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Power and Grounding for ESS instruments

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3 June 2015

Grounding objectives

From a facilities perspective grounding is all about safety

- Prevent electrocution – all exposed metal associated with electrical installations should be grounded sufficiently well to to ensure fuses will blow in case of a hazardous fault condition.
- Mitigate surge from lightning strike (protect people and equipment)

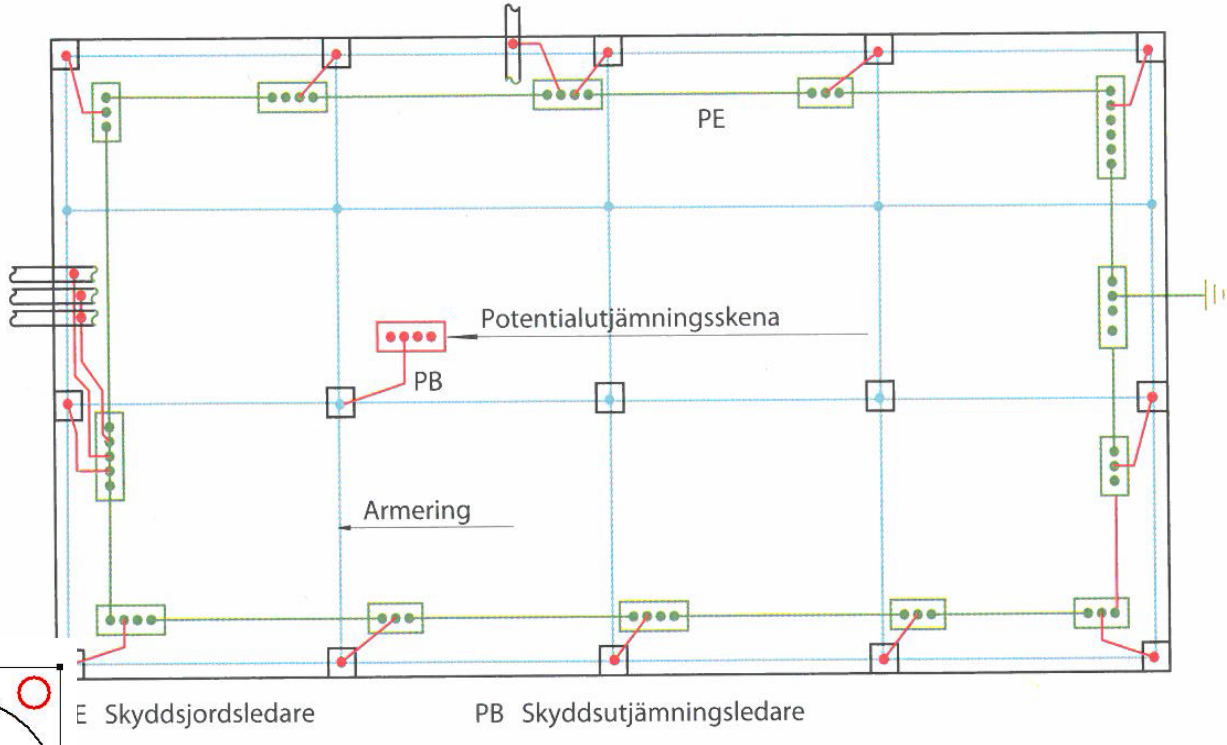
From an instrumentation perspective ground is the reference potential against which signals are measured. Often referred to as ‘functional’ or ‘clean’ earth or ground. Noise or movement on ground will reduce the integrity of the signal.

It is a practical reality that frame of an instrument will almost always need to be grounded….

