A Roadmap for Sustainable Ecosystems of CSE Software

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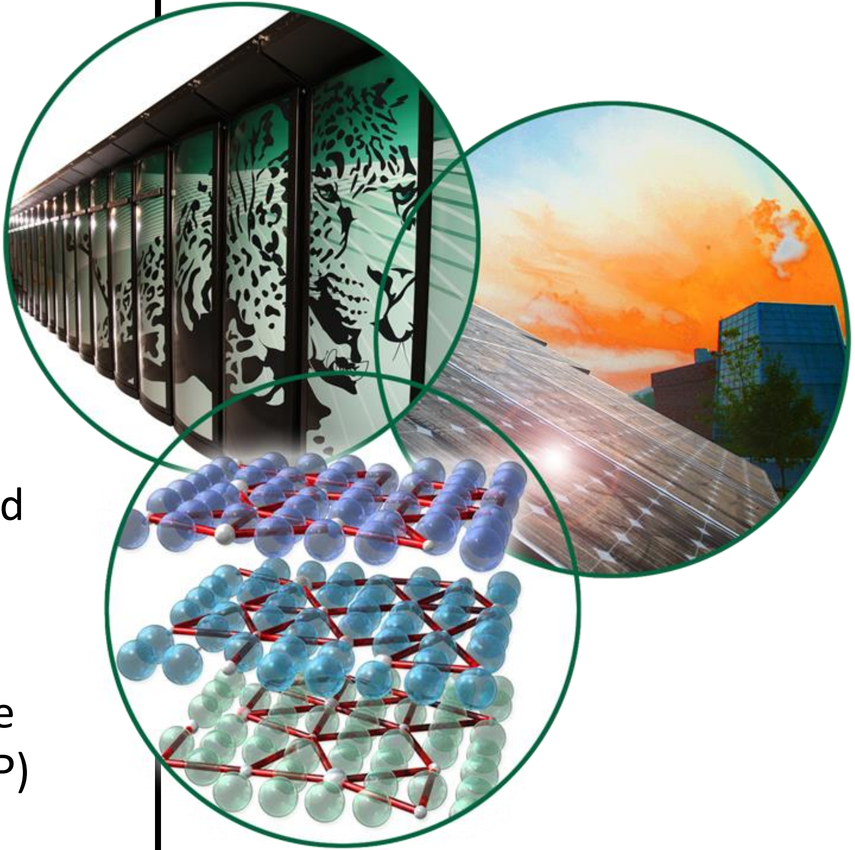

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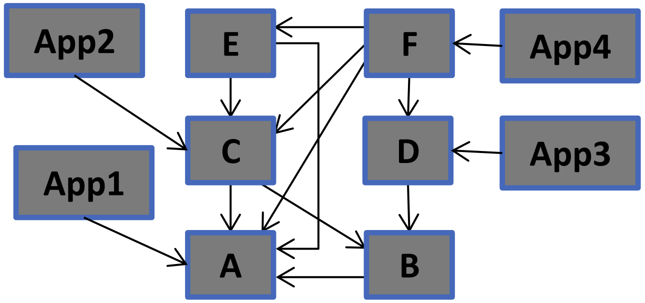
Overview of CSE Software Ecosystem Challenges



Example: Small ecosystem of packages and applications

Overview of CSE Software Ecosystems:

- Sophisticated cutting-edge algorithms implemented by PhD experts from different fields
- Packages independently implemented, maintained, and released by different organizations and institutions
- Many packages constantly developed over many decades and changes to programming models, computer architectures , etc.
- Many APPs (i.e. customers) need access to the latest versions of some packages (e.g. driving research).

