FUTURE
CIRCULAR
COLLIDER

POST-FEASIBILITY CIVIL ENGINEERING

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gratefully acknowledging the contributions of the FCC Host States and Civil Engineering WG and all FCC study teams and collaborating partners

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Feasibility Study Goals

- The civil engineering objectives of the current study is to ascertain a cost and schedule associated with a specific and technically achievable configuration of the FCC.
- This civil engineering cost and schedule will be a key parameter in the overall assessment of the feasibility of the FCC.
- The process of defining the FCC configuration has continuously taken into account civil engineering constraints and preferences, aimed at ensuring an optimum cost and schedule, whilst achieving overall functional requirements of the machine, experiments and their associated supporting infrastructure.
- To achieve the overall objectives, the following specific tasks will need to be completed before the feasibility study for the civil engineering can be considered complete.

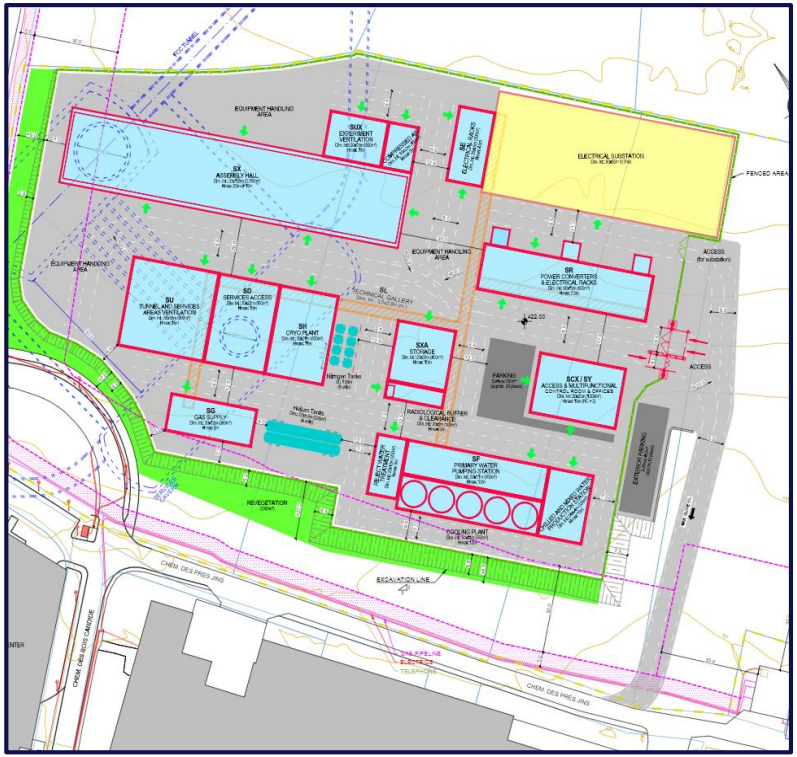
Feasibility Study Goals

- Reduce geological and geotechnical uncertainties to acceptable levels.
- Ensure that engineering solutions exist for the construction of the tunnels, shafts and caverns for the expected geological conditions.
- Develop a Class 3 cost estimate (-15% <>+20%) for the underground civil engineering based on preliminary designs for major structures only.
- Develop a Class 4 cost estimate (-20%<>+30%) for the surface buildings based on conceptual/preliminary designs and sampled bills of quantities.
- Development of a high-level but robust schedule for the civil engineering works showing all major activities for the underground activities and summary bars for surface works.
- Develop delivery scenarios/strategies for the FCC civil engineering works.

[1] AACE International Recommended Practice No. 56R-08 - *Cost Estimate Classification System*

Feasibility Studies for Surface Works

- Up to now, studies, planning and estimates have focused mainly on the underground works.
- As the placement work is now quite mature, studies have recently commenced for the surface sites.
- Dedicated engineering resource and designer resource are being assigned to FCC within SCE Department.
- A collaboration agreement with DOE/FNAL is being finalized in order to allow FNAL staff to work on several topics including developments of surface layouts/buildings.
- Target is to have preliminary designs for costing purposes for inclusion in the FS Report.