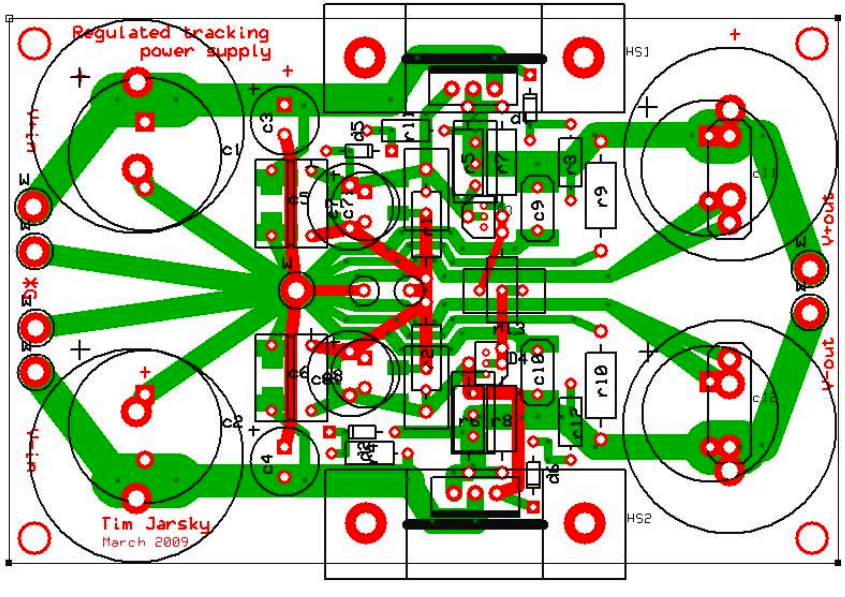
These requirements have to co-exist

Typical Grounding Schemes

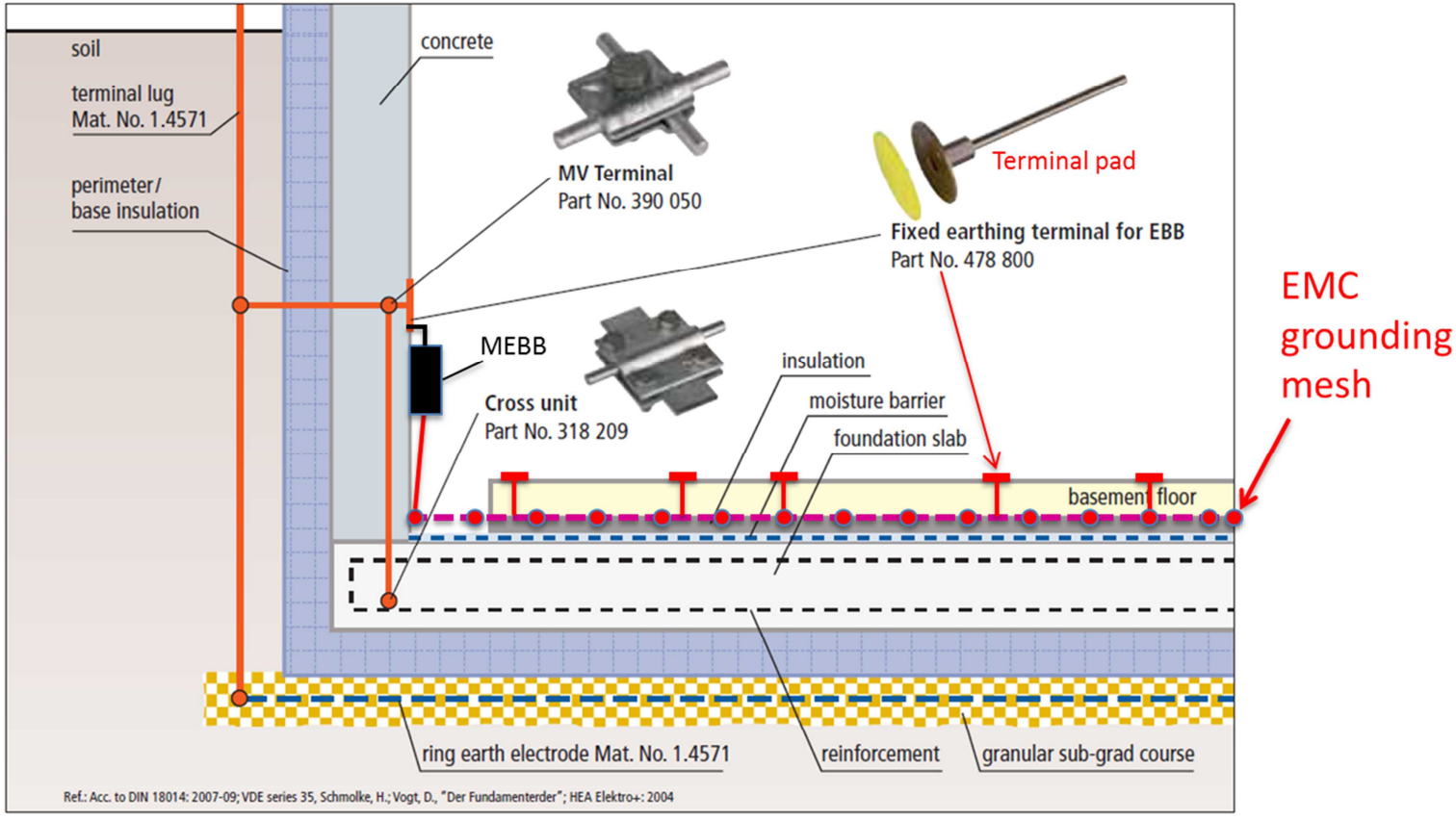
MESH



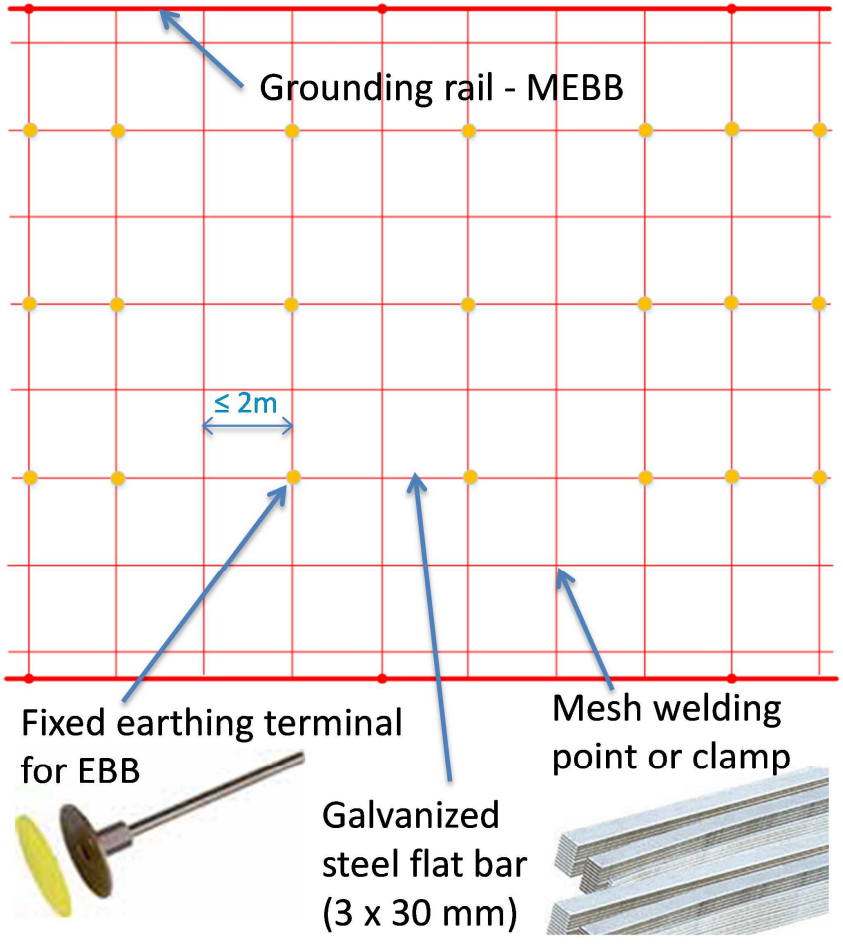
STAR



Accelerator Grounding Scheme

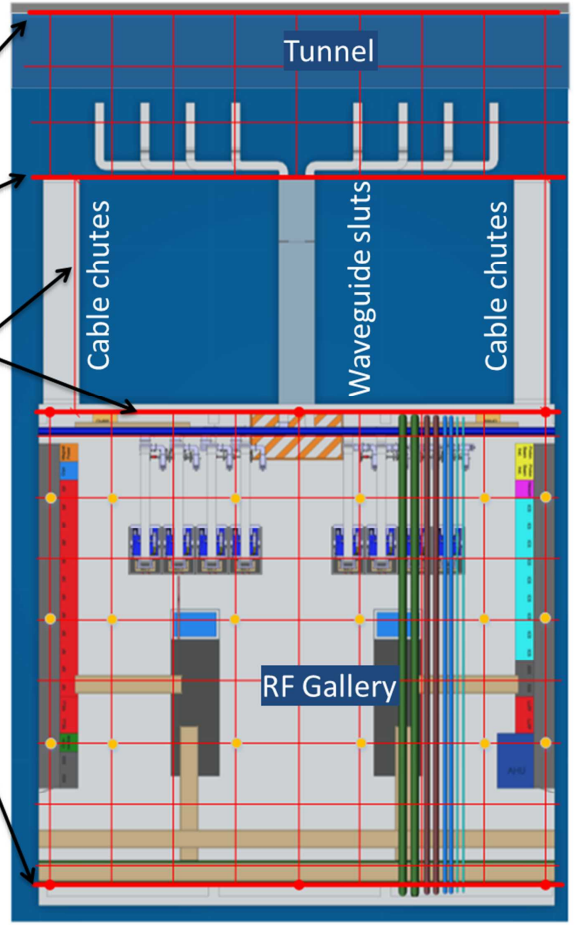


Accelerator Grounding Scheme



Grounding rails – MEBB's
(lightning and safety ground, as per IEC 62305)

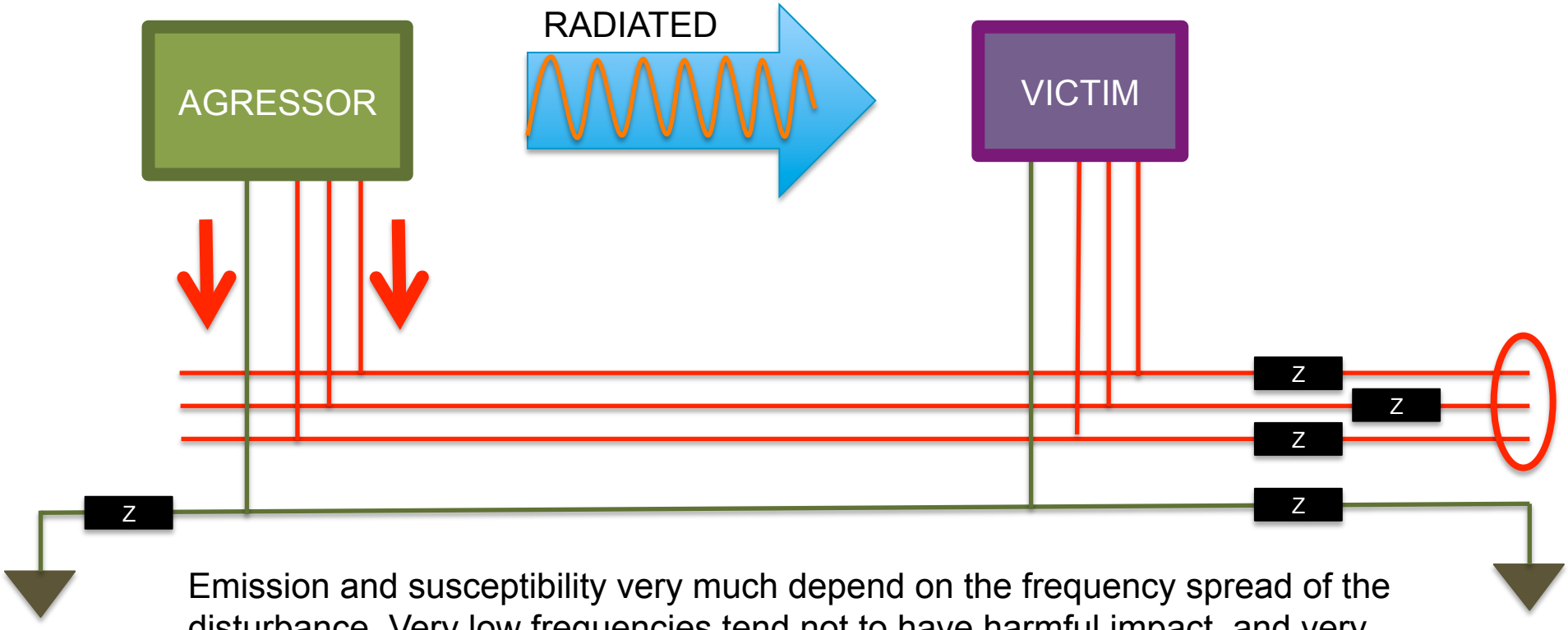
Ground interconnection rods or cables
(could be cable pipes, if metallic)



How Two Installations Interact

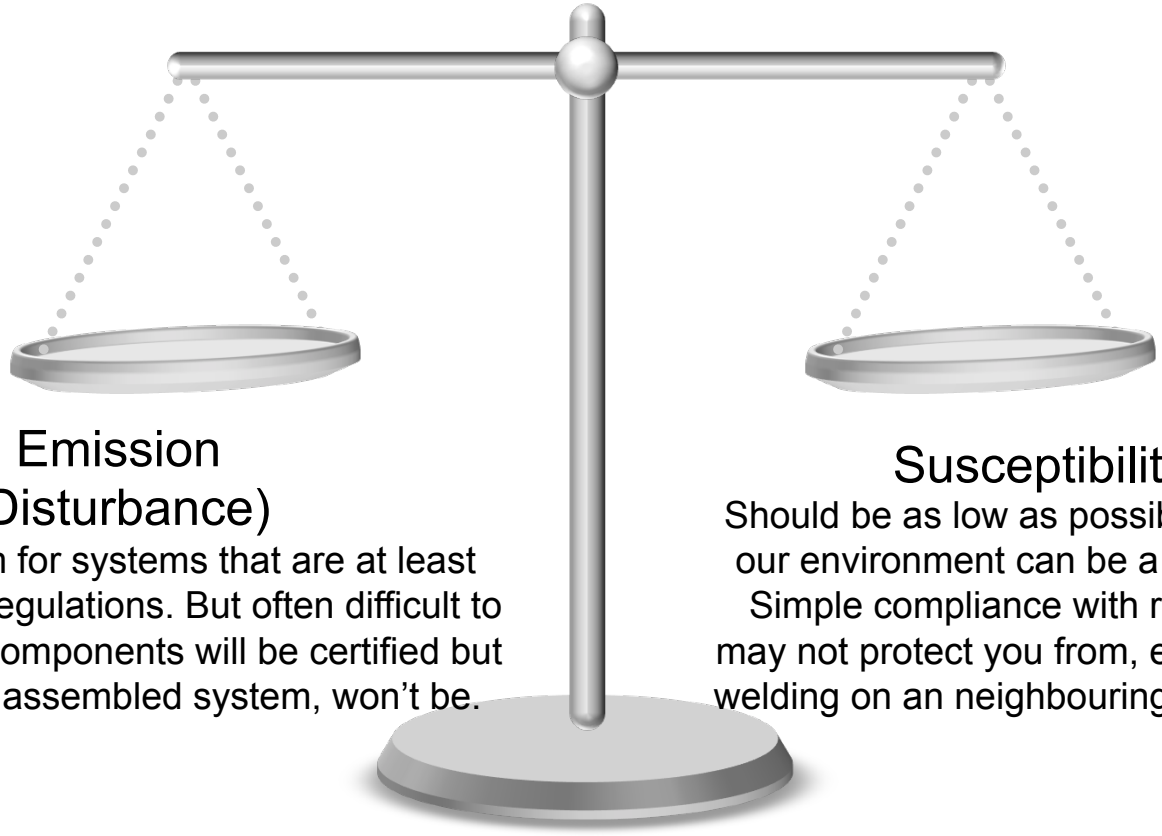
Two installations can electrically interact (or interfere) with each other in two main ways

- Radiated - Electromagnetic radiation that is picked up by 'aerial effects' in another installation
- Conducted – Current on shared power supply, or current into ground/neutral supply lines



Emission and susceptibility very much depend on the frequency spread of the disturbance. Very low frequencies tend not to have harmful impact, and very high frequencies are relatively easy to shield against. Intermediate frequencies are often the most problematic.

Balancing Requirements



Emission (Disturbance)

We should aim for systems that are at least compliant with regulations. But often difficult to ensure... Most components will be certified but some, and the assembled system, won't be.

