the operating phase

In the previous sections, we have just described a standard situation for which a new fibre link is equipped with optical equipment. Two other main cases can happen as optical and fibre contracts do not start or end at the same time.

III.C.1 Switching on a new fibre

We can have the situation where only the fibre provider changes. For example, as shown in the flowchart of Figure 6, we have to switch from fibre #1 to fibre #2. To make sure data traffic is impacted as little as possible, the NREN will ask the optical equipment provider to equip and configure the new fibre with a “cloned” photonic line. At an appropriate date and time (generally during the night when traffic is low), fibre #1 is disconnected at the extremity sites of the link and instantaneously, the new fibre #2 is plugged in. From then on, the services will be sent over the new fibre path.

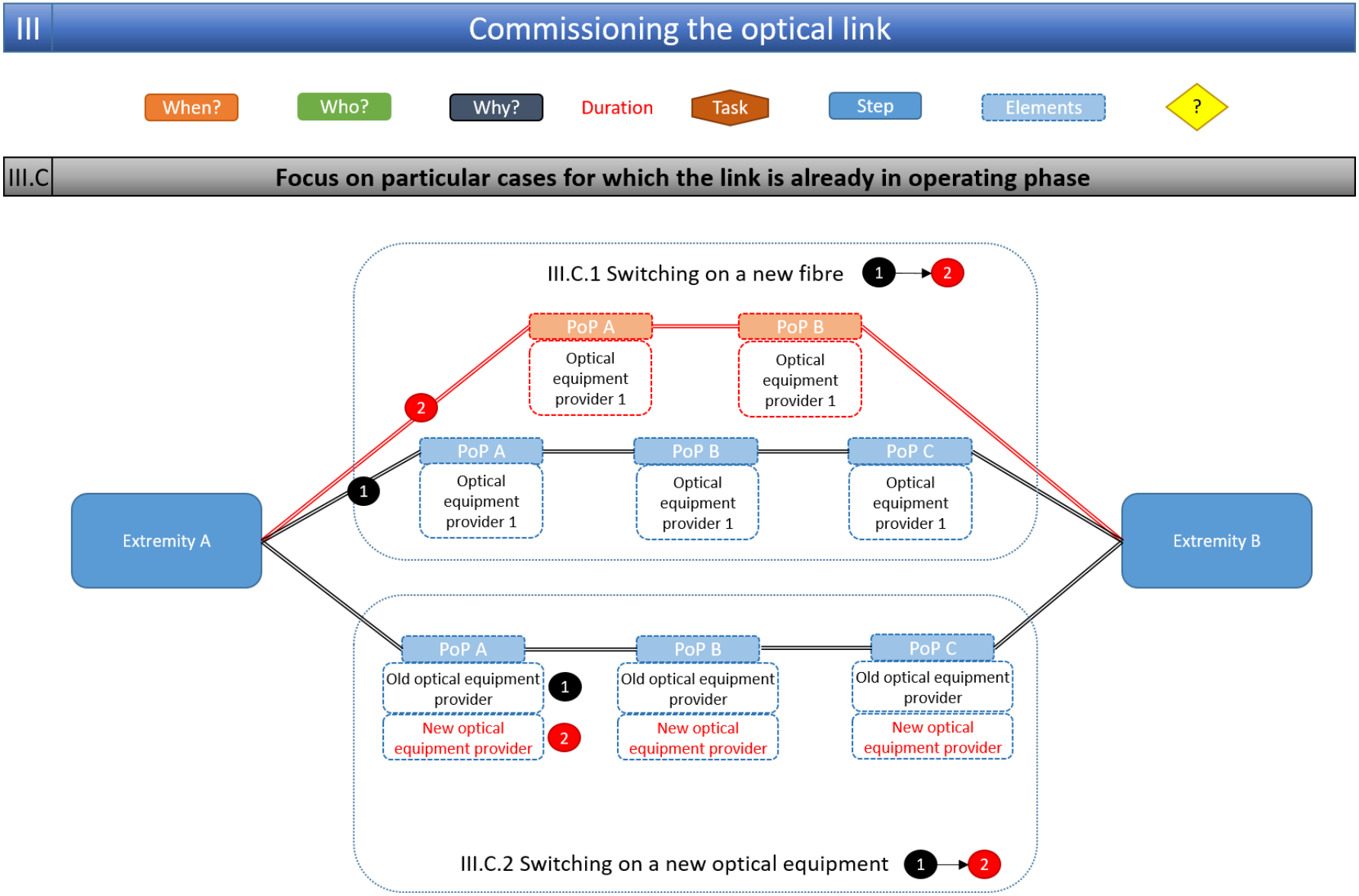

Figure 6. Commissioning the optical link: Particular cases: links already in the operating phase.

