Defining a computing R&D program in the context of the Energy Frontier Snowmass planning

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The timeframe conundrum

- The HL-LHC program is the baseline for the Energy Frontier (EF), a "given"
  - EF Snowmass process will focus on **EW physics, QCD and strong interactions, and BSM physics** under different **future accelerator scenarios**, including lepton-lepton, hadron-hadron, and lepton-hadron colliders

- The HL-LHC program is "not a given" for the Computing Frontier (CF)
  - CF Snowmass focus is to establish a technically robust and well-funded R&D program to address the many Software & computing (S&C) challenges within the next ~10-15 years

- The success of the HL-LHC program is a pre-condition for any future EF facility
  - Involves improved understanding of the Higgs sector, the nature of dark matter, the energy scale of BSM physics. Physics will guide decisions on the nature of the new facilities
  - Conditioned to the *success of a S&C R&D program* resolving shortages of CPU, disk, tape
    - without sacrificing simulation and reconstruction quality, physics content of analysis-level files

The CF needs a plan and resources for breakthroughs during the next 10-15 years, and to (at least) identify the challenges posed by future accelerator scenarios

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The next 10-15 years

- Snowmass 2021 does not start from scratch defining a S&C R&D plan for EF
  - The international community (HEP Software Foundation – HSF) produced a [A Roadmap for HEP Software and Computing R&D for the 2020s](#), Comput. Softw. Big Sci. (2019) 3, 7
    - A request from NSF to fund the Institute for Research and Innovation in Software (IRIS-HEP)
  - There is a thriving program funded by DOE and NSF which targets S&C R&D for EF
    - Physics generators, detector simulation, trigger/reconstruction algorithms, analysis tools, DOMA, storage, performance portability

- Snowmass 2021 offers a chance to reframe and strengthen the existing program
  - Focus on topics of interest, leveraging US skills and experience, for maximum impact
  - Increased collaboration across institutions, experiments, agencies (DOE-NSF), fields (computing researchers, applied mathematicians), and with industry

- Snowmass 2021 should dig deep into the opportunities arising from emerging technologies – e.g applications of AI, hybrid computing with accelerators, HPC facilities

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The far future

- The EF will explore physics programs for potential future facilities: ILC, CepC, SppC, CLIC, FCC-ee, FCC-hh, Muon Collider

- Computing challenges need to be addressed within two timescales
  - Tools for prospect studies and construction phase (~2020-2060) [R&D within 10-15 years]
    - Accelerator modeling software (lattice, beam dynamics), detector simulation tools for next generation detectors (geometry, physics models at higher energies), generators/theoretical calculations (processes, NNLO contributions) – precision/speed
  - Challenges to address by commissioning and run time (~2040-20XX) [Longer term R&D]
    - Computing model, big data handling, software languages, software collaboration tools
      - Very difficult to predict given rapidly evolving technologies!
    - Algorithms for data processing
      - Examples are reconstruction in a 800-1000 pileup environment (FCC-hh), rejection of HE photon backgrounds (muon collider), in general adaptations to far future architectures, etc.
    - Algorithms for theoretical calculations, effective field theories, global fits including pdfs, etc.

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The next steps

- Most topics of conversation between the CF and the EF cut across the other physics frontiers, as well as the Accelerator Frontier
  - Communication channels must be opened in many directions. **Action Item 1 (AI-1)**

- In conversation with the EF conveners (Meenakshi Narain, Laura Reina, Alessandro Tricoli), we discussed the following potential course of action
  - Identify volunteers in EF to take interest on the following CF-EF cross-cutting topics **(AI-2)**
    - Algorithm techniques for theory calculations, simulation of detector complexity, parallelization of trigger/reconstruction algorithms, AI applications, exploitation of hybrid architectures, analysis tools, quantum computing, data formats/reinterpretation/preservation
  - This team of volunteers would develop ideas related to software and computing components, features, tools that may be needed by the EF
    - Evolve these ideas into a wish list for short-term and long-term R&D **(AI-3)**
      - Think where emerging or disruptive technologies can take us: AI, Quantum Computing, etc. What would we be able to do that we don't do in current experiments? **(AI-4)**

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