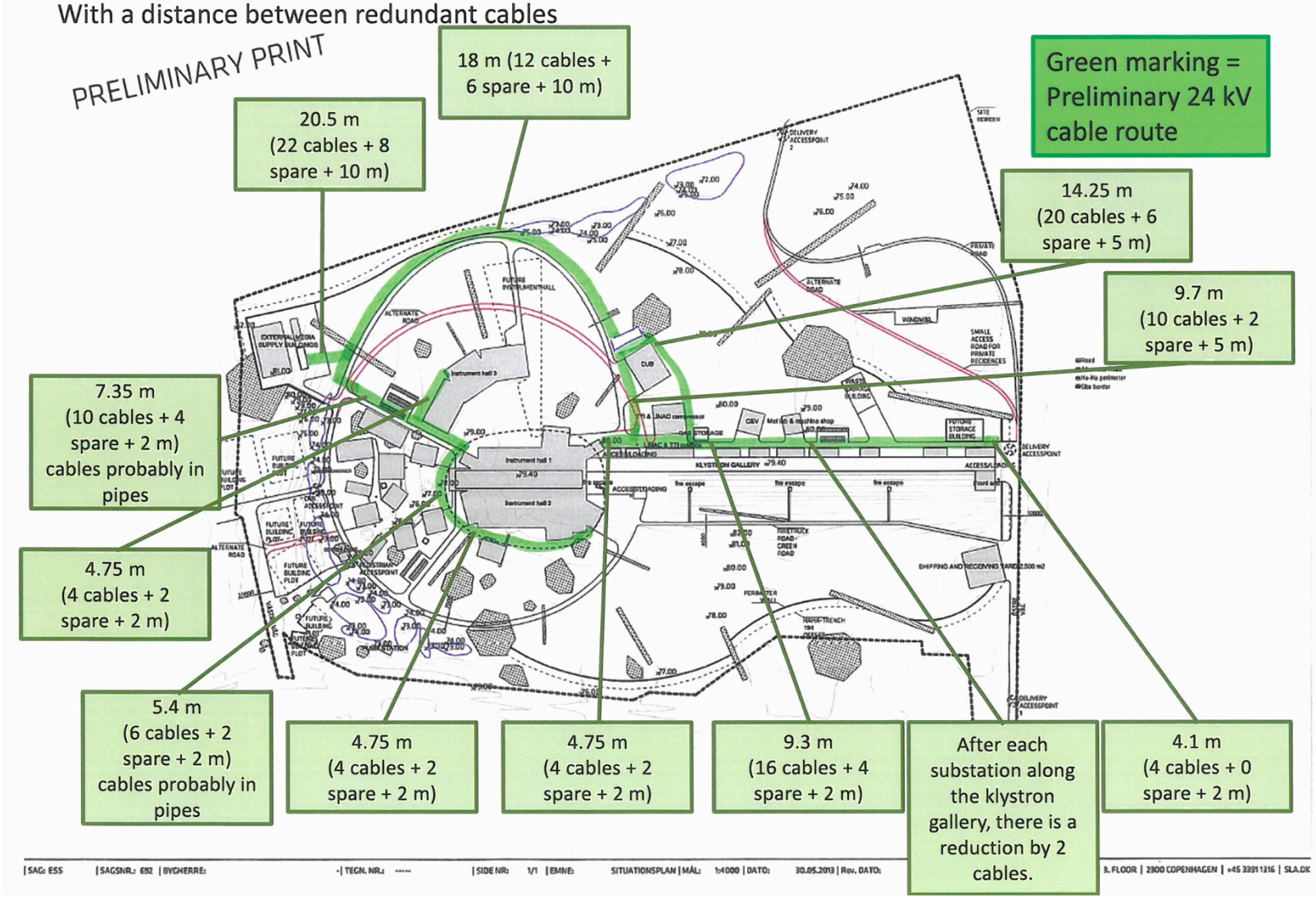
Susceptibility

Should be as low as possible because our environment can be a harsh one. Simple compliance with regulations may not protect you from, eg, someone welding on an neighbouring installation.

Standards exist (IEC/EN 61000, EU 89/336/EEG), and everyone should aim to comply.

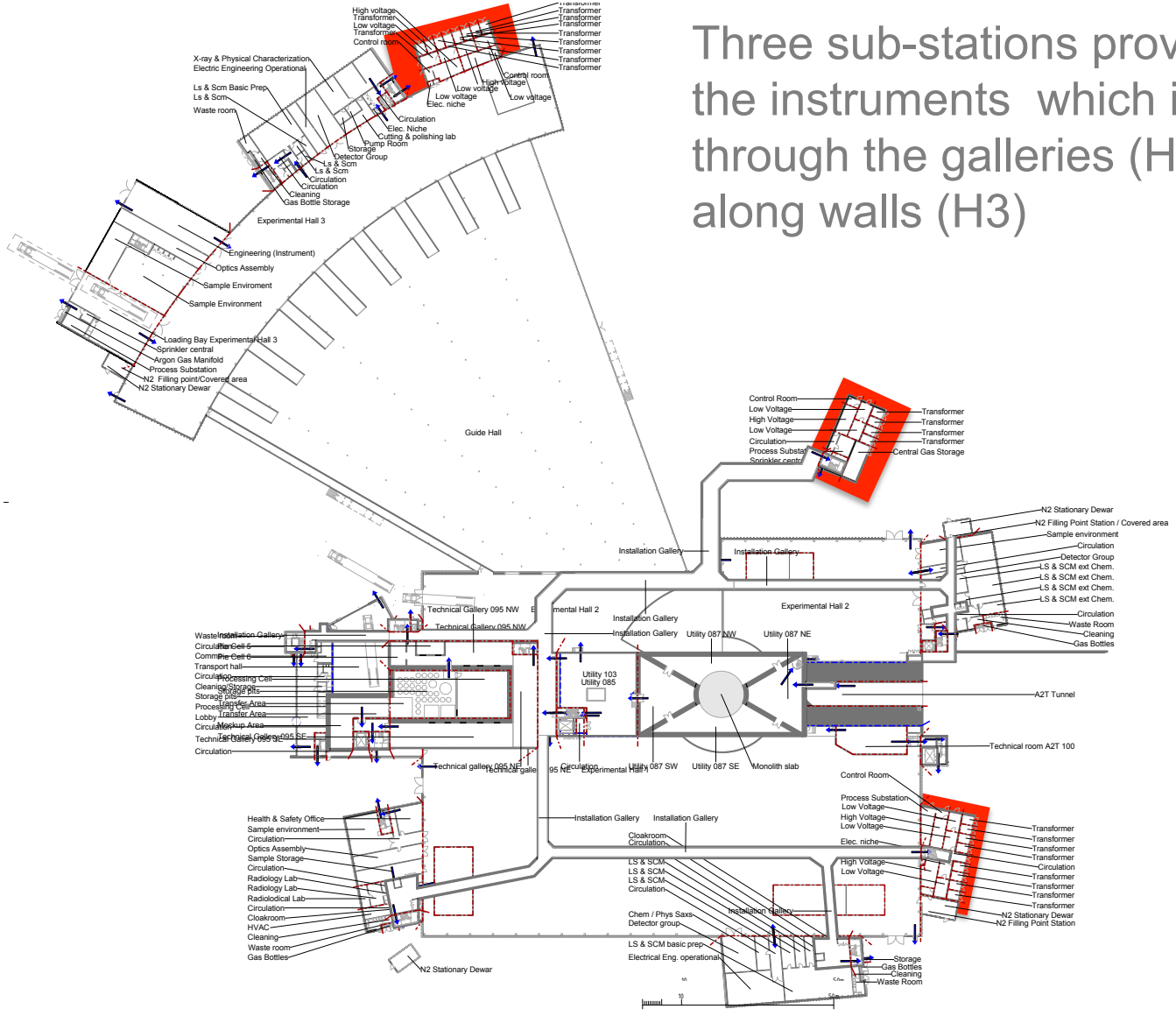
Constructors are expected to 'clean up their own mess'. In cases where instruments interfere the ESS technology groups will 'arbitrate'.

Power Distribution



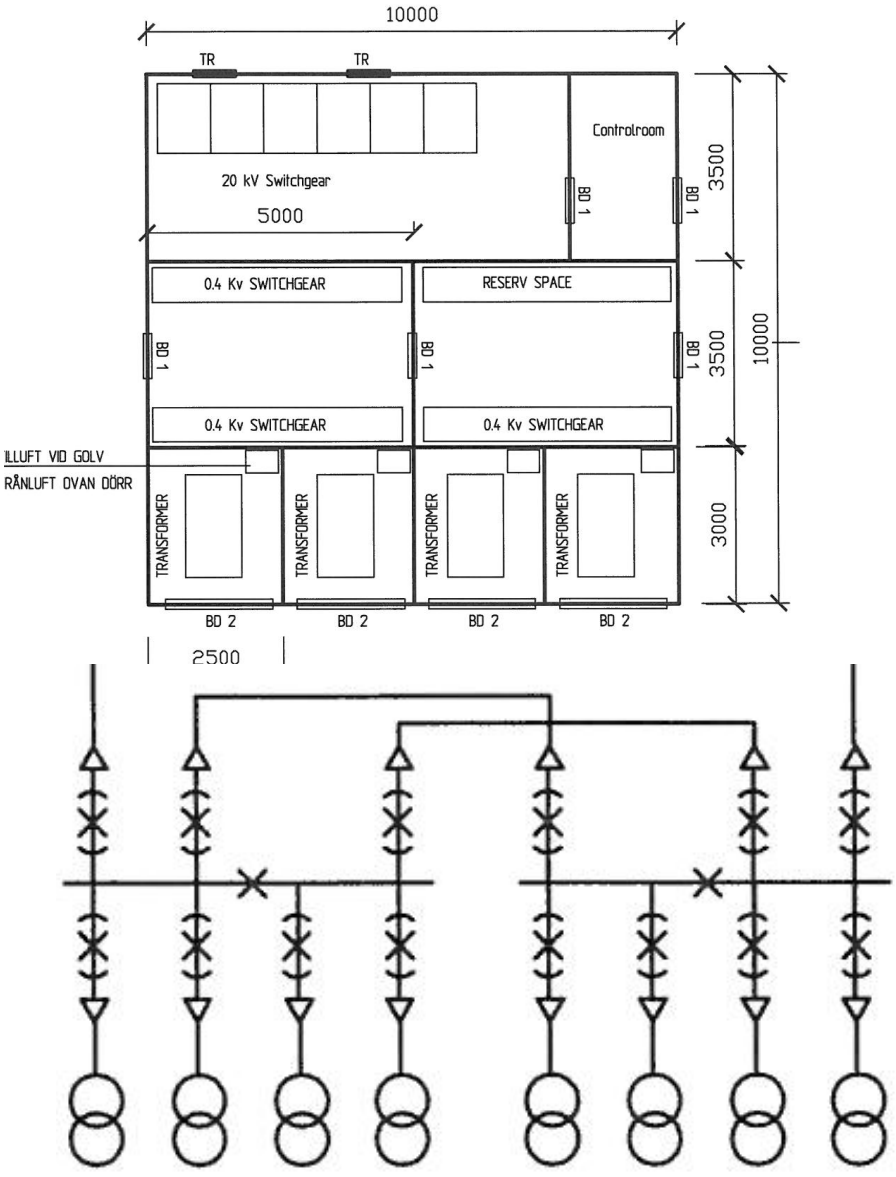
Slide from Frithiof Jensen

Power Distribution

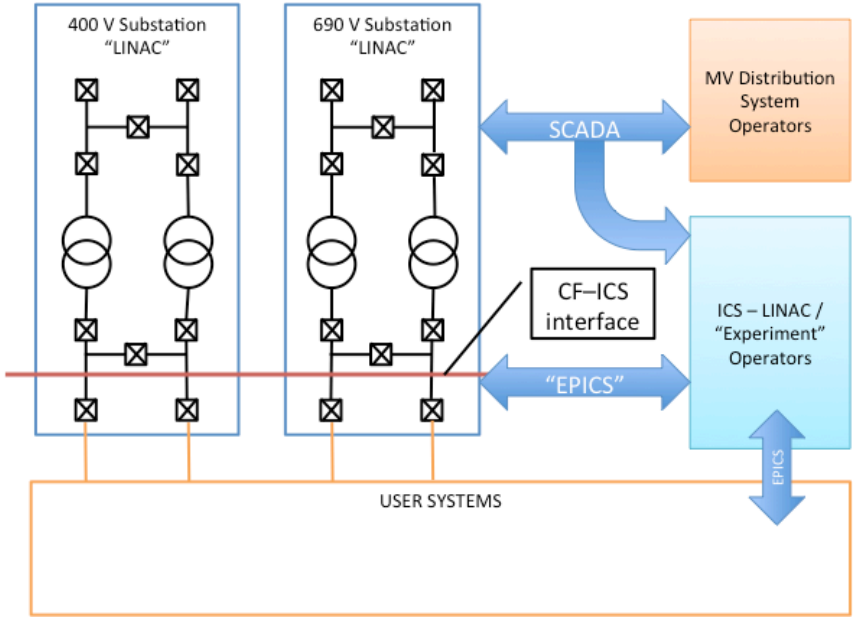


Three sub-stations provide power to the instruments which is routed through the galleries (H1 &H2) or along walls (H3)