Conceptual layout for an experimental surface site

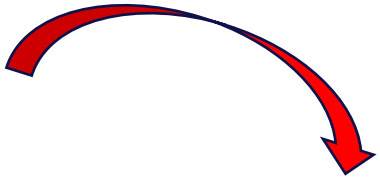
Feasibility Studies for Surface Works

- Continue to gather user requirements. Key in this respect is the development of a generic Assembly Hall derived from a high-level assembly and installation plan to be prepared by the Work Package 2 team.
- On the basis of documented requirements, develop in conjunction with FNAL surface layouts for at least one experimental site and one technical site.
- Internally within the WP 5 team, develop plans for the other 6 sites using the FNAL work as a basis.
- Develop cost estimates from Bill of Quantities for the two FNAL sites and extrapolate to obtain total costs for surface works.
- User requirements for two potential surface sites need to be prepared within the coming months in order for FNAL to start their input to the FCC Study.

Feasibility to Construction

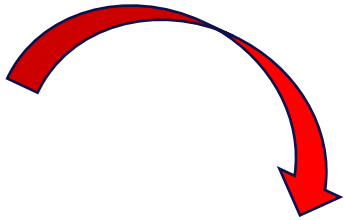
- No technical show stoppers
- Cost estimate
- Schedule for works
- Strategies for works

Feasibility Phase



- Complete site investigations
- Develop designs
- Finalise contracting strategy
- Select contractors for works

Post - Feasibility Phase



- Contractors selected
- Designs complete
- Ready to start work on site

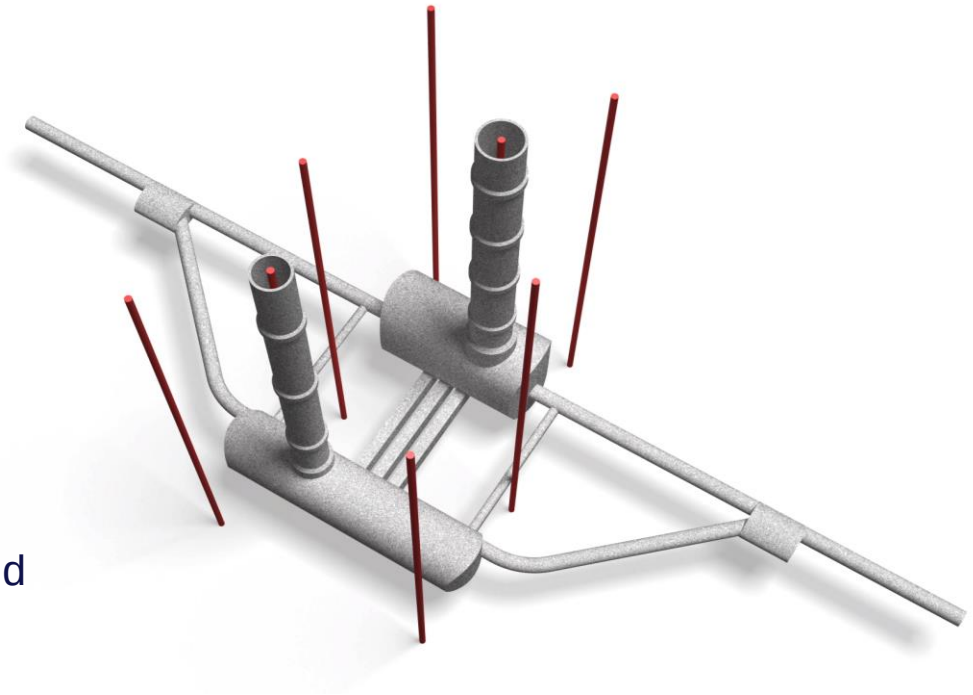
Prepare for construction

Complete Site Investigations

- The ongoing HRASI will cover about 40% of the perimeter of the tunnel and is intended only to cover those areas where geological/geotechnical uncertainties lead to significant cost and schedule risk.
- The scope is primarily aimed at identifying location of the target lithology for the tunnel (Molasse), identifying interfaces of the key geological units and identifying key structural features such as faults that could impact construction and/or operation.
- Additional site investigations will be required in order to provide more detailed information in specific areas such as:
  - 3D geological model for the experimental cavern complexes
  - Additional drillings to ascertain hydrogeological regime around shaft locations and in the limestone zones (karstic formations)
  - Specific testing to determine in-situ stress regime especially in the locations with high overburden.

