Electrical Engineering Group

Thoughts on strategy for cable procurement for HL-LHC

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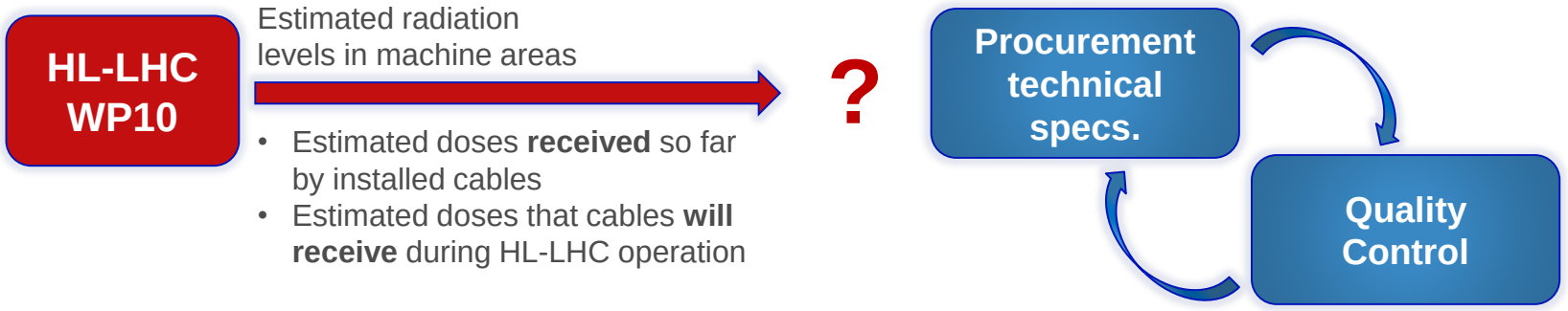
Foreword

- We refer to the presentation of WP10 at the 111th Technical Coordination Meeting (TCC) on "radiation effects on HL-LHC cables" https://edms.cern.ch/document/2404819

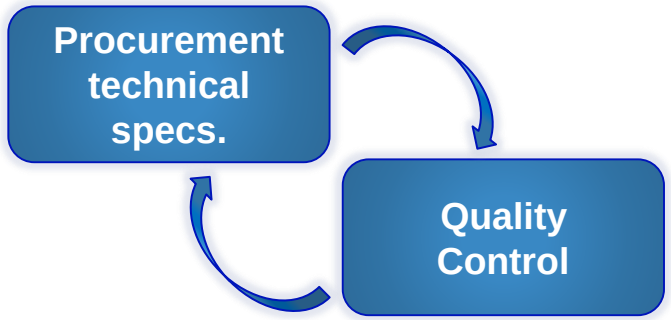


Outline

1. Role of EN-EL in the Procurement+QA process

2. Approach/expectations of EN-EL in the Procurement+QA process

3. Summary/Discussion



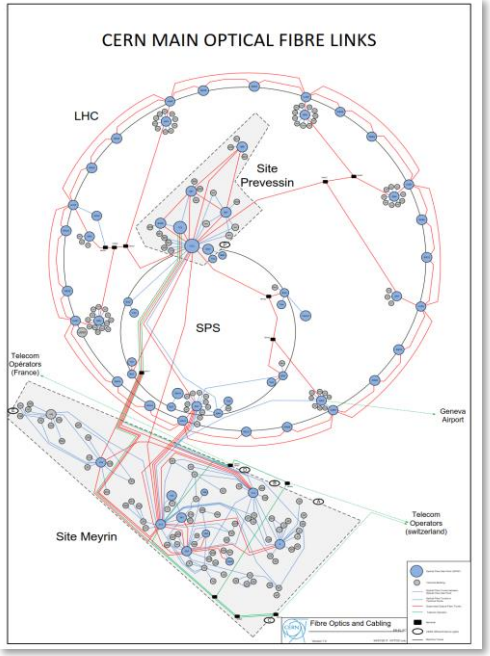
Role of EN-EL in cable procurement

1. OPTICAL FIBRES

- 99% is procured via frame contract **managed by EN-EL**
- 1% is procured by users for private cabling networks
- Cables qualification done by EN-EL during contract preparation/execution
- Fibre cable = optical fibre (glass) + cable material (sheathing)