Substation



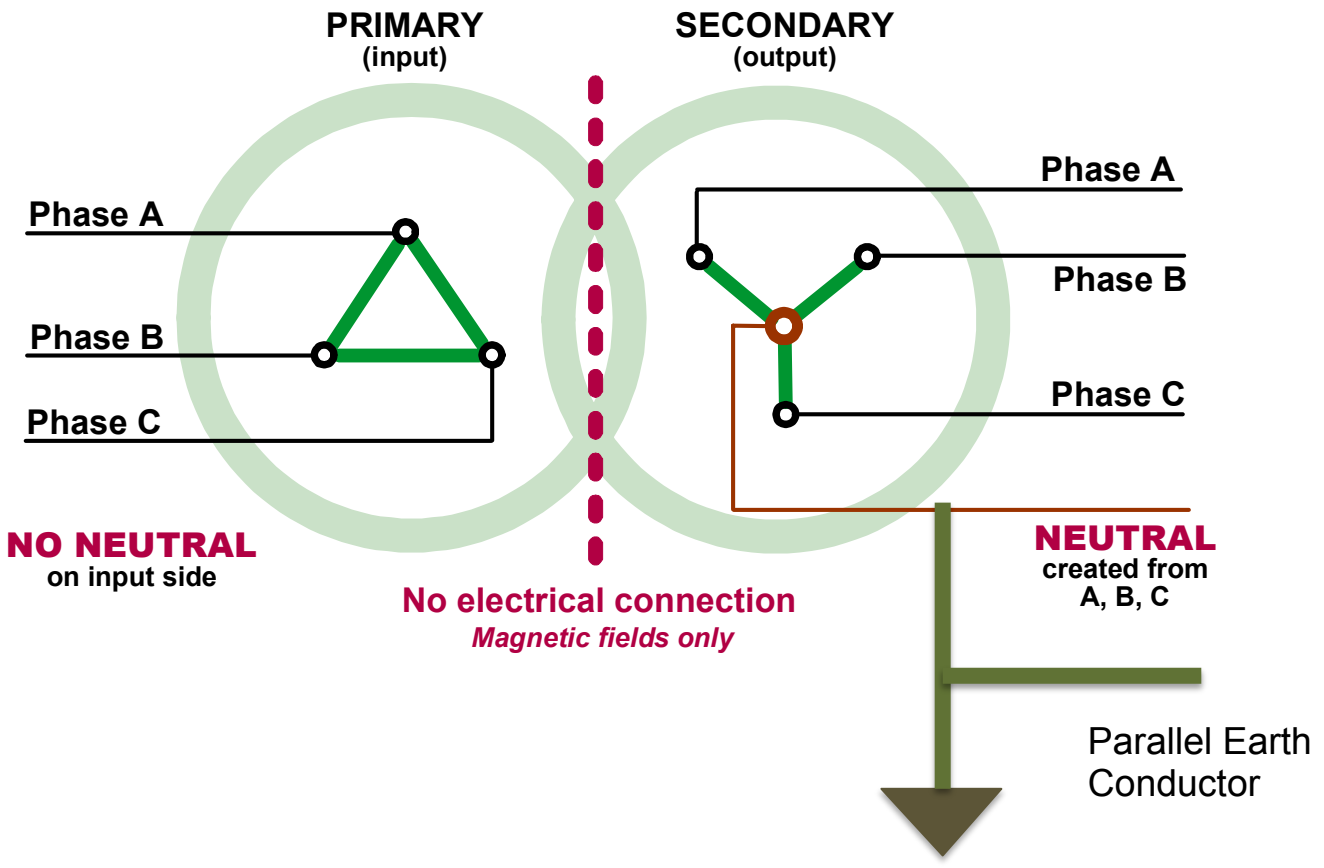
Each substation provides redundant switching between MV supply lines and can also route instrument feeds to different transformers in case of failure, maintenance etc.



Drawings from Frithiof Jensen

Delta – Wye Transformer

Step down transformers isolate power feed to a local ground connection.



Backup Power

Generator backup for total power outage…. supposed to be less often than once a decade (triple power grid feeds). Generators take ~20 seconds to fire up.

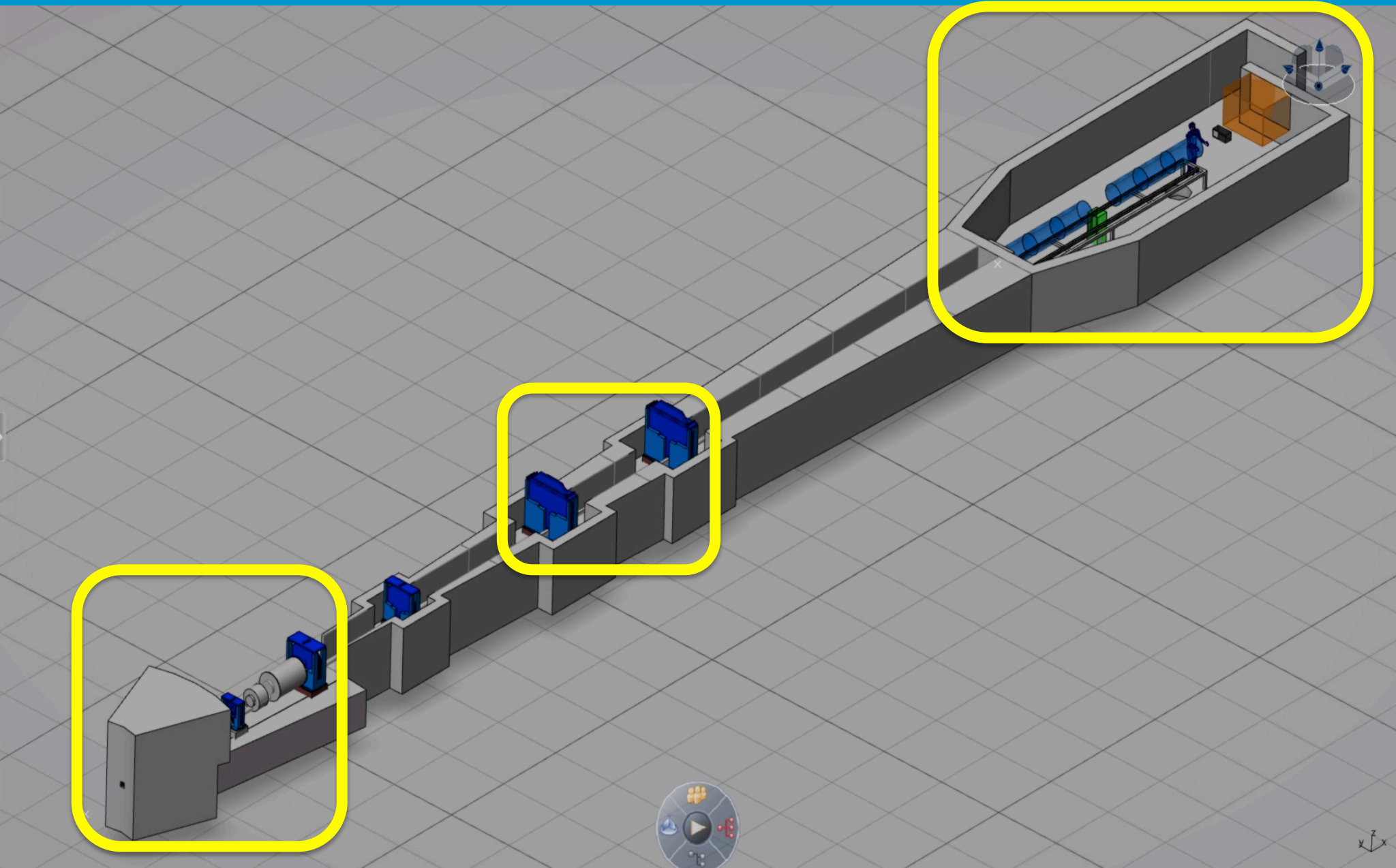
Short endurance ‘always online’ UPS systems distributed rack by rack. These will allow graceful shutdown of equipment (5-15Mins).