III.C.2 Switching on new optical equipment

We can also have the situation where only the optical provider changes (from #1 to #2). At an appropriate date and time (generally during the night when traffic is low) and at every Point of Presence (PoP), the fibre is disconnected from the optical equipment of the old provider and reconnected to the equipment of the new provider, who from then on provides the services. Whenever these situations occur, the NREN always keeps the previous setup in place, in order to have the possibility to roll-back if needed. Decommissioning only starts after the CRS of the new setup has been fully approved.

IV. MAINTAINING AN OPTIMAL OPERATION CONDITION

IV.A NSOC: Network Service Operational Centre

The NSOC is the organization responsible for maintaining the network in an optimal operating condition. It can either be internal to the NREN or outsourced to a private company. The NSOC's responsibility consists of:

- global supervision of the network (check QOS alarms…);
- management and monitoring of the network resources;
- administration of the network security (physical as well as IT);
- management of the network evolutions (tests and implementation of software, plug-ins, new functionalities, etc.);
- coordination of all service providers interacting with the network including support services.

IV.B Reaction to fault

The management of incidents is guaranteed 24/7/356. When an incident occurs, the NSOC is in charge of:

- performing the appropriate diagnostics on the impacted equipment;
- resolving the incident within the scope of its responsibility;
- setting up maintenance interventions (for instance, when a material upgrade or replacement are required);
- sending detailed reports after every major change/progress in the incident evolve procedure.

- **Step 1**: An incident begins whenever an alarm is sent to the Network Operational Centre (NOC) through its supervising platform.
- **Step 2**: The NSOC generates a ticket associated with the incident and instantly (within 15 minutes) informs the NREN.
- **Step 3**: A first analysis is done and the incident is categorized based on the impact on the network (see Table 2).

Category	Incident
Critical incident	• impacts the NSOC supervision platforms • interrupts data traffic
Major incident	• prevents an intervention to be carried out (e.g. the implementation of any new network equipment or the upgrade of any equipment) • leads to the degradation of QOS (increased attenuation without any traffic interruption)
Minor incident	• changes a technical parameter without degrading the QOS.

Table 2. Categorization of fault incidents.

- **Step 4**: In case of a critical or major incident, the NSOC communicates the detailed step reports mentioning the nature of the fault, the impact on the services and the way the incident is being managed and when the next information should be sent. If there isn't any progress in the expected time frame, an information update and the reason for the delay are sent.
- **Step 5**: If the incident requires a third party intervention (for example, if the replacement of an optical DWDM card is needed), the NSOC is in charge of creating, supervising and closing the tickets with the third party's maintenance service.
- **Step 6**: The NSOC supervises the resolution of the incident.
- **Step 7**: After the services have returned to normal, the NSOC produces a detailed report on the incident and informs the NREN of the closure of the ticket.

Two conditions that are often contracted with organisations involved in the supervision are Guaranteed Intervention Time (GIT) and Guaranteed Recovery Time (GRT). As soon as a ticket is opened, the GIT and GRT have to be complied with. Their exact values may vary between the different NRENs; Table 3 below gives typical values.

Category	GIT (Guaranteed Intervention Time)	GRT (Guaranteed Recovery Time)
Critical incident	< 4 hours 24/7/365	< 15 hours 24/7/365 (terrestrial right of way) < 48 hours 24/7/365 (fluvial right of way) < 72 hours 24/7/365 (aerial right of way)
Major incident	< 4 hours 24/7/365	< 48 hours 24/7/365 (terrestrial right of way) < 48 hours 24/7/365 (fluvial right of way) < 72 hours 24/7/365 (aerial right of way)
Minor incident	< 30 days 24/7/365	< 30 days 24/7/365

Table 3. Typical values of GIT and GRT.

IV.C Planned maintenance

Planned maintenance stands for any proactive task enabling the network to be maintained in an optimal operating state. Planned maintenance can consist in:

- Software maintenance:
  - minor software updates;
  - security patches;
  - functional patches.
- Material maintenance, for which the NSOC:
  - schedules a preventive intervention (e.g. switching of ineffective optical modules or twisted optical fibres, checking power supplies, etc.) in order to detect irregularities in the network;
  - supports any intervention after a material failure;
  - guarantees the compliance of the installations.

Third parties can carry out planned maintenance if approved by the NSOC. Planned maintenance windows can be postponed if the network integrity is momentarily at risk. If so, the NSOC will propose alternative dates.