❑ Reasoning of current approach

- EN-EL acts toward users as responsible of the (passive) optical fibre infrastructure, therefore designs, maintains and operates it.
- EN-EL assists users during the deployment of their systems while choosing the most appropriate optical fibre types and infrastructure topology.
- The infrastructure serves all CERN (machines, experiments, tertiary)
- Fibre Optics technology requires a high degree of technical expertise to be designed/qualified, which sits in EN-EL



Role of EN-EL in cable procurement

2. COPPER CABLES

- 90% of what EN-EL installs is **procured by the CERN stores** (SMB-SSL)
  - Example of LS2 procurement for EN-EL: 883 km **(~ 94%)**
- 10% is either procured by EN-EL or procured directly by the CERN users.
  - Example of LS2 procurement by EN-EL: 54 km **(~ 6%)**

❑ **Reasoning of current approach (signal cables)**

- EN-EL acts toward users as service provider (installer) and isn't in charge of system -and related cabling- definition
- EN-EL serves only the machines (and not even for the totality)
  - Experiments served by: EN-EA; Tertiary served by: SMB, IT, BE-ICS, …
- CERN stores standardize and procures cables that are regularly consumed by multiple users.
- Specific (not standardized) cables for a given installation project, are procured directly by EN-EL or by the users, upon definition of technical specification/price enquiry (punctual consumption).

❑ **Special Case: high radiation resistant cables (IS23: up to 10MGy)**

- Only few types are standardized by CERN store, therefore they are mostly procured by EN-EL or users. This is typically done in the scope of large cabling works for replacement of irradiated cables.

EN-EL approach/expectations for fibre optics

As main responsible for the procurement+QA process, EN-EL:

- **Optical fibre glass**
  - Maintains since >15 years high level of technical expertise
    - Including in-house laboratory for QA/QC on the received cables
  - Periodically qualifies new fibre types
    - Survey the market, liaise with manufacturers, conducts irradiation tests.
  - Issues a catalogue of qualified fibres
  - Is equipped to monitor the fibre degradation during operation and to suggest replacement
- **Fibre cable material (sheathing)**
  - Expects a reliable input on radiation levels in machine areas (as well as for the ”glass” case above)
    - It is understood that this is done by WP10 in the case of HiLumi (https://edms.cern.ch/document/2302154)
    - It is expected to be provided by on a more general and regular base (by MCWG) and in a format exploitable for cables (to be discussed)
  - Tailors the technical specifications to the best match over concurrent needs
    - Radiation levels + specific users need + resistance of fibre glass w.r.t. resistance of sheathing material, etc.
  - Liaises with companies for identifying new cable materials. However expects those materials to be qualified by a central service at CERN (CARE with the help of R2M activity in R2E ?).
  - Expects assessment of material degradation during cable lifetime to be coordinated by a central service (CARE)

EN-EL approach /expectations for copper cabling

As an installation service provider, EN-EL:

- **Entirely relies on procurement+QA done by CERN stores***
  - Advances an overhead to CERN stores on the cable price, which is eventually paid by the end users
  - Organises a local cable park as a buffer for the worksites
  - Maintain a cable database for the installed cables

- **Supports with organising replacement campaigns for irradiated cables**
  - On request: either by LS coordination, for large campaigns, or the users (i.e. the cable owners) for punctual cases
  - The requestors, typically expect assessment of material degradation during cable lifetime to be coordinated by a central service (CARE)

* w.r.t. the <10% of cables purchased directly by EN-EL, the approach/expectations are the same as for fibre cabling

Particular case: high radiation resistant copper cables

- **Decision making**
  - Typically **taken by users/project** in collaboration with EN-EL which act mainly as installation expert.
  - It must be consistent for a given area and will have consequences on cabling topology as well as on future replacements of irradiated cables.
  - The requestors, typically expect a reliable input on radiation levels in machine areas.
  - It is expected the cable materials to be qualified by a central service at CERN (CARE with the help of R2M activity in R2E ?), similar case as for conventional cables .

- **Deployment topology**
  - Typically the radiation resistant cables are very costly (x8), therefore they are mainly deployed in the highly radiation areas
  - Patch-panels (or junction boxes) are installed at the limit of the highly radiation area, to segment the cable in two part: highly radiation area / low radiation area.
    - It reduces the cabling procurement costs and enables future replacement of irradiated cables limited to the concerned irradiated cable segment.

Particular case: high radiation resistant optical fibre cables

- **Decision making**
  - Decision making is typically **taken between EN-EL as infrastructure designer and the project**, following:
    - a technical study on infrastructure topology
    - consequences on future replacement of irradiated cables.
  - Expects a reliable input on radiation levels in machine areas.
  - Reminder: for a fibre cable the fibre glass is the main driver when it comes to radiation damage.
  - It is expected the cable materials to be qualified by a central service at CERN (CARE with the help of R2M activity in R2E ?), similar case as for conventional cables.