Possible borehole layout for an Experimental Area

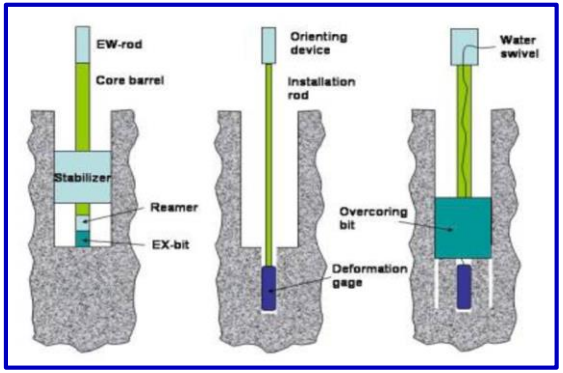
- Additional boreholes every 500m
- 7 additional boreholes for each of the 4 experimental areas
- New boreholes for beam dumps and injection lines
- Total of about 150 new boreholes
- Additional testing will be required to determine critical parameters such as in-situ stress regime, groundwater flow regime, extent of disturbed ground around faults etc.
- Additional geophysics may be necessary to confirm molasse boundary



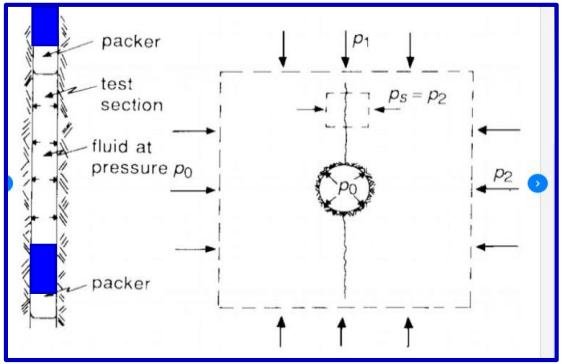
In-situ Stress Measurement

Why:

- With 600m of overburden, vertical in-situ stress is 16MPa.
- Horizontal stress regime is rarely uniform and can be significantly greater that the vertical stress.
- Strength of Molasse can be as low as 1 MPa and typically is between 10 and 30 MPa.
- In these conditions the excavation process will induce failure of the rock around the excavation can become difficult to control.
- Although we cannot control the in-situ stress, knowing its magnitude and direction will help us design suitable structures and will help plan the excavation sequencing.