Only a small fraction of the total facility power can be powered by generator. Assume we don’t use that, but various schemes available if needed…

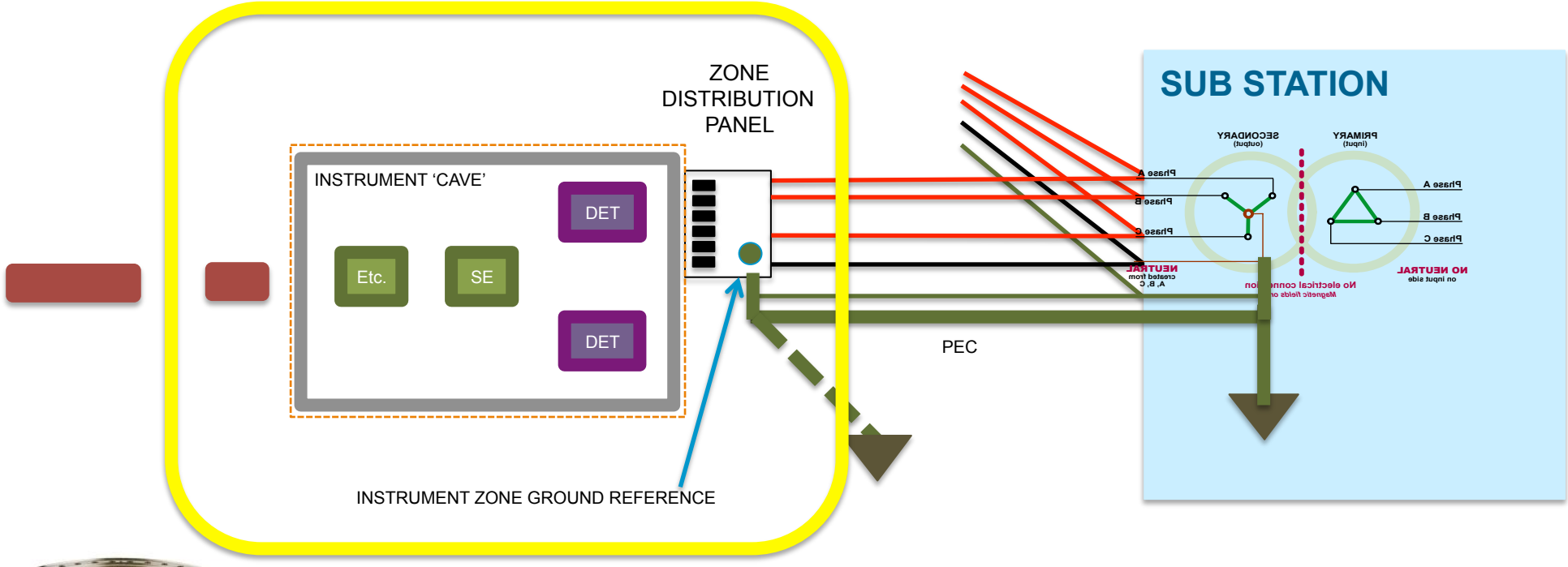
How ‘clean’ is our power?

- Nominal voltage 400, 690 or 6600 V
  - Maximum voltage variations +/- 10 %
  - Typical voltage variations +/- 5 %
  - Backup power + 10 % / -15 %
  - Random step changes of 1.5% (increase and decrease) of the supply voltage may occur due to operation of the tap-changers of the main transformers.
- Nominal frequency 50 Hz, +/- 1 %
  - Maximum variations 50 Hz, +4 % / −6 %
  - Backup power 50 Hz ± 15 %
- Total Harmonic Distortion, THD
  - Maximum value 8 %, 40’th overtone inclusive
  - Typical value 2 %
  - Voltage unbalance < 2 %
- Voltage Dips
  - A drop in phase voltage below 10% of nominal value.
  - Electrical supplier is not required to care about dips shorter than 150 ms

Instrument Zones



Main Instrument Zone Power



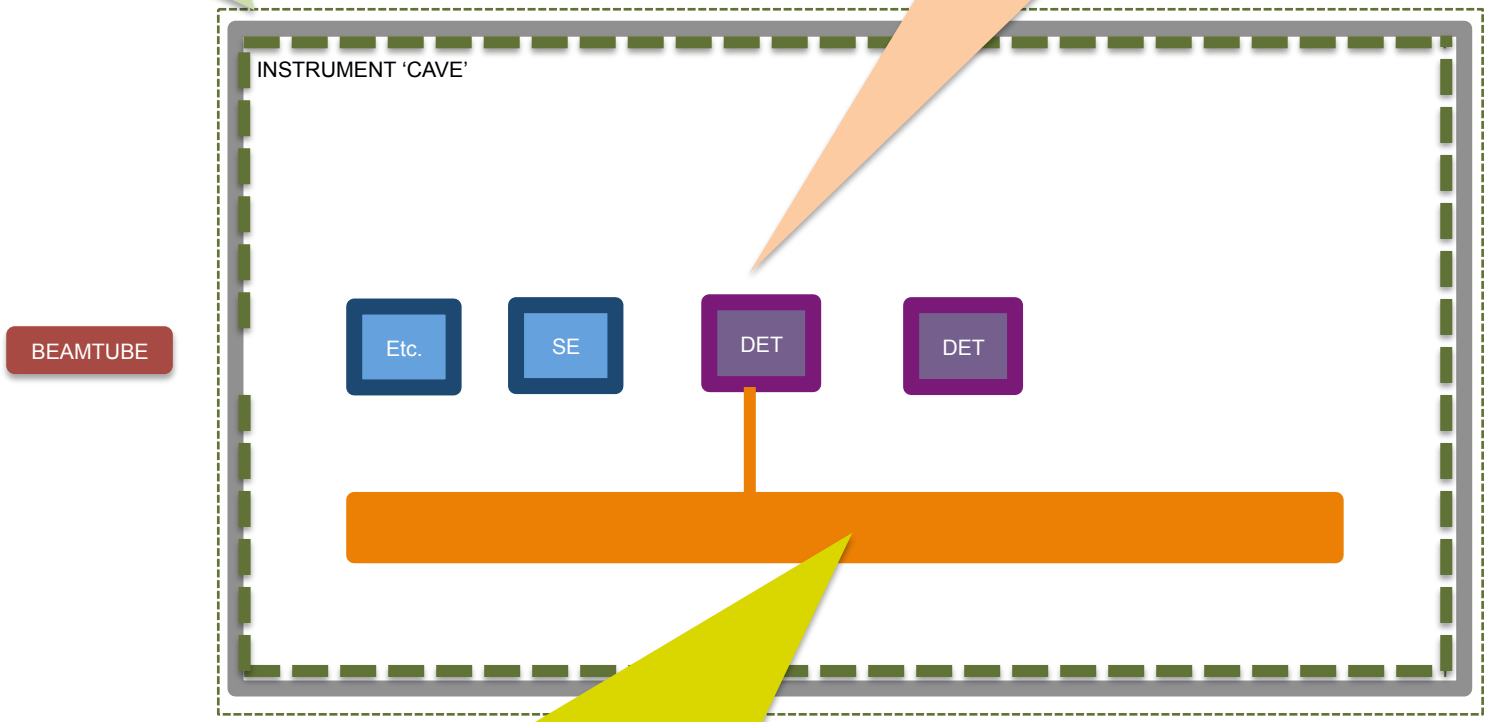
The Instrument Cave Zone must not be bridged to other zones unintentionally. For example, the beam guide should not provide an electrical path that connects multiple zones.

Instrument Grounding

Shown for an instrument cave but similar for other zones (except bunker)

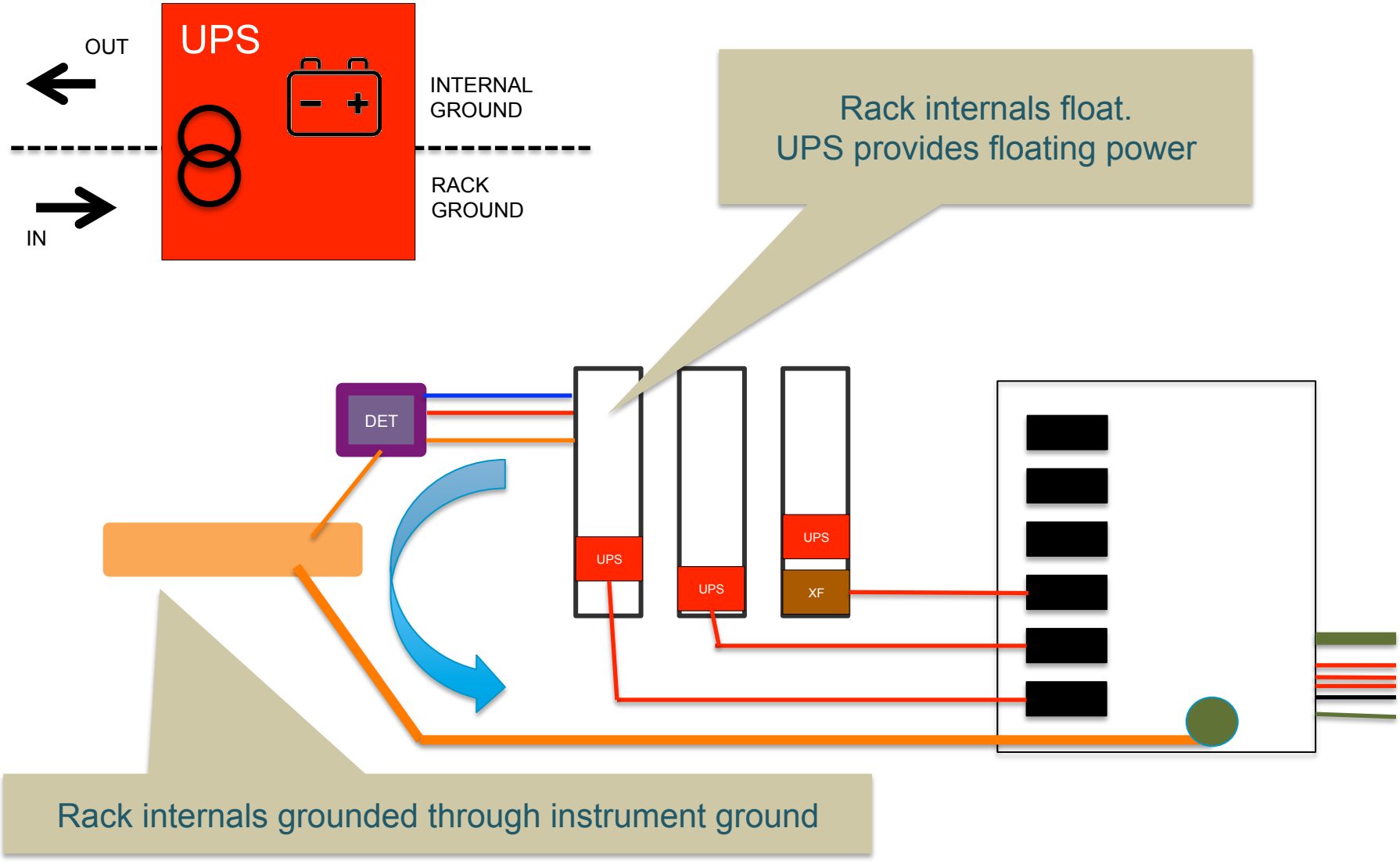
Shield Ground is general purpose ground. Connect everywhere. Radiological shielding is typically in steel cans that can (indeed must!) be grounded)

Signal Ground is for electrically sensitive equipment. Selectively connect.