- **Deployment topology will integrate**
  - The users requirements in terms of optical budget
    - To be coupled with the expected radiation induced attenuation over the fibre operation time
  - Optimizing the multi-user infrastructure, in particular w.r.t. :
    - The costs of future replacement of irradiated fibre cables.
    - The dose taken by the people in such replacement works.

Procurement lead times

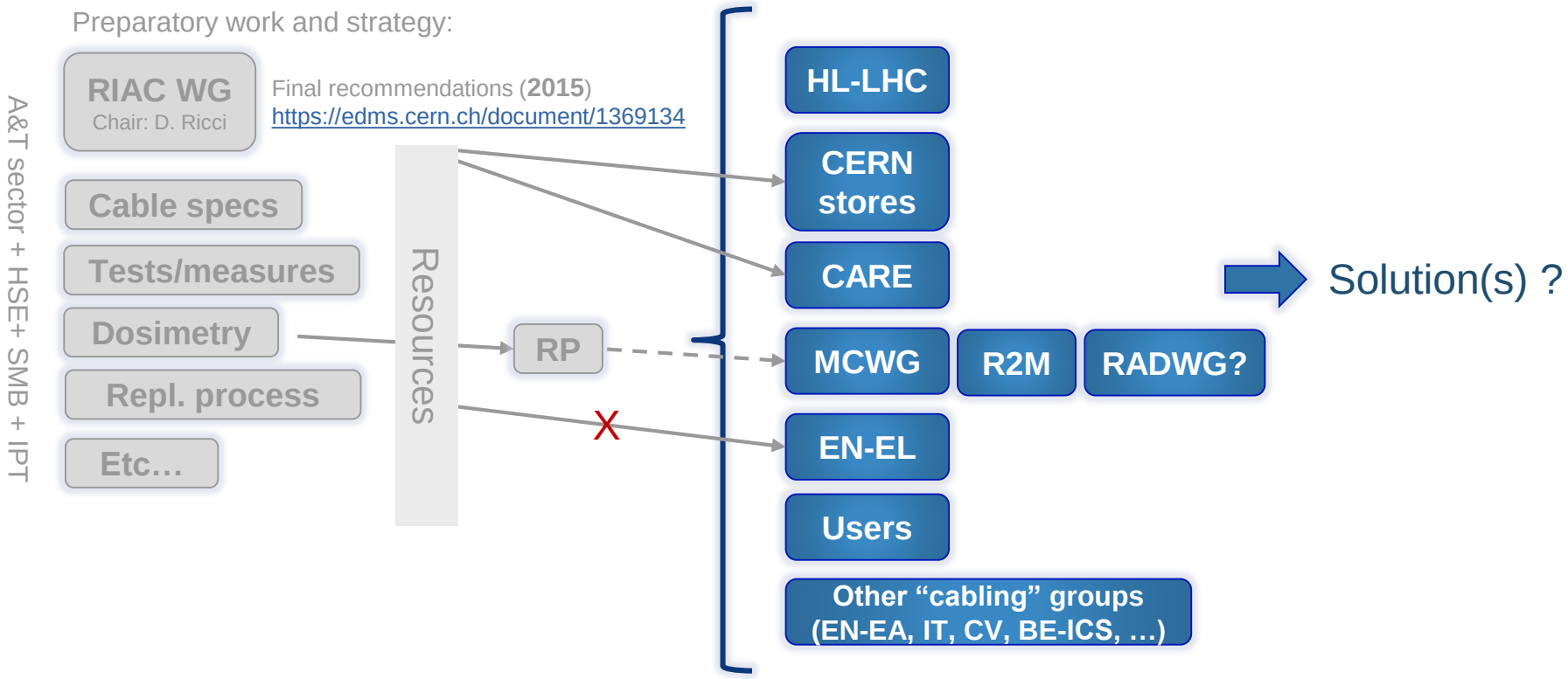
- **The typical delivery time (to review wrt COVID-19 situation)**
  - 4 to 6 months for most common copper/fibre cables types in function of quantities
  - 9 to12 months for highly radiation resistant copper cable types (> 500 kGy)
  - 24-33 months for highly radiation resistant fibre cables, which includes:
    - 12-15 Months: Optical fibre qualification tests, market survey and invitation to tender
    - 12-18 Months: Ordering, Fibre production, Irradiation tests for preform validation, cable production and deliveries

- **Preventing procurement to become a showstopper**
  - 80% of the LS required cables shall be at CERN premises one year before. For LS3, which start at 2025, this means having cables ready at CERN **early 2024**.