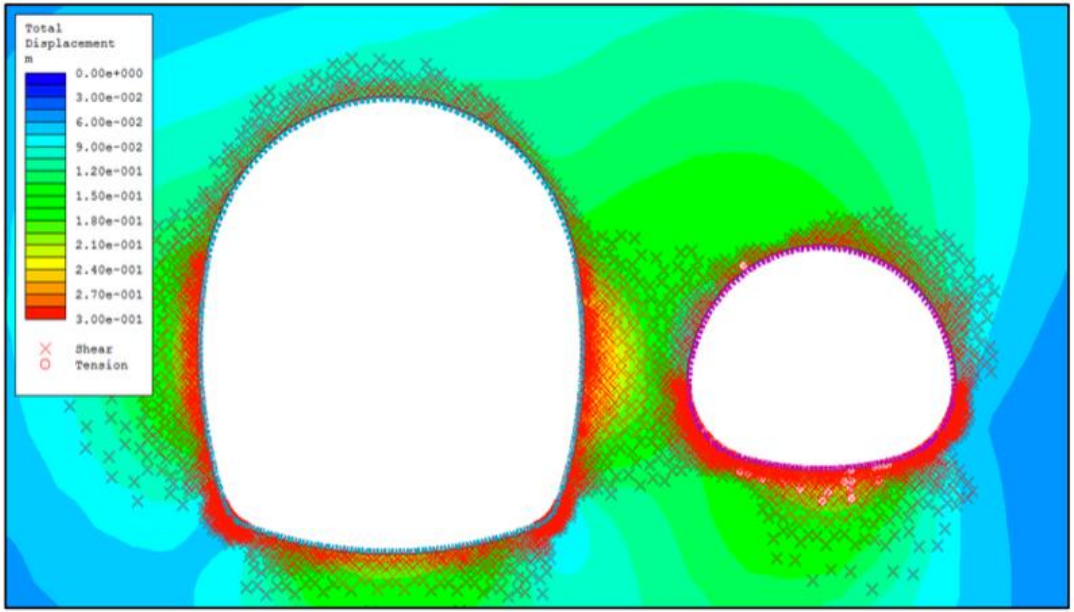


Over-coring



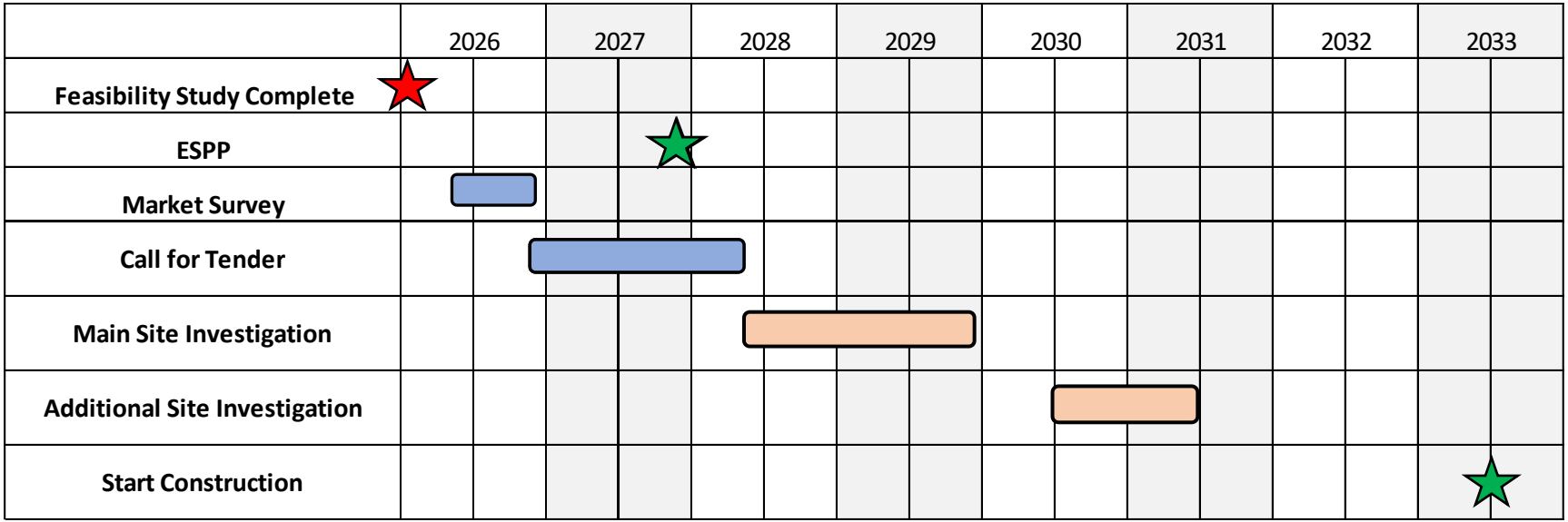
Hydrofracture

600 litres/min Water Inflow
during LEP Construction



Failed Zone around excavation –ILF
Conceptual Studies for FCC Study (2018)

