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LLNL Capabilities Relevant to the INFUSE Program

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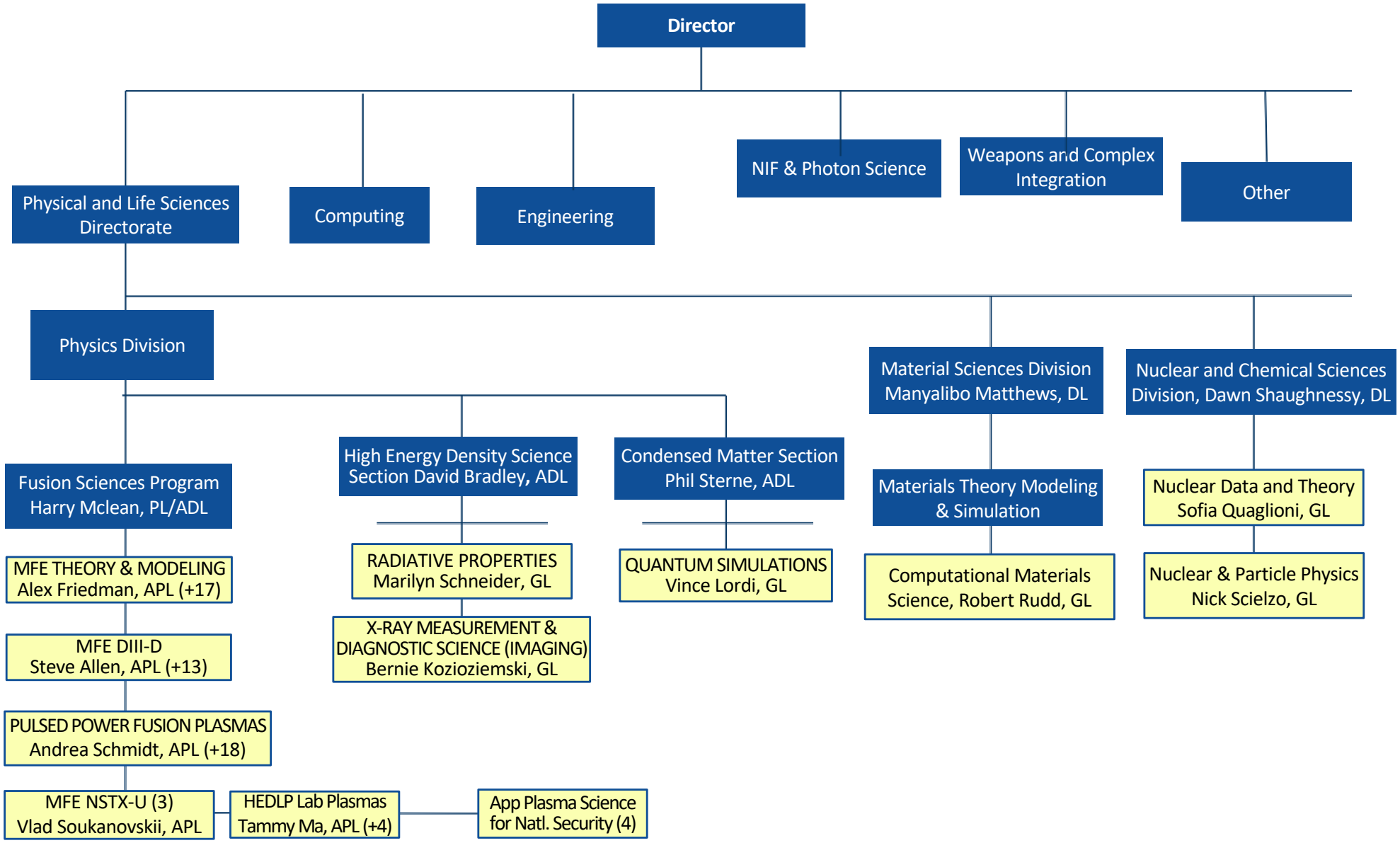
Outline

- LLNL – some background
- Organization of LLNL's fusion-related departments
- LLNL's technical expertise related to fusion
  - MFE
  - IFE
- Software
- Facilities of potential interest for collaboration
  - User facilities
  - Other facilities of potential interest
- Student intern and university faculty programs