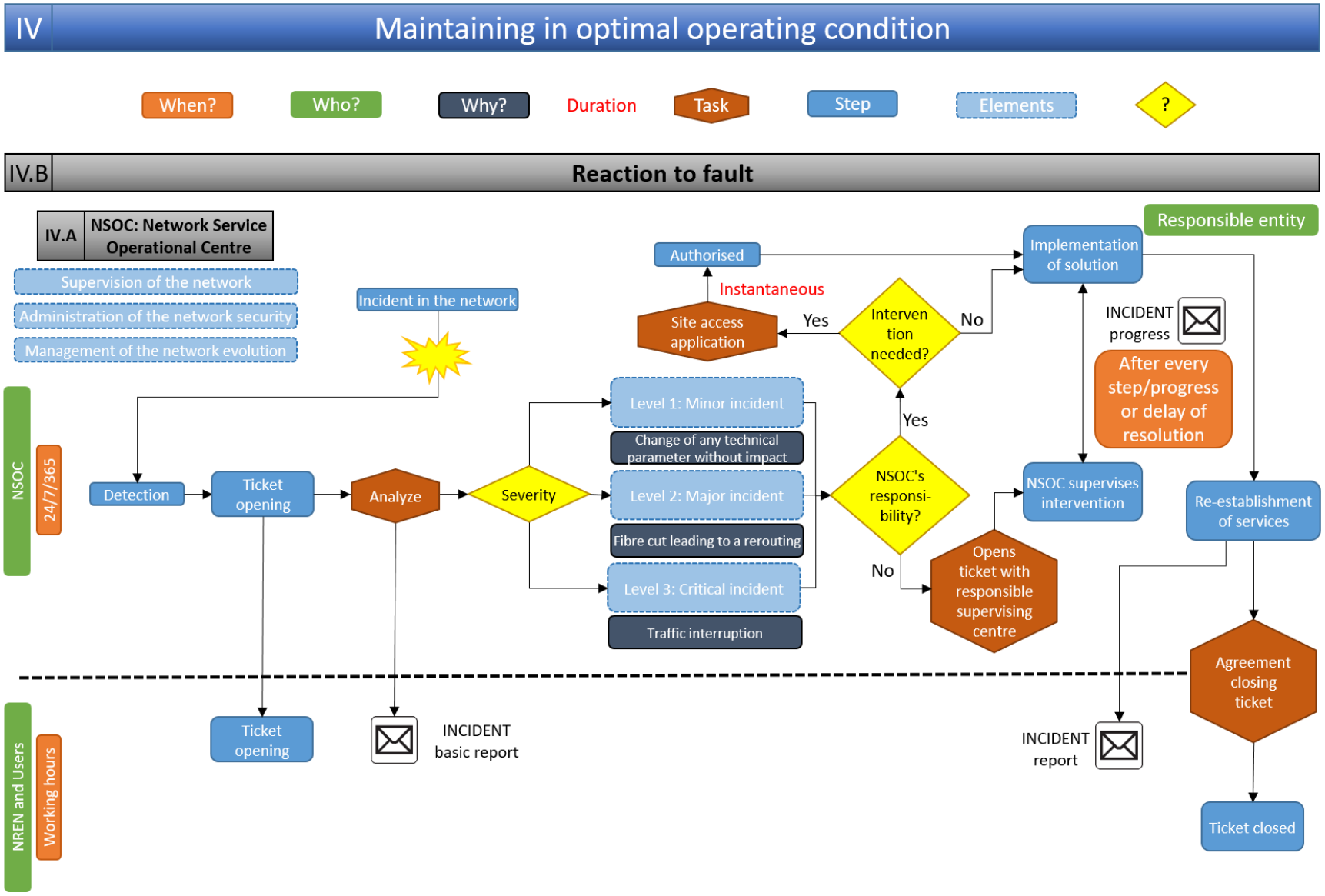

Figure 7. Maintaining in optimal operation condition: Reaction to fault**.**