Post-Feasibility Site Investigation Activity



CERN Procurement activity

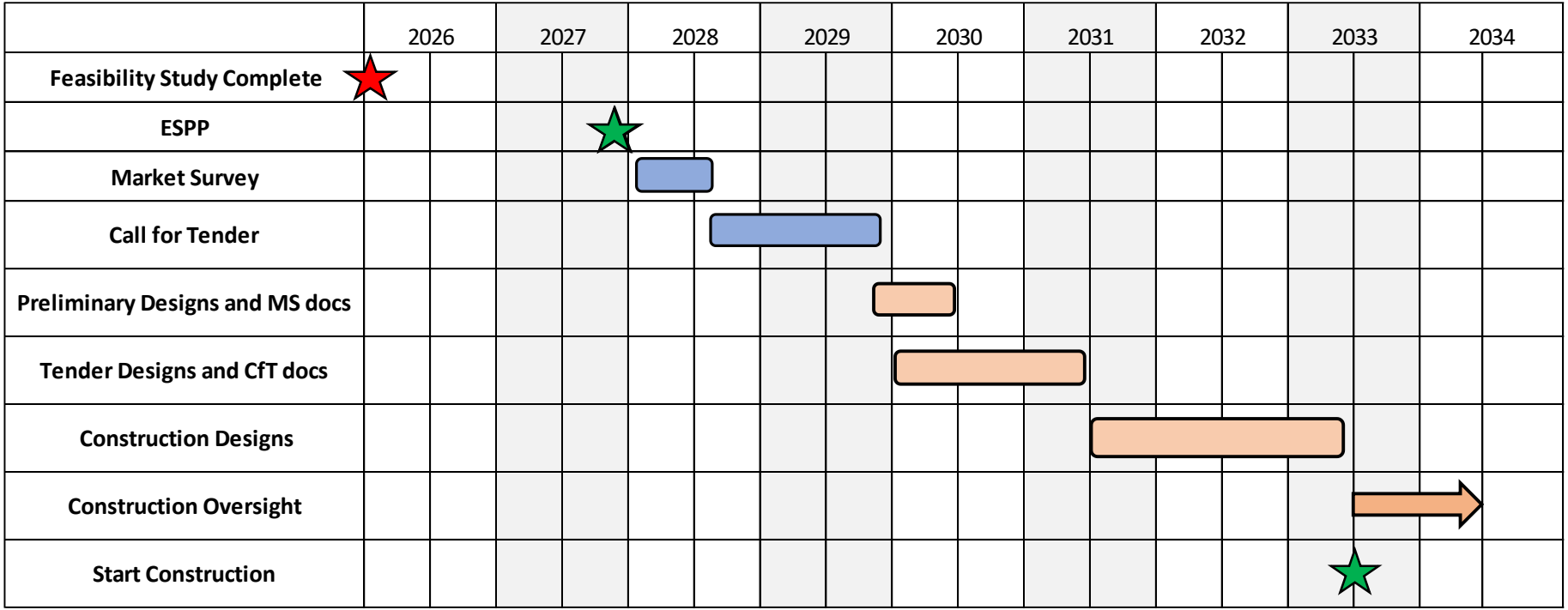
Contractor activity

Note this schedule assumes no further SI consultants will be procured

Develop Designs

- CERN will need to contract with one or more civil engineering consultants.
- Likely that 4 or 5 consultancy contracts will be set up to ensure competition and spread risk as well as to enable work distribution across member states.
- Precise scope will depend on strategy but detailed designs at least for subsequent tendering for the construction works will be required. Likely that construction oversight will be included in the contracts.
- Other technical disciplines will be required either as stand-alone contracts or within the scope of the civil engineering consultancy contract(s) such as architecture, landscaping, permitting, environmental impact monitoring etc.
- Development of the detailed designs will run in parallel with finalization of the requirements and gathering of additional site investigation data.