- **EN-EL anticipated qualification and procurement of optical fibres (glass) for enabling fibre cabling production**
  - More than 100 irradiation tests over last 10 years during fibre qualification
  - Production of 2400 km of radiation resistant single-mode optical fibres for LS1/LS2/LS3 projects
  - Production of 1500 km of radiation resistant multi-mode optical fibres for LS2/LS3 projects

Summary/Discussion

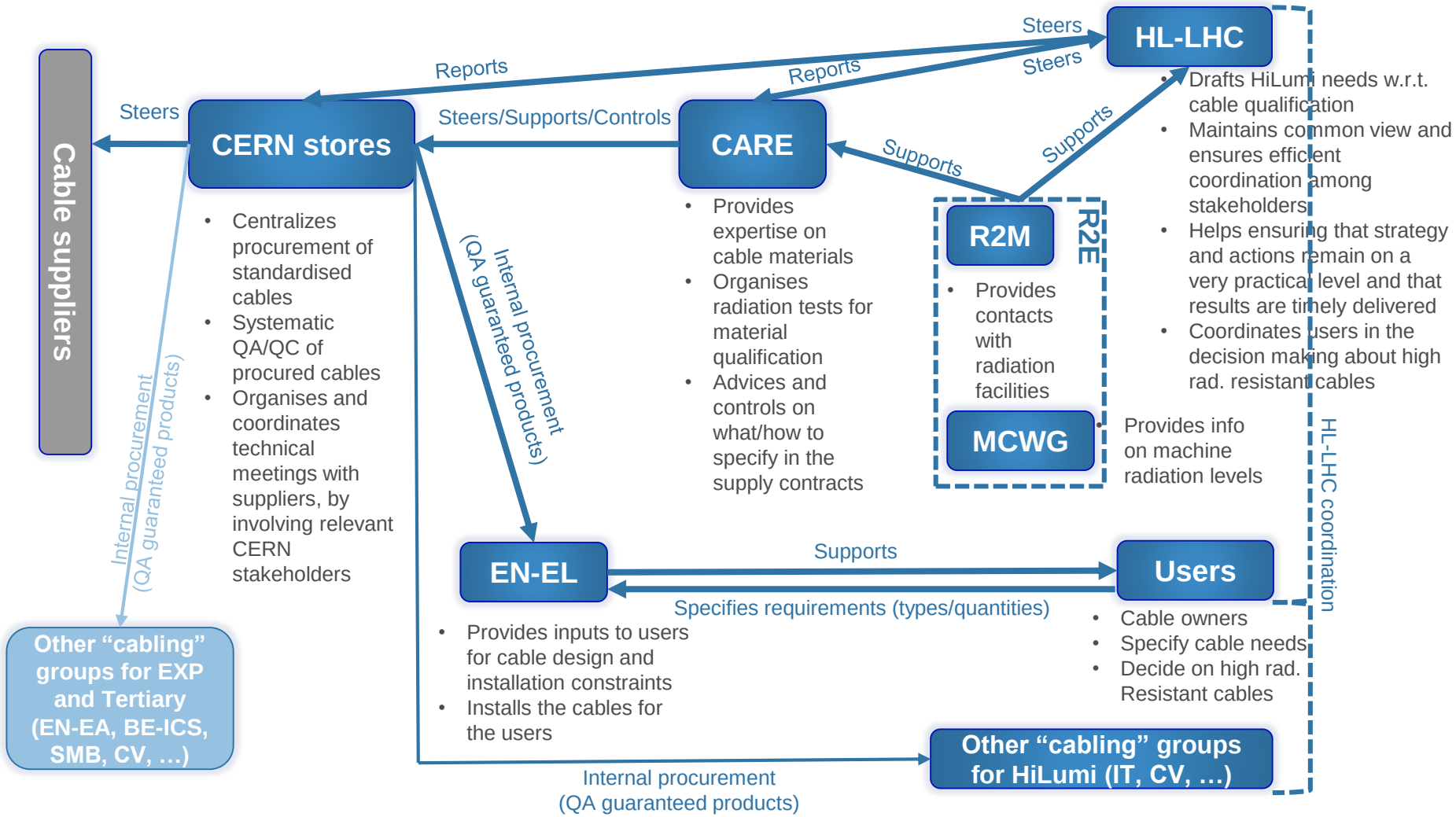
A system with many variables:



Priority: update the "old" list of cable materials (TIS-TE/MTR/2002-05) by qualifying new materials proposed by manufacturers and by clarifying the guidelines for the Radiation Index (RI) requirements to be specified in the contracts.