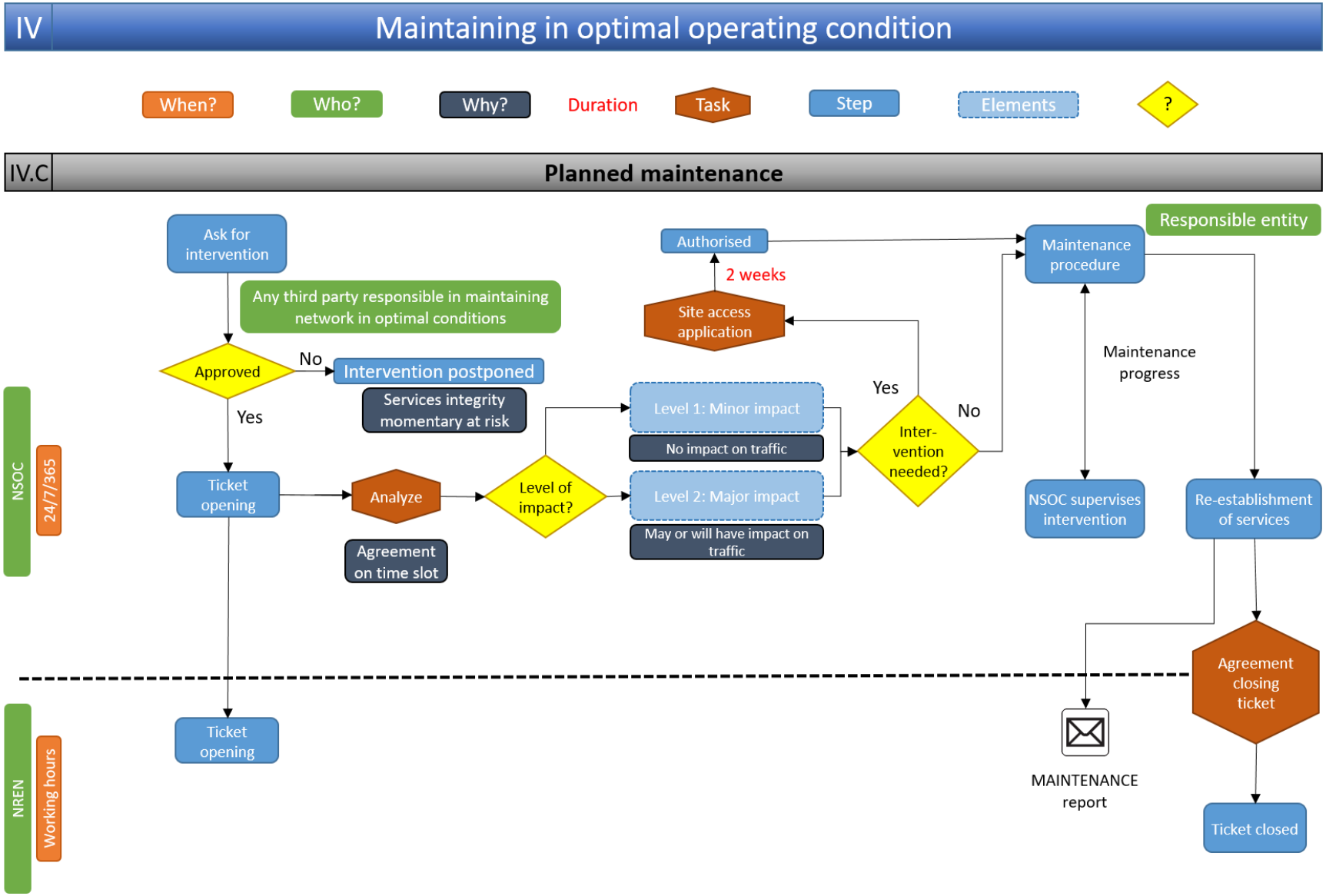

Figure 8. Maintaining in optical operating condition: Planned maintenance.