Design/Consultancy Services



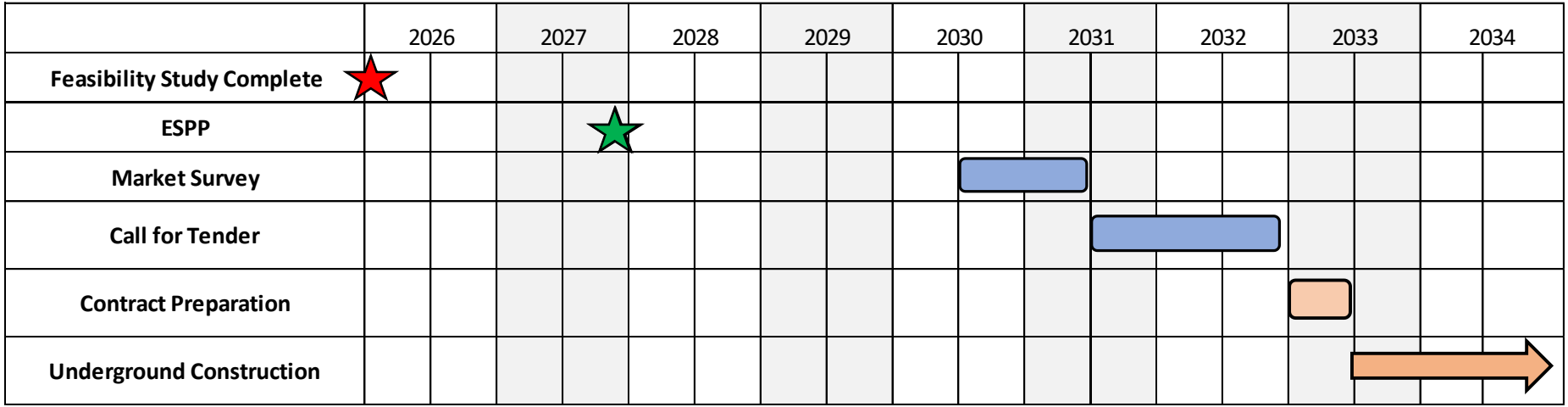
CERN Procurement activity

Contractor activity

Procure Contractors

- Strategy is a pre-requisite before contractors can be selected;
- Most likely scenario is that CERN will contract a number of construction packages to spread risk and allow broad participation across member states.
- Most obvious split would be one TBM drive from each shaft and one contract per TBM drive giving at least 8 construction contracts.
- Other possibilities would include a Special Purpose Entity set up to construct all infrastructure (not necessarily limited to Civil engineering) however the advantages and disadvantages of this of this in the CERN context have not yet been developed.
- The resources needed by CERN to undertake such massive procurement and contract management are not developed at this stage but clearly it would be significantly greater than CERNs current capabilities.