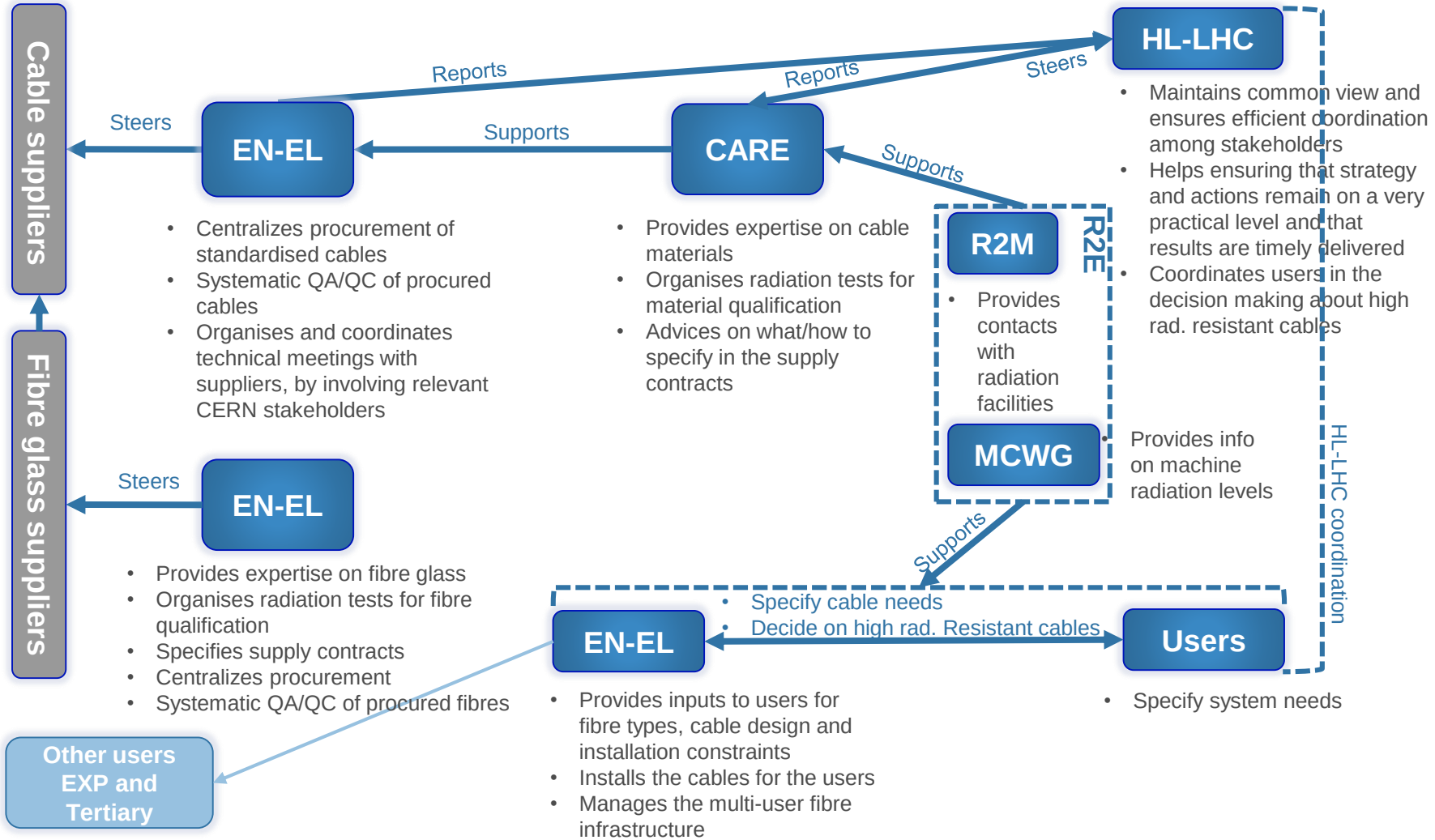
Ideal vision

CABLE PROCUREMENT (COPPER)