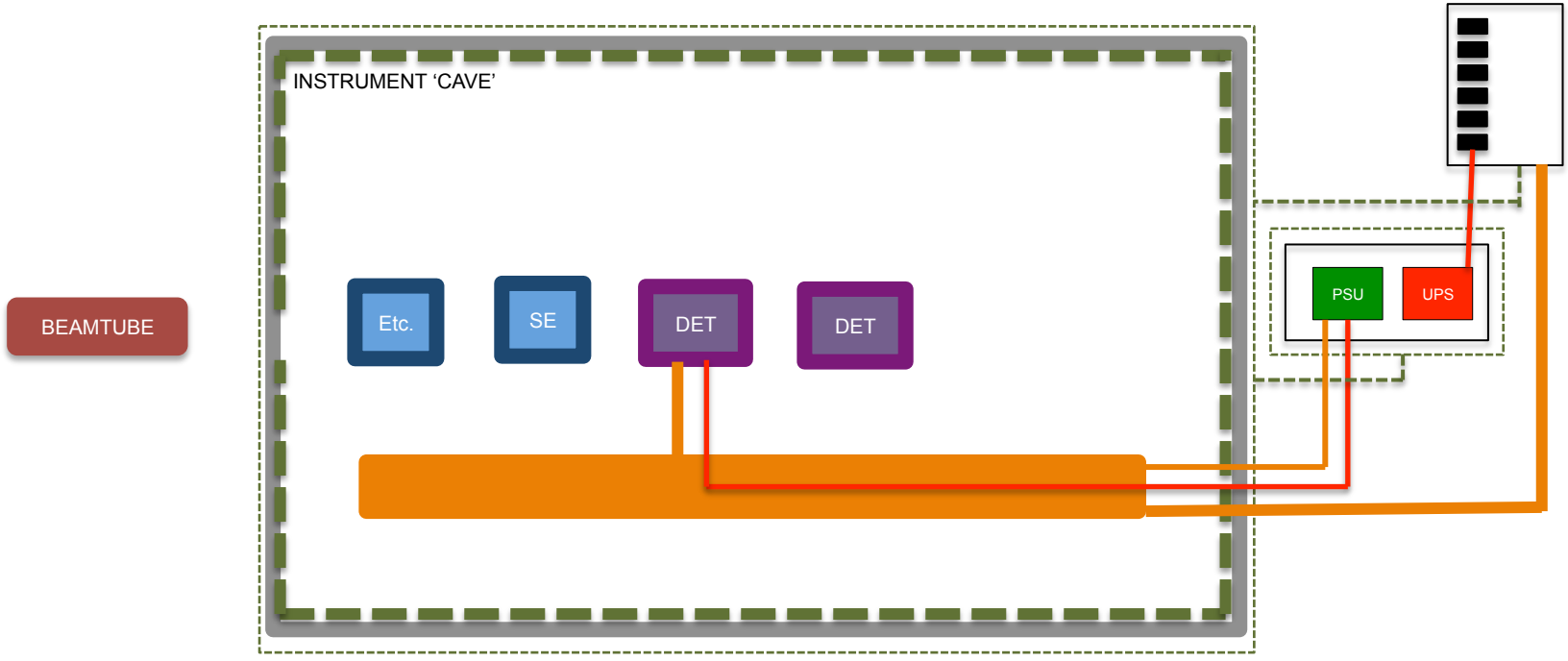
Grounding Structures (bus bars, etc.) as required

Grounding Path for Sensitive Equipment



Small Signal Quiet Implementation

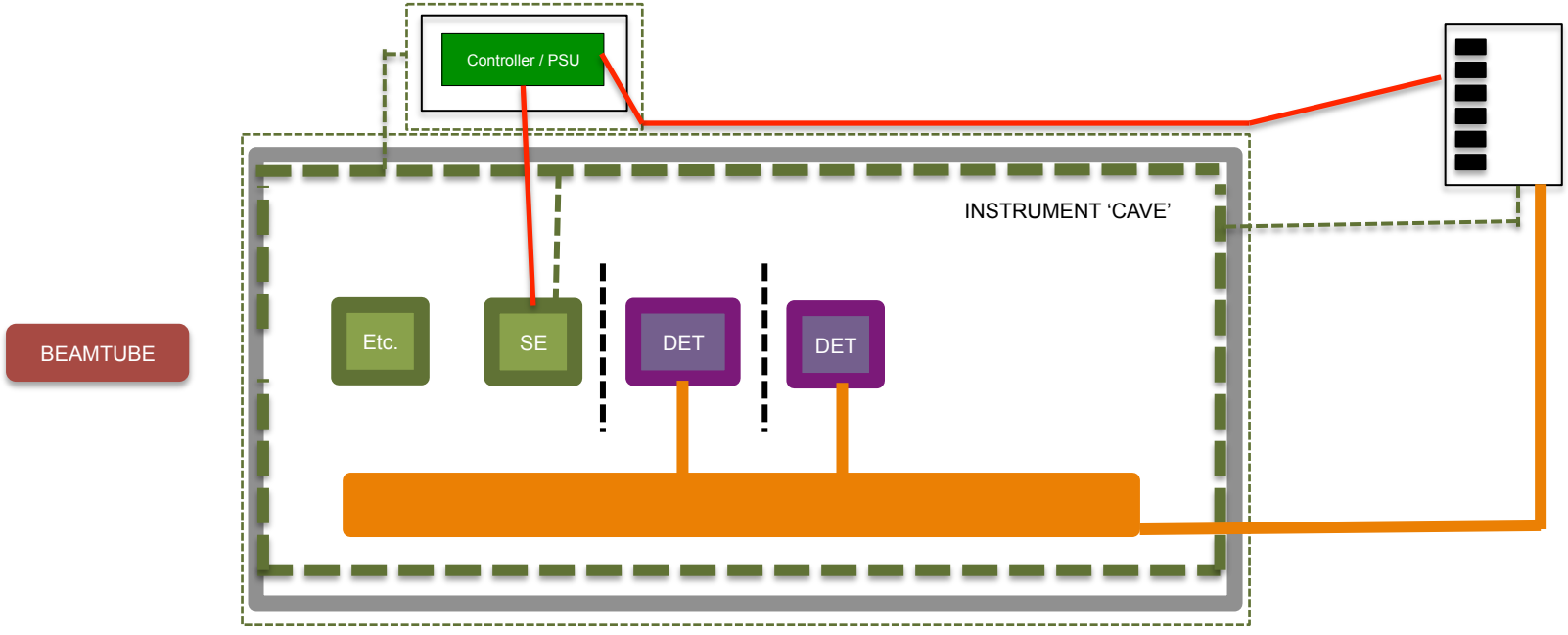
As shown on the last slide, rack internals are grounded through their connection to the instrument. This may be on some grounding structure (eg copper bar) rather than the actual subsystem itself. The rack frame is connected to shield ground, and the rack itself needs to be placed close to the outer shield of the cave structure.



Noisy Drive System

In cases where we expect some current into neutral/ground we isolate from the signal ground. All such are connections to the shield ground. This is a mesh type ground within this zone (but only this zone).

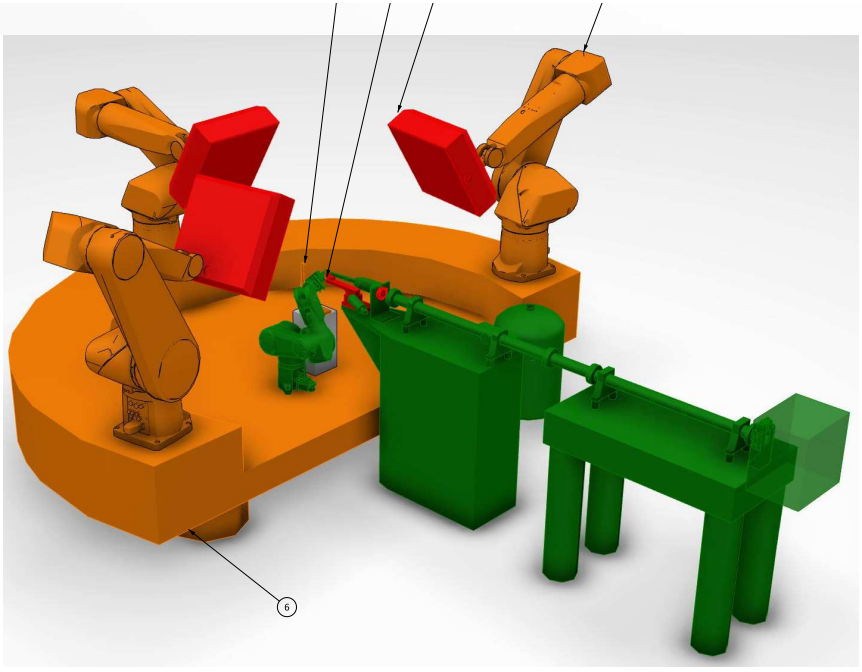
Accordingly it is very important that sensitive systems (such as detectors) can isolate their grounding from adjacent equipment. As best practice, you should aim to be able to isolate each internal module from its neighbours, and provide only one well defined grounding point for each module.

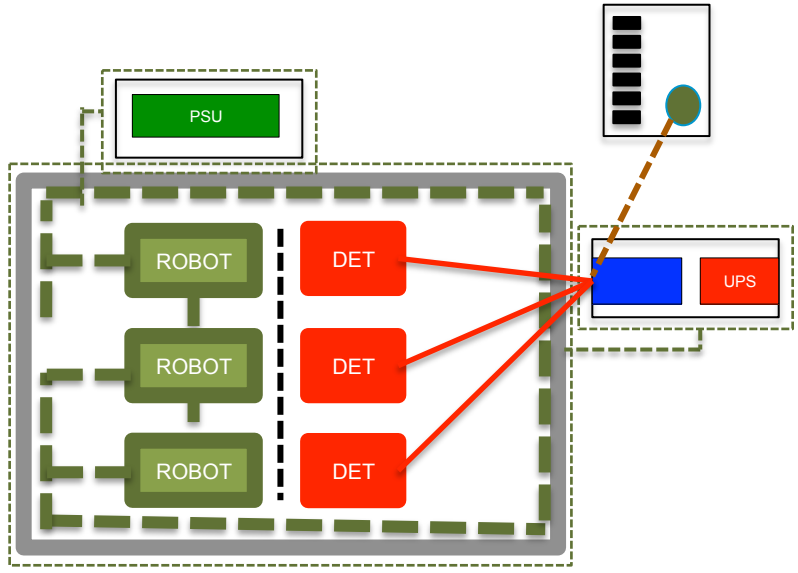


Multi Strands Eg NMX

In many cases it will not be obvious how best to partition the grounding.

For example, detector arrays may be independent. Nevertheless, the same principles apply. For example, in NMX (where detectors sit at the end of robot arms) the detectors themselves might be isolated from the mechanics of the robot arm, each an independent strand of the signal ground.....