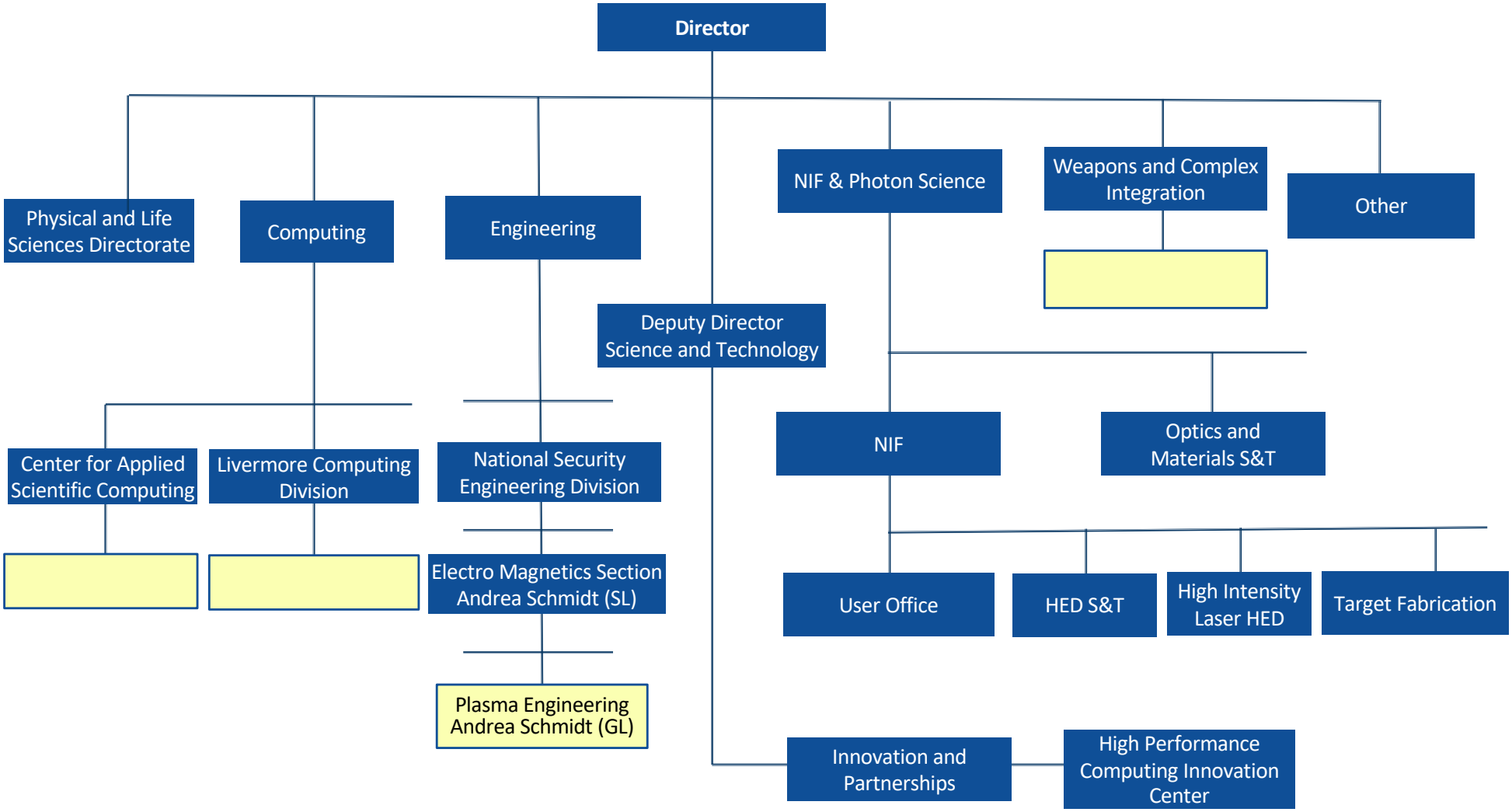
LLNL – Some notable facts – (www.llnl.gov/about)

- Managed by Lawrence Livermore National Security, LLC for NNSA
- ~7,900+ employees
- Established in 1952 on the grounds of the decommissioned Livermore Naval Air Station
- Prior to that, second site for UC Radiation Laboratory (Berkeley)
  - "Materials Testing Accelerator"
  - Development of diagnostics for nuclear weapons testing
- Early involvement in controlled fusion
  - Magnetic mirrors (R. F. Post experiments, 1952 – MFTF-B, 1987)
  - Laser-based ICF
    - Nuckols 1960 – proposed idea of controlled ICF based on computations
    - Shiva laser 1977
- Wide array of activities in controlled fusion (ICF, MFE, IFE), HED sciences, materials sciences and other areas relevant to fusion energy

LLNL departments relevant to fusion-energy: Physical and Life Sciences Directorate



LLNL: Other departments relevant to fusion-energy research



LLNL's technical MFE expertise: Physical and Life Sciences, Fusion Sciences Program

- Edge and scrape-off-layer modeling and theory
- Involvement in SciDAC's modeling/code-development
  - RF Actuators (RF)
  - Tokamak Disruption Simulation (TDS)
  - Plasma Surface Interactions (PSI)
  - Multiscale Gyrokinetic Turbulence (MGK)
  - Advanced Tokamak Modeling Environment (ATOM)
- Other projects and capabilities
  - Finite-element methods for MFE stability and transport
  - Quantum computing
  - Machine learning
- Tokamak equilibria with 3D error fields (GPEC code)

LLNL's technical MFE expertise: Physical and Life Sciences, Fusion Sciences Program