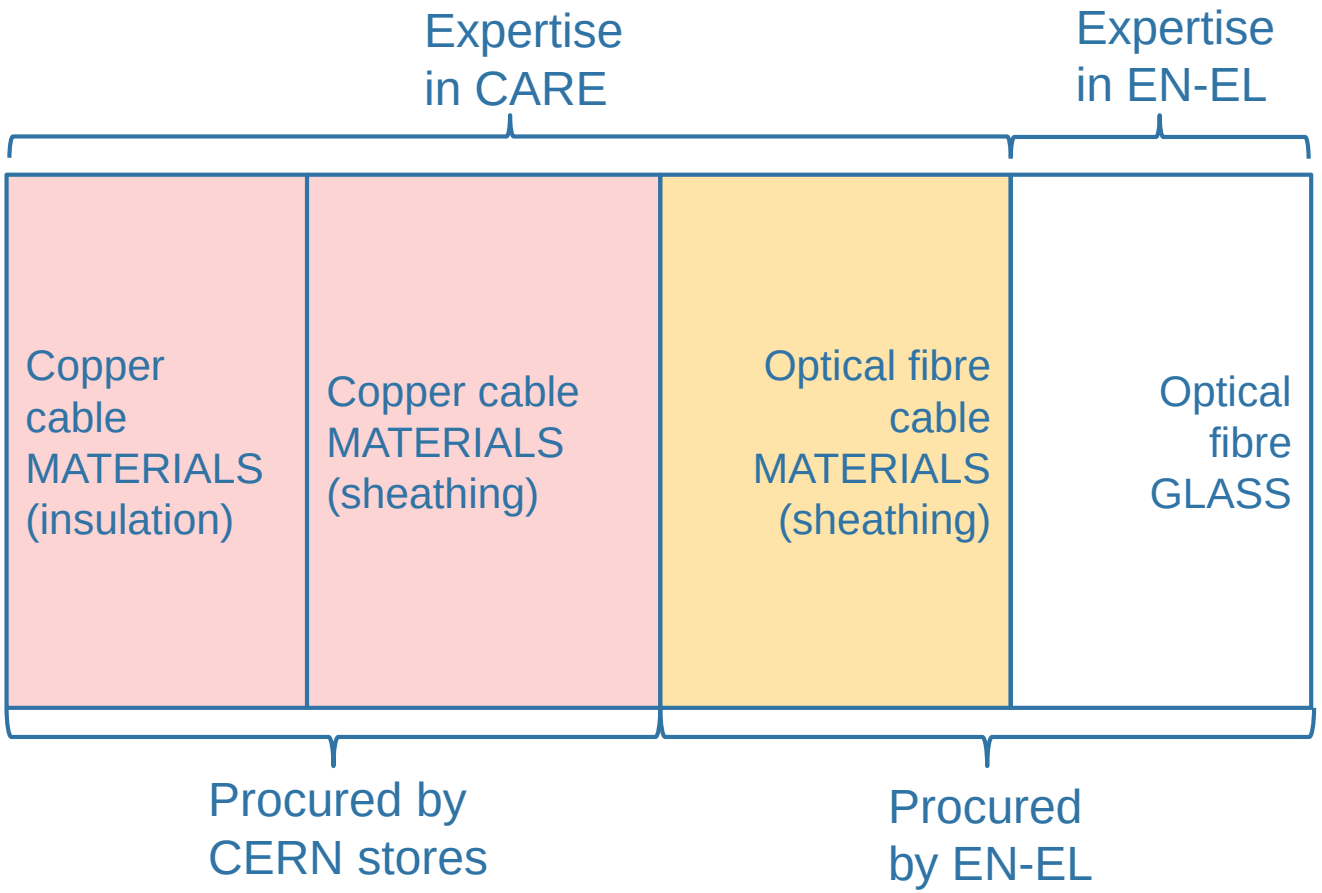


Ideal vision

CABLE PROCUREMENT (OPTICAL FIBRES)



Synoptic view



Thank you for your attention!

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Backup slides

Fibre Cabling Procurement

Ionizing radiation effects on fibre cabling

❑ Ionizing radiation impact on fibre cabling

- The major concern for optical fibre cabling is the optical fibre itself (glass), much more than the cable sheathing material. As only optical signals are transmitted, a degraded sheath doesn't present electrical risks as with the copper cables.

- At microscopic level, the radiation-matter interactions will result in defects, which will reduce the optical fibre capacity of transmitting an optical signal. These effects, such as radiation induced attenuation (RIA) can be detected using optical time domain reflectometer (OTDR).