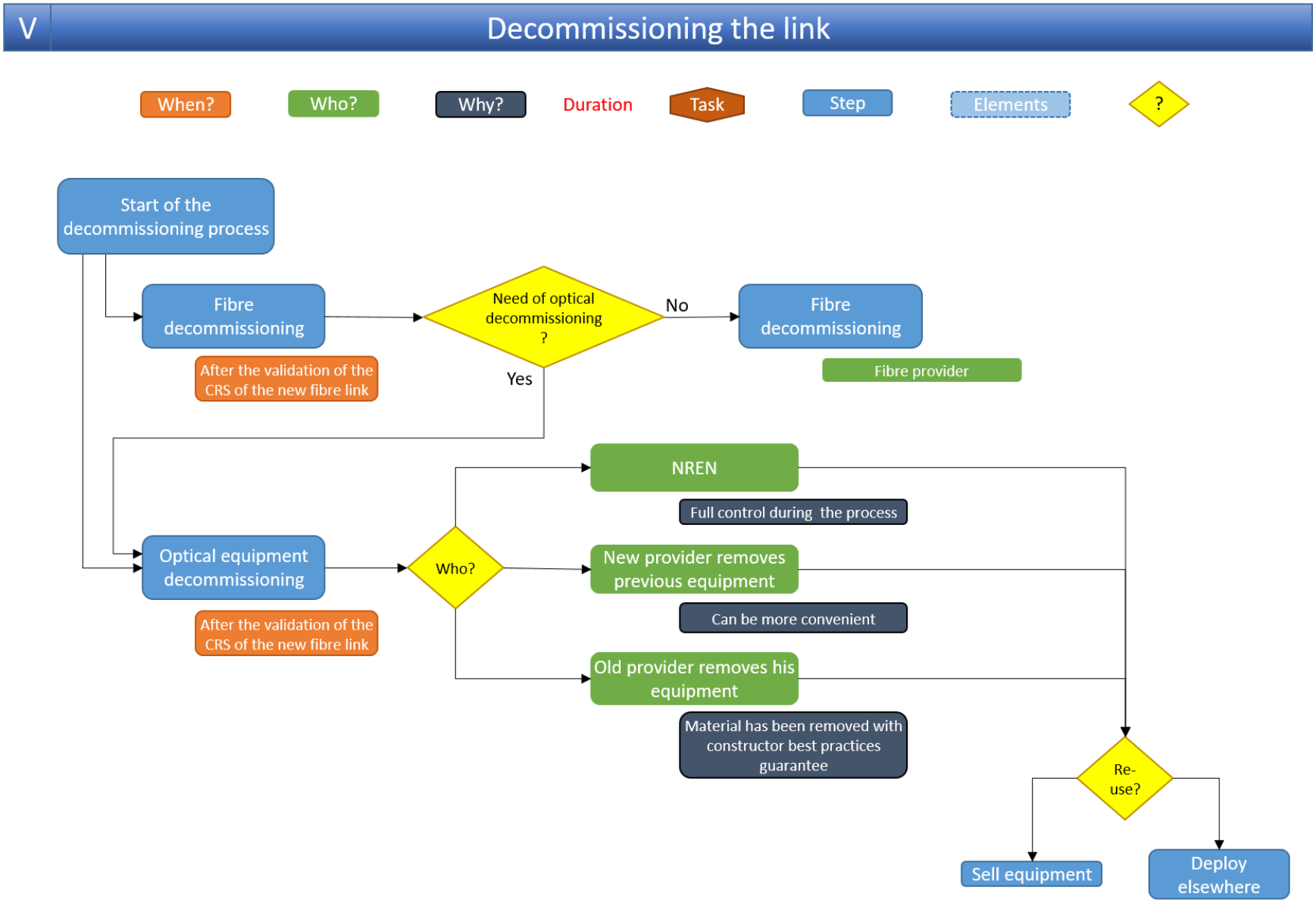

Figure 9. Decommissioning the link.

IV.D Adding new services or projects to an operating network

An optical network is in perpetual adaptation to the demand. If required, new services are deployed on operating links. Any user or research project can ask to benefit from specific architectures. If the demand is relevant and achievable without perturbing the operating network, the current network can be adapted for this new project. The deployment will then go through the normal phases of any new optical project:

- Step 1: Creation of a project
- Step 2: Internal study (impact on in-use equipment)
- Step 3: Contact with the optical provider to obtain their remarks
- Step 4: Deployment (POC, deployment, operating phase)

V. DECOMMISSIONING THE LINK

Decommissioning is the final step of every fibre link.

V.A Description of the process

As mentioned in Section III.C, decommissioning only occurs if the fibre or equipment are no longer in use (operating state or ready for a potential roll-back). This is either because a fibre link between the two extremity sites is no longer required or because the fibre/optical equipment provider has changed and the decommissioning of previous equipment is necessary.

V.B Re-use of the equipment

Depending on the contract with the provider, the equipment can then be stored, sold (if property of the NREN), or re-deployed somewhere else in the network.

VI. CONCLUSION

GÉANT is the pan-European data network for the research and education community. It interconnects national research and education networks across Europe, enabling collaboration on projects ranging from biological science to earth observation and to arts & culture. In the GÉANT Compendium-2015, European NRENs reported that at the beginning of 2015 the total number of kilometres of dark fibre in their networks stood at 140 000 km. This is up by 4% from 2014. This shows a continued commitment by NRENs to their dark fibre since the question was first asked in the 2005 Compendium survey. Nearly all NRENs are reporting an increase in the amount of fibre in their networks. Of the GÉANT partners, CESNET, Belnet, RESTENA have all increased their fibre footprint by between 8% and 10%. Managing the network deployment is a long and technical project that requires an in-depth study by many NREN departments but which brings flexibility and resilience to the network and is therefore a key step for every telecommunication network.