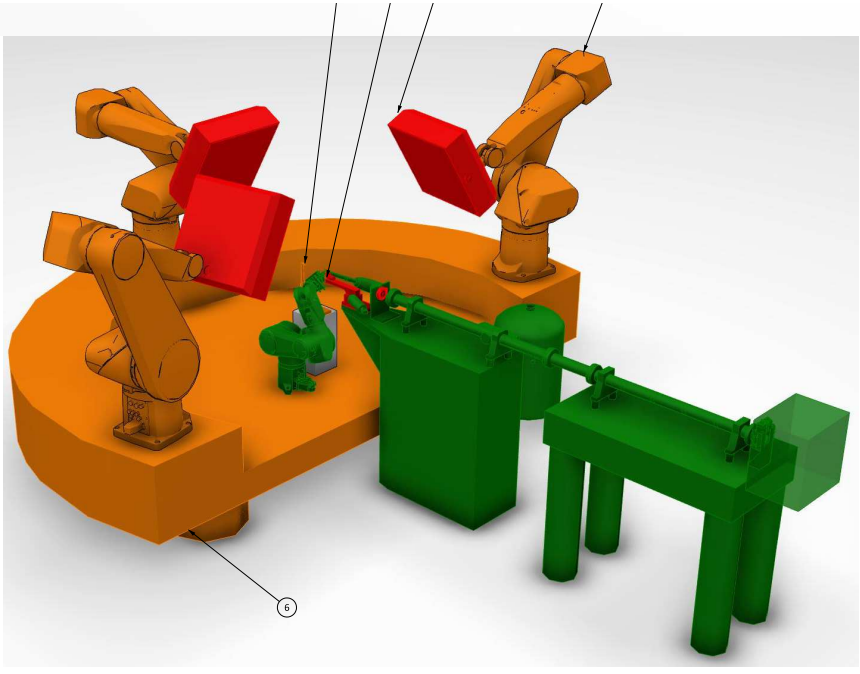


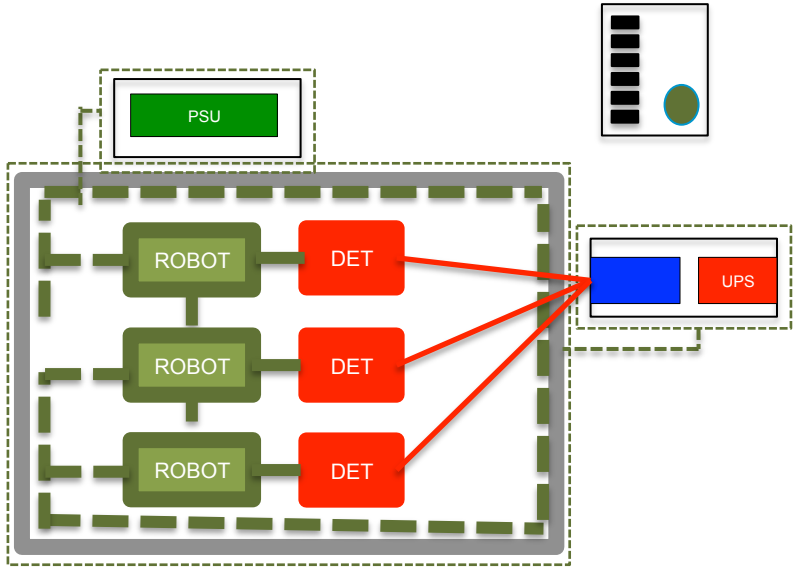
Multi Strands Eg NMX

....or it may be equally satisfactory to connect through to the shield ground.

Or the robot system (etc.) may be connected to signal ground.

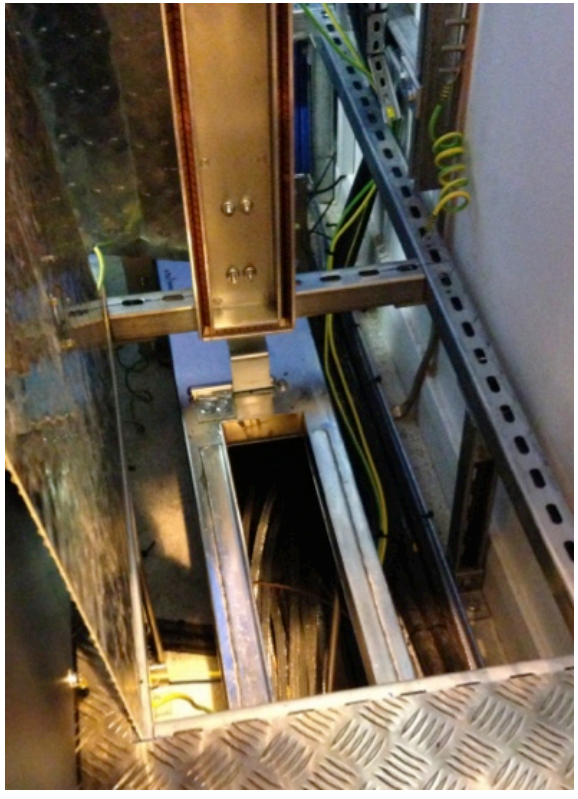
The relevant technology group (eg Detectors, Motion Control, or Sample Environment) can advise the best course to take in the context of the overall instrument design.



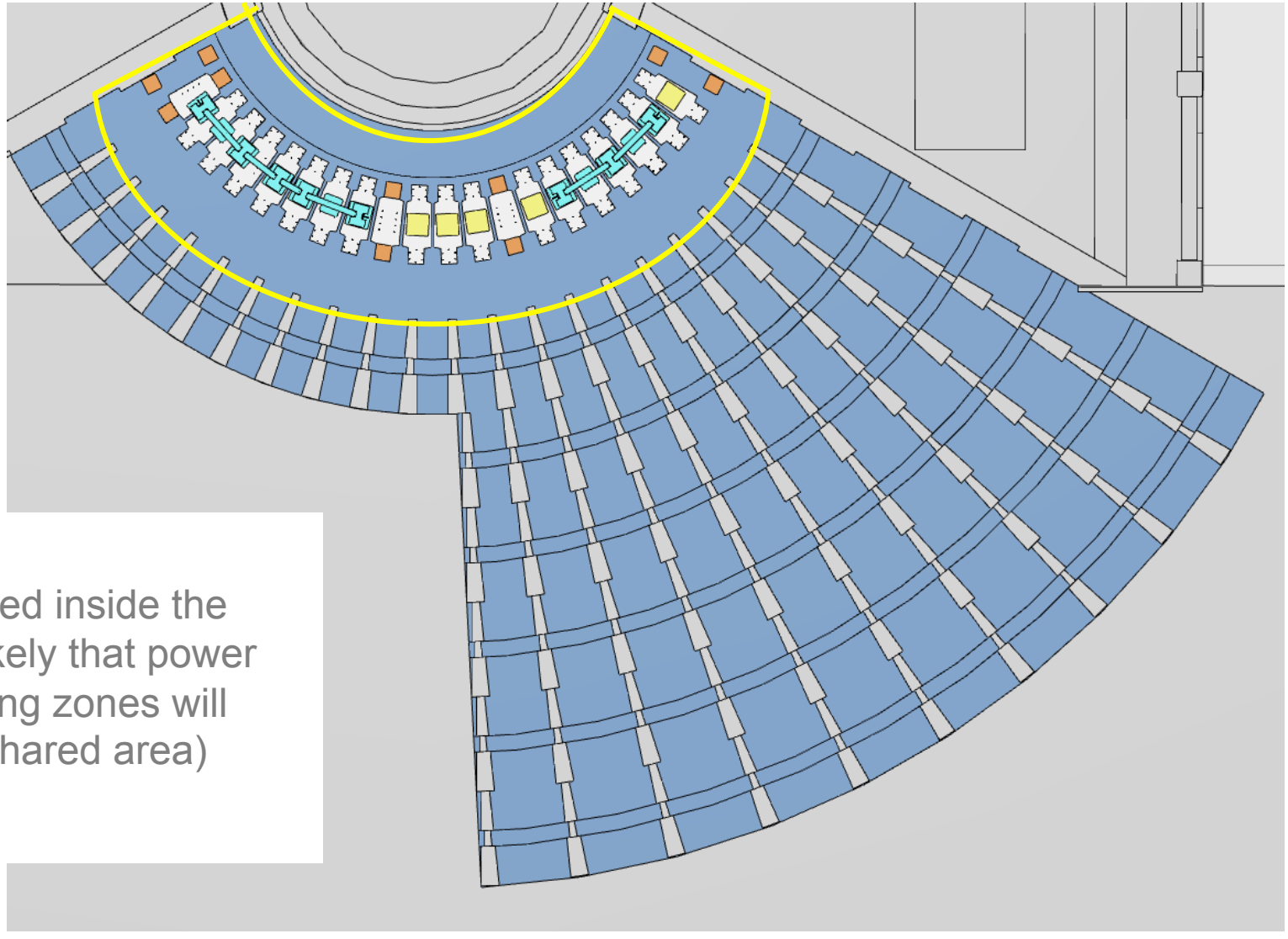


Other Special Measures

By adopting these simple rules we should be able to avoid special measures,
eg full EMC shielded rooms.
Only consider such measures where we anticipate significant problems



Bunker Zone



Space is very limited inside the bunker, and it is likely that power feeds and grounding zones will merge (eg in the shared area)

Conclusions

- At macro level ‘Star’ ground preferred over ‘Mesh everything’ – instrument zones are isolated from surroundings. Must be rigorously applied.
  - Services (pipes, etc) must not bridge ground
  - Global connections (network, timing, PPS, etc.) must be optically coupled

- At local level grounding is a mix of mesh and star as appropriate. At least two independent grounding systems available within cave to isolate sensitive equipment. The grounding system may have many strands to the ‘star’. Standard ESS readout components can comply with any permitted implementation.

- Independent readout/control makes it easy to partition instrument zones

- Power feeds and backup reasonably well defined.
  UPS backup on an individual rack by rack (or subsystem by subsystem) basis.
  Generator backup possible but not foreseen. Using generator power would require a special parallel power feed, or manipulating breakers at fail time.