Construction Contracts

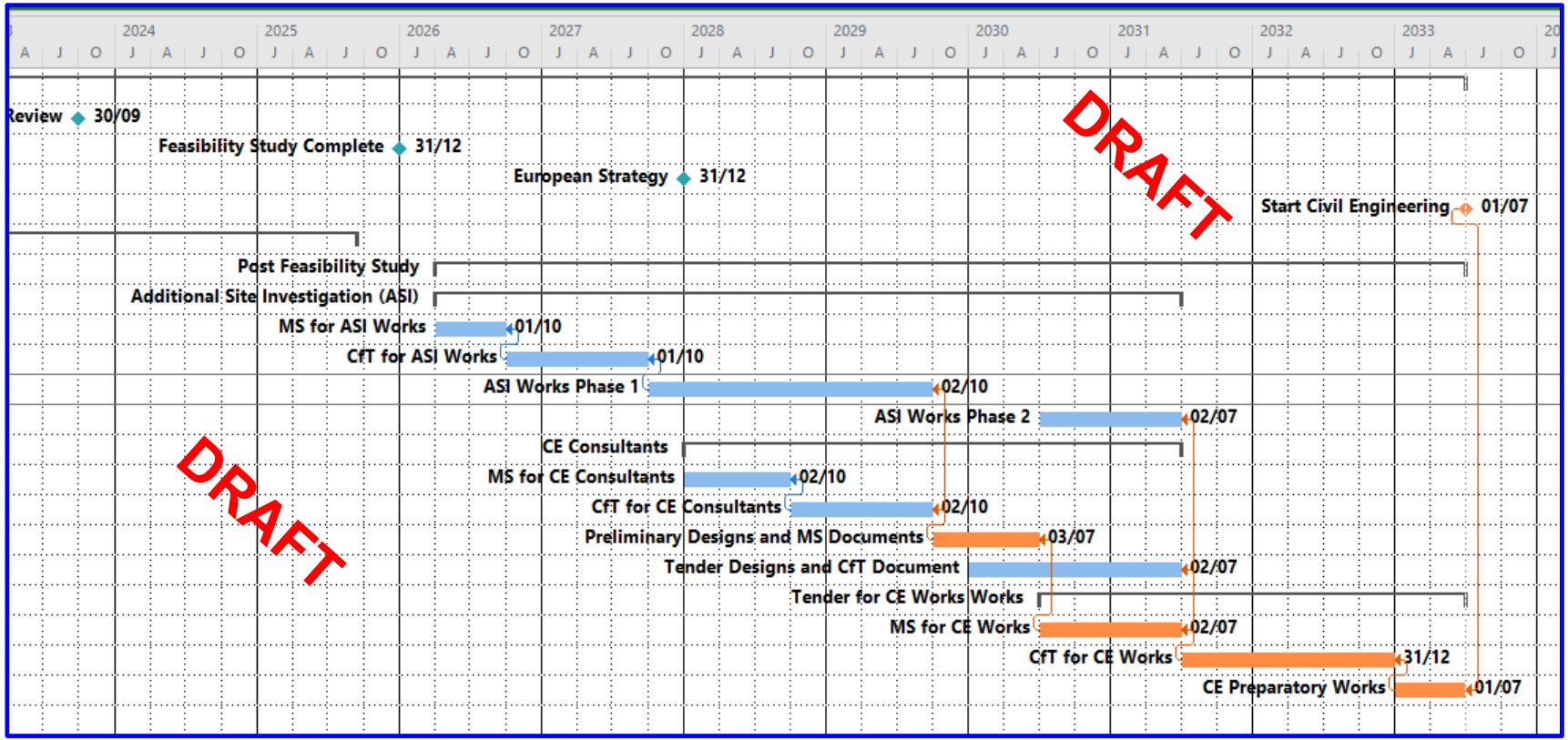


CERN Procurement activity

Contractor activity

- Contracts would need to be procured largely in parallel
- Civil engineering construction period is estimated to be about 7 years

Post Feasibility Study Schedule



Finalise Contracting Strategy

- Very unlikely that complete civil engineering scope will be awarded to a single Contracting entity.
- Most obvious split would be one package for each surface site.
- However geographical, political, environmental considerations or other factors may require two or zero TBMs to be launched from one surface site.
- Surface works could also be separated out from underground works.
- CERN is likely to seek advice in this matter during the current feasibility study period and the agreement with FNAL will include for collaboration on this topic.
- Contract type will also need to be considered although historically CERN has adopted re-measurement contract using FIDIC contract conditions.