Fig. 1. Optical fibre cable

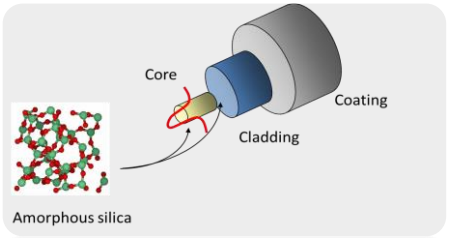


Fig. 2. Optical fibre

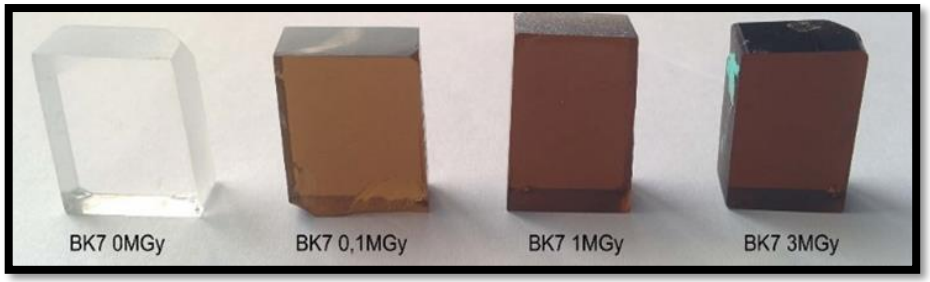


Fig. 3 – Silica natural (left) and after irradiation at 0,1 MGy, 1MGy and 3MGy.

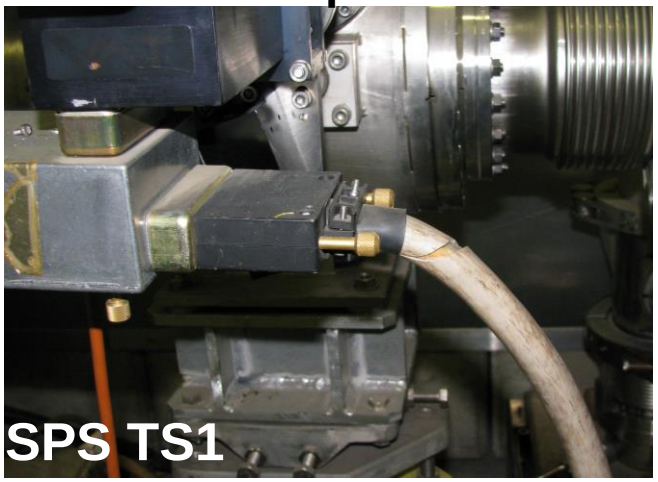
Copper Cabling Procurement

Ionizing radiation effects on copper cabling

Ionizing radiation impact on copper cabling

- According to IS23, the copper cables shall all perform correctly (both mechanical and electrical) up to an integrated dose of 500 kGy. This is a CERN technical requirement while preparing technical specification for price enquiries.
- The impact of ionizing radiation into copper cables is observed mostly by a premature ageing of the sheathing materials, which may become brittle along the time. This leads to a cable malfunction or even short-circuits between cable wires.