- Pulsed Power Fusion Plasmas group – experiment & modeling
  - Dense plasma focus
  - Flow-stabilized z-pinch
- Scrape-off layer experiments: Optical spectroscopy, imaging and analysis (DIII-D and NSTX groups), divertor Thomson scattering
- X-Ray measurement and imaging – various groups
- Residual experience and knowledge base on magnetic mirrors

LLNL has additional world-class technical expertise and facilities relevant to fusion energy

- Laser based ICF and HED science
  - NIF
  - Jupiter Laser Facility
- https://lasers.llnl.gov/about/nif-partners
- Residual experience and knowledge base
  - Heavy ion beam fusion
  - Fast Ignition
  - Fusion technology
- Diagnostics and imaging
  - X-ray measurements, signals, spectroscopy, imaging
  - Time-resolved neutron measurements

Software – PLS/FSP

- UEDGE – T. Rognlien, M. Umansky
  - MFE fluid edge/scrape-off layer transport code
  - Fast, robust, capable; results generally supported by kinetic-neutrals models
- Expertise with LSP and Chicago PIC/hybrid codes (esp. in Pulsed Power group – A. Schmidt, A. Link, D. Higginson and others)
- Generalized Perturbed Equilibrium Code (GPEC), N. Logan
  - Tokamak equilibria with 3D error fields
- BOUT++ – B. Dudson, X. Q. Xu
  - Fluid edge transport and turbulence library/framework and codes
- COGENT – M. Dorf
  - Eulerian kinetic edge transport and turbulence code based on Chombo
- Gingred – M. Umansky
  - Grid generator for UEDGE, BOUT++
  - Capable of setting up novel null-point (e.g., snowflake) and divertor geometries
- SciDAC codes: RF (RF-turbulence, A. Dimits), PSI (I. Joseph), TDS (I. Joseph), AToM (M. Dorf), MGK (L. LoDestro)
- Warp, Warp-X – HIF/accelerator PIC codes (A. Friedman, D. Grote)

Software – Other groups

- CASC
  - MFEM (Modular Finite Element Methods Library https://mfem.org/ – T. Kolev); high-order, flexible, scalable; used by
    - RF SciDAC - for RF propagation as scalable upgrade from COMSOL
    - TDS SciDAC (at LANL) and LLNL LDRD - for new MHD code
    - RF SciDAC and LLNL LDRD - for new plasma transport code
  - Leading-edge solver and preconditioner libraries Sundials (C. Woodward), HYPRE (R. Falgout); both are widely used
- Expertise with Chombo for plasma applications in CASC, FSP…. (J. Hittinger, D. Ghosh, M. Dorr, M. Dorf, G. Vogmann)
- Other codes and expertise e.g., in NIF organization & others
  - World class ICF codes

Facilities potentially available for collaborations

- Physics Division
  - User facilities https://pls.llnl.gov/resources/user-facilities
    - CAMS Center for Accelerator Mass Spectrometry
    - Jupiter Laser Facility – Three laser platforms Titan, Janus, Comet https://jlf.llnl.gov/laser-facilities
  - Other facilities/equipment may be available via collaborations, e.g., CRADAs
- Engineering - https://engineering.llnl.gov/collaboration
  - User facilities
    - Non-Destructive Characterization Laboratory (NDCL)
    - Design Optimization Laboratory (DOL)
    - Advanced Manufacturing Laboratory (AML)
  - Other via collaborations, e.g., CRADAs
- Livermore Computing – https://hpc.llnl.gov
  - Computer time/access may be available to LLNL researchers and collaborators
- See also Industrial Partnerships Office site https://ipo.llnl.gov

Student intern programs and on-going university faculty programs

- https://pls.llnl.gov/careers/internship-programs
- Science Undergraduate Laboratory Internships (SULI) for college and university students (4 year schools)
- A variety of summer internship programs https://pls.llnl.gov/careers/internship-programs
- Community College Internships (CCI) community college students (2 year schools)
- Visiting Faculty Program (VFP) for faculty and students from institutions historically underrepresented
- Graduate scholar program (PhD students)

Other facilities

- Livermore Computing https://hpc.llnl.gov/about
  - State-of-the-art computing facilities available to LLNL researchers and collaborators

- Livermore Valley Open Campus (LVOC) https://lvoc-org.llnl.gov/vision.html
  - High Performance Computing Innovation Center (HPCIC)
    - Meeting/collaboration space

Summary

- LLNL has technical expertise in a variety of areas relevant to controlled fusion
- Particular MFE focus and expertise is on edge and scrape off-layer physics (DIII-D, NSTX-U, other existing & future experiments, theory, modeling.)
- Leading laboratory on laser-based ICF
- High-intensity, short-pulse lasers (HED, ion acceleration, radiography….)
- LLNL has world-class expertise in and resources for a wide array of relevant areas
  - Applied and computational math
  - Pulsed-power plasma science and technology
  - Diagnostics
  - Materials sciences
  - Innovative new technologies, e.g., quantum computing, machine learning
- Active student intern and university faculty programs
- Robust business organization to facilitate industrial partnerships