- Detailed technical specifications for things like cable routing/shielding to be addressed in coming months…

- Draft docs available at ESS with wider circulation planned very soon.
  Please don’t hesitate to consult ESS technology teams if you have questions.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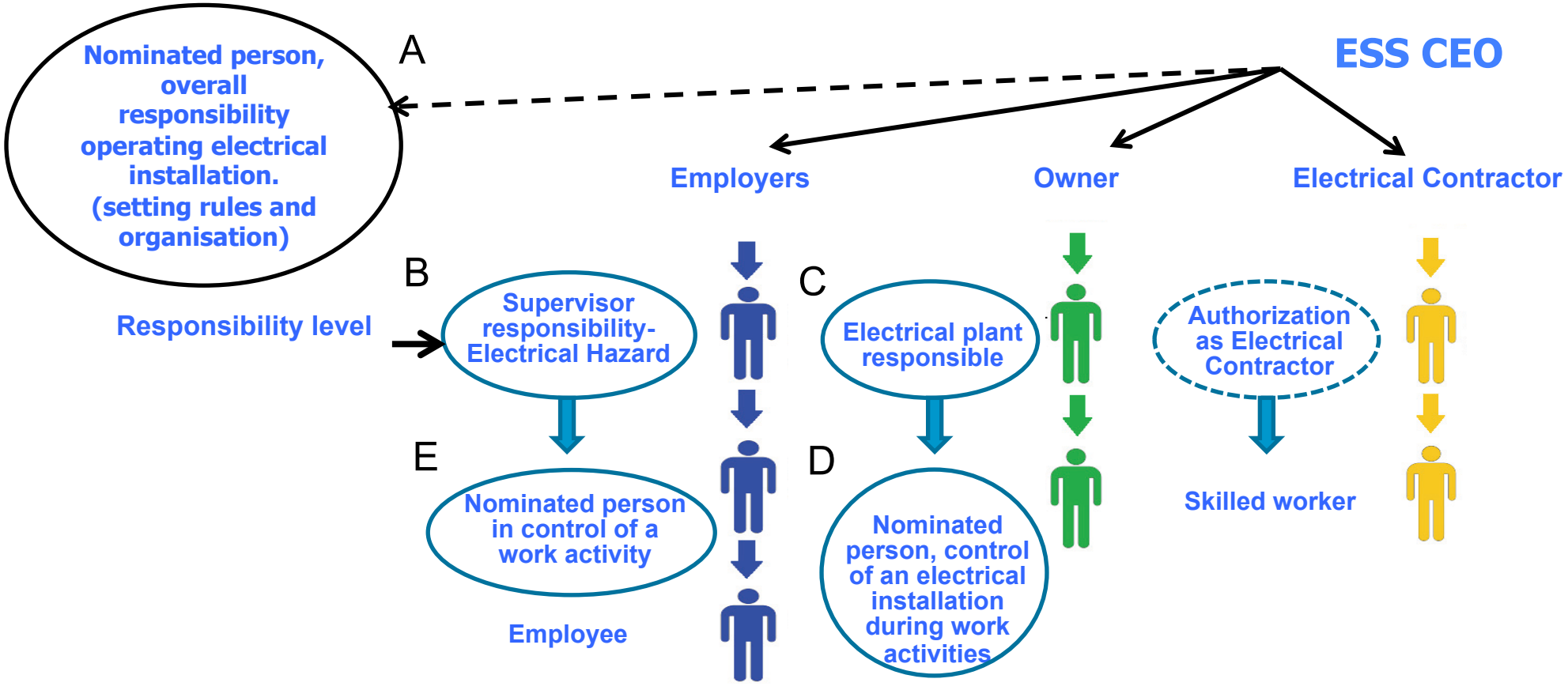
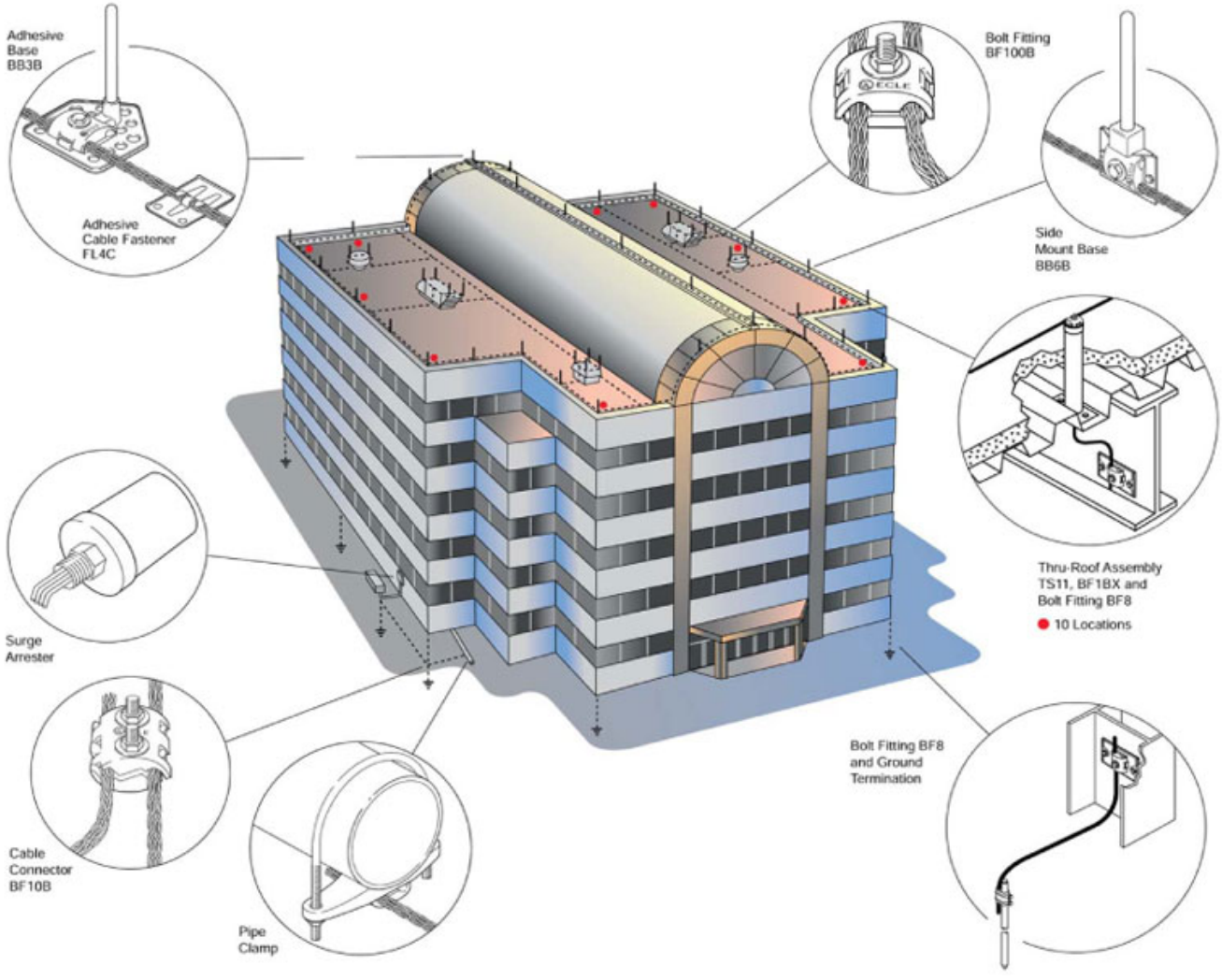
Backup Slides

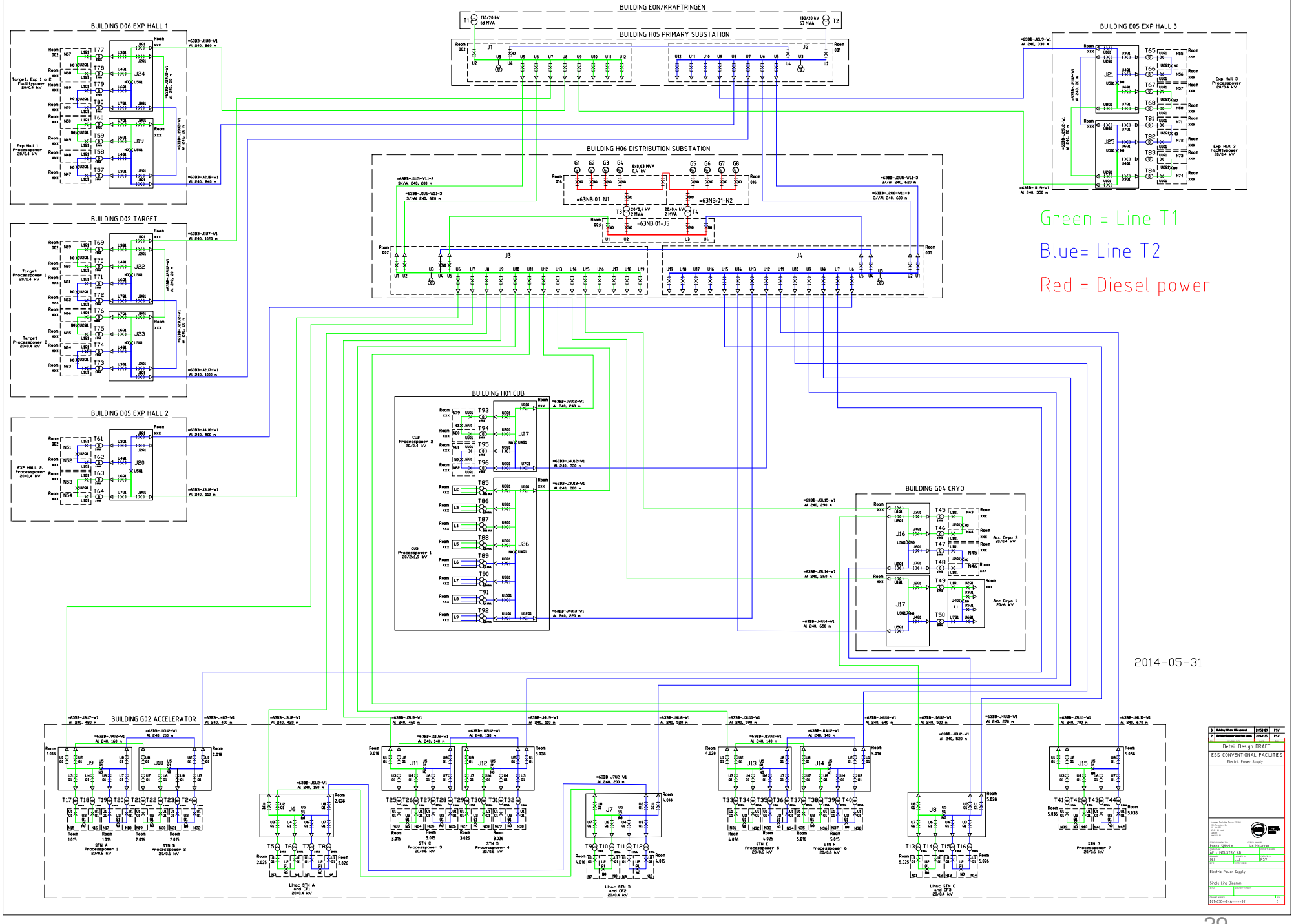
Responsibility for Electrical Safety within ESS



A. Elsäkerhetssamordnare/Nominated person, overall responsibility for operating electrical installation. (setting rules and organisation)
B. Linjechef/Line manager
C. VD/CEO
D. Eldriftansvarig/Nominated person, control of an electrical installation during work activities
E. Elarbetsansvarig/Nominated person in control of a work activity

Lightning Protection




BUILDING EON/KRAFTRINGEN
BUILDING H05 PRIMARY SUBSTATION
BUILDING D06 EXP HALL 1
BUILDING D02 TARGET
BUILDING D05 EXP HALL 2
BUILDING H06 DISTRIBUTION SUBSTATION
BUILDING H01 CUB
BUILDING G04 CRYO
BUILDING G02 ACCELERATOR
BUILDING E05 EXP HALL 3
Green = Line T1
Blue= Line T2
Red = Diesel power
2014-05-31