Control cable problem

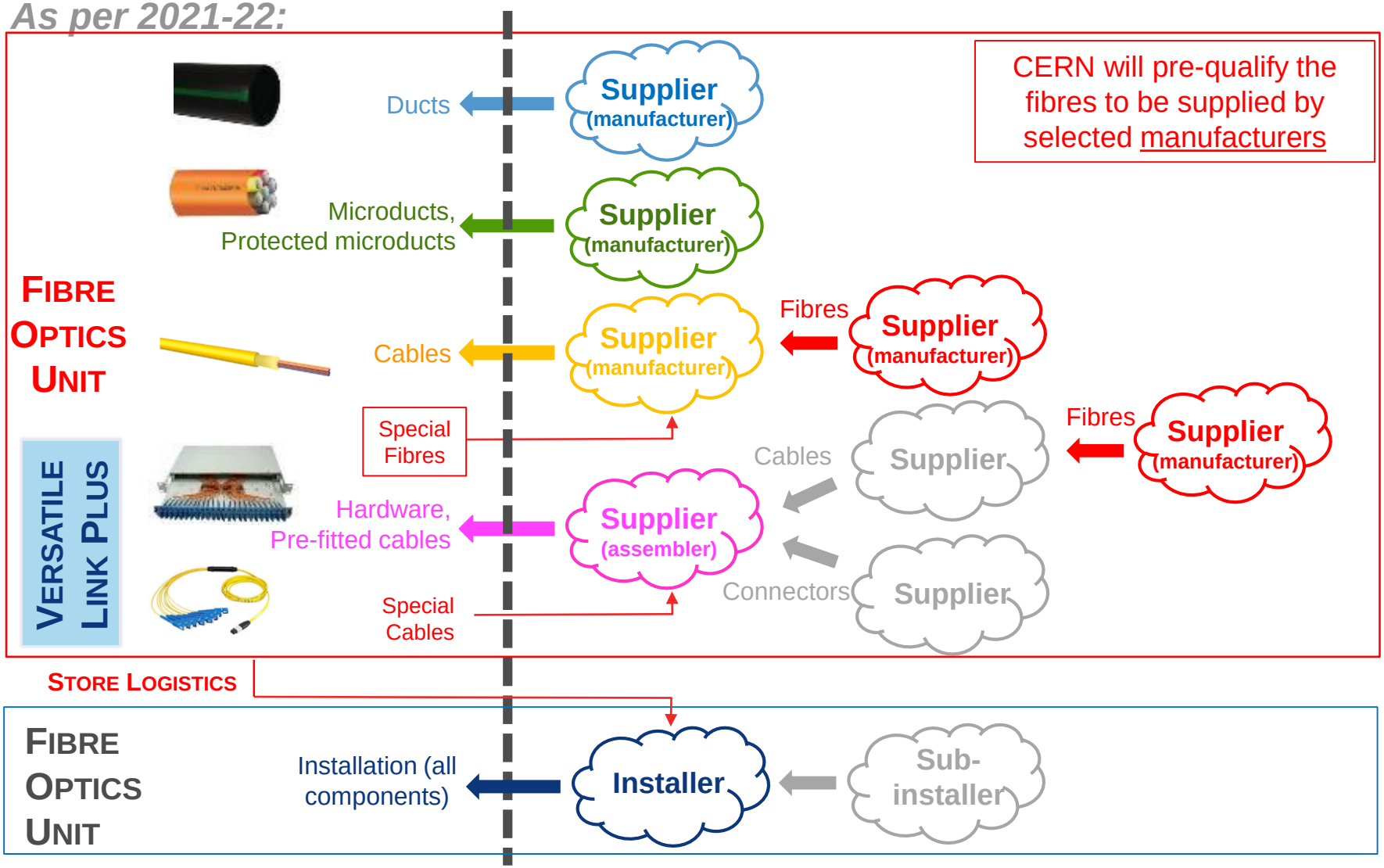


SPS TS1

Multi-pair control cable problem

Cracks on wires (BA81)

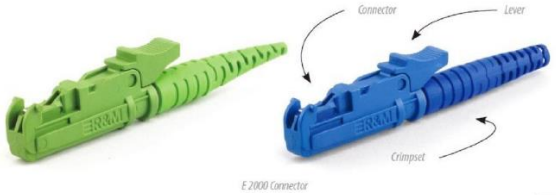
Frame contracting strategy (full view)

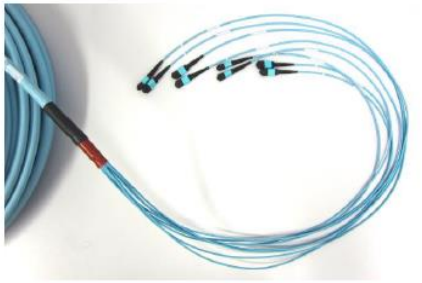


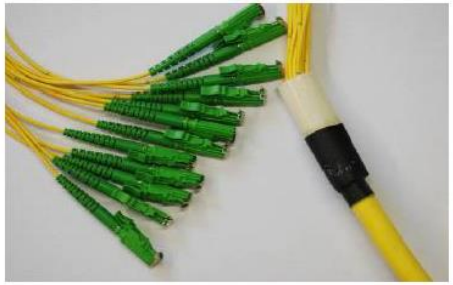
Procurement of material - examples

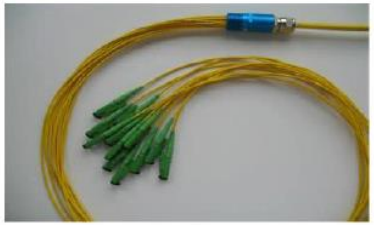
Patch cords and cables

- Large variety in connectors type and lengths (also customizable)









Termination modules, cassettes, boxes