Delivery Strategy – Traditional Approach

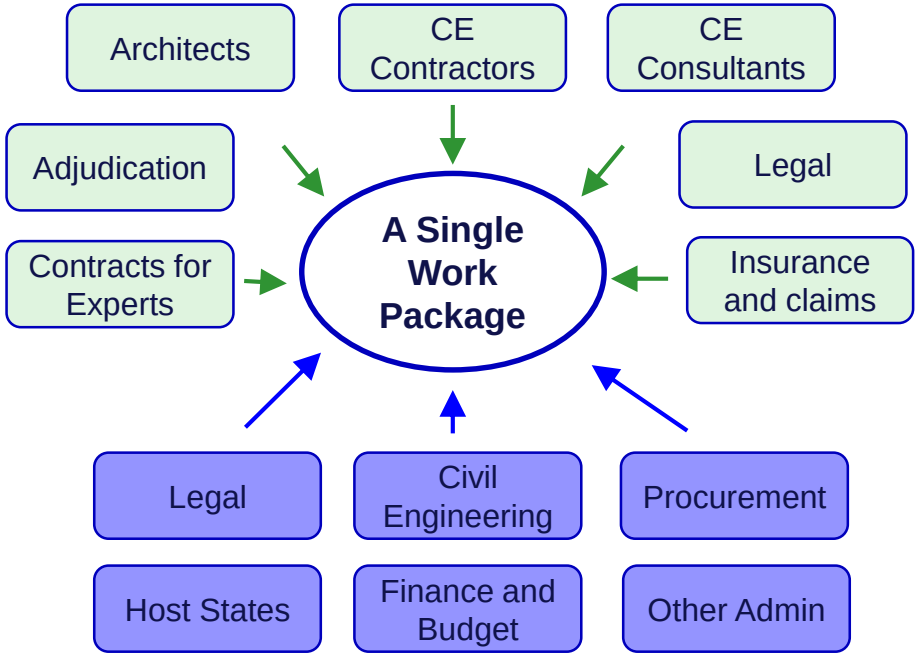
CERN maintains small core team to set up and manage contracts

8 or more parallel contracts for consultants, architects, contractors, legal services, adjudicators, specialists etc. would need to be set up and managed.

Significant increase in procurement, legal, and civil engineering resources would be required.

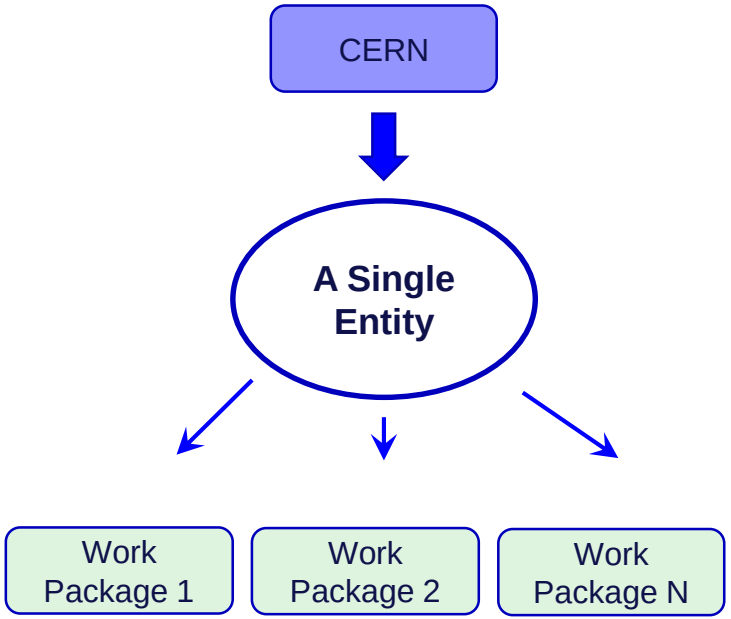
Significant increase in resources to deal with host state interfacing would be required

Increase in administrative services to support the contracts would be necessary



Delivery Strategy – SPV Approach

- CERN creates of contracts with a single entity set up specifically to deliver FCC civil engineering
- The single entity would be responsible to deliver all civil engineering and create and manage all necessary contracts
- CERN resources significantly reduced but similar resource types will be required within Single Entity
- Concept could be extended to other infrastructure beyond Civil Engineering
- Not clear how this would work from legal and procurement perspective given CERN's status
- Not necessarily the cheapest delivery model but would avoid the need for CERN to set up a huge internal team of resource.



Conclusions

- To meet a construction commencement date in mid-2030's CERN must already start planning for the post-feasibility study contracts and site investigation works.
- Initial thoughts have been presented today but these will need to be taken forward within an wider context than purely civil engineering works.
- Careful consideration with regard to CERNs future in-house capabilities will need to be taken into account when drawing up strategies for delivery of the FCC civil engineering.
- Most importantly and not covered today, the lengthy and complex processes associated with obtaining the necessary authorisations for the FCC within the two host states may require a longer period of time than the civil engineering preparation works. This will become clearer during the feasibility study period.

FCC

Thank you
for your attention.