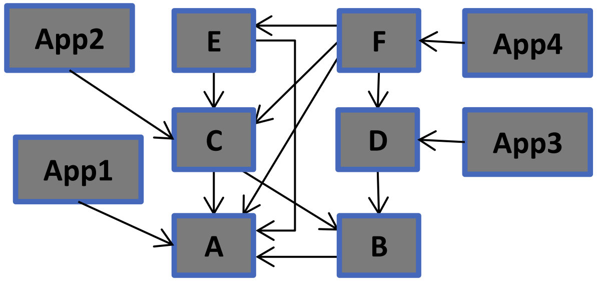
Motivating/example ecosystems:

- **Trilinos:** 68 native pkgs, 90 upstream TPLs (third party libraries), many critical downstream pkgs/apps
- **CASL VERA:** 18 repositories integrated with almost CI, 10 upstream TPLs => TPLs #1 portability issue!
- **SNL SIERRA:** Uses 30+ upstream pkgs/TPLs (including Trilinos, PETSc, etc.)
- **IDEAS xSDK:** Trilinos, PETSc, SuperLU, HYPRE (and several upstream TPLs) and BER app codes

Challenges to Sustainable Ecosystems of CSE Software:

1. ***Lifecycle and software quality of individual packages***: Is a package by itself ready to be used by customers and participate in an ecosystem?
2. ***Sustainability of software packages:*** Is a package sustainable over long lifecycle?
3. **Maintaining compatibility of packages in the ecosystem:** Can the compatibility of interdependent packages be maintained over decades and satisfy customer needs?
4. ***Building a compatible set of packages for a given application from source***: Can a compatible set of interdependent packages be effectively deployed to customers?

Roadmap for Sustainable CSE Software Ecosystems

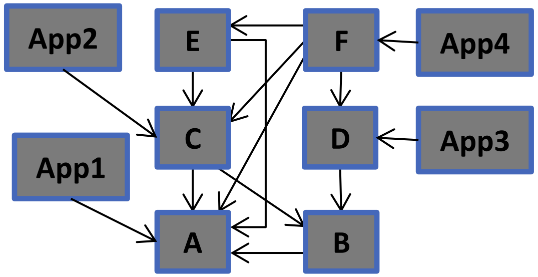


1. ***Lifecycle and software quality of individual packages***: Is a package by itself ready to be used by customers and participate in an ecosystem?
   – Lean/Agile lifecycle for CSE software:
      - Exploratory (EX) => Research Stable (RS) => Production Growth (PG) => Production Maintenance (PM)
      - Existing software grandfathered in using *Legacy Software Change Algorithm*
2. ***Sustainability of software packages:*** Is a package sustainable over long lifecycle?
   – Self-Sustaining Software: open-source license, strong automated tests, clean design/code, minimal controlled internal and external dependencies (stopping at standards)
3. **Maintaining compatibility of packages in the ecosystem:** Can the compatibility of interdependent packages be maintained over decades and satisfy customer needs?
   – Continuous Integration (CI) => e.g. Trilinos packages, Google online apps (5K+ developers)
   – Almost Continuous Integration (ACI) => e.g. INL MOOSE, CASL VERA, SIERRA/Trilinos, …
   – Punctuated Releases => Semantic Versioning Standard X.Y.Z , sets of backward compatible releases (i.e. fixed X, increment Y), buildable against multiple versions of upstream packages
4. ***Building a compatible set of packages for a given application from source***: Can a compatible set of interdependent packages be effectively deployed to customers?
   – Build & Install wrappers around heterogeneous build systems (CMake, autotools, raw makefiles, etc.) => e.g. CMake ExternalProject, Spack, PETSc --download-xxx, CASL VERA TPLs
   – Uniform build system for all packages: => e.g. SNL SIERRA (replaced native build process with new bjam files for 30+ TPLs), TriBITS/CMake (Trilinos, CASL VERA (Trilinos, SCALE/Exnihilo, COBRA-TF, MPACT, …)), Google online apps (2K+ projects)

Example: Maintaining Compatibility and Deploying Packages Over Many Released Versions

Assumptions:

- **Start out all compatible packages**, version 1.0
- **New releases on same cadence** (e.g. every quarter/year, etc.)
- **Upgrade to most current allowed version** of upstream packages
- **No coordination/staging** between package developers or releases
- **Package 'A' breaks backward compatibility with each release**, all other packages maintain backward compatibility



Release Set 1: A1, B1, C1, D1, E1, F1

Release Set 2: => All release against A1!

- **A2**
- **B2**: **A1**
- **C2**: B1(**A1**), **A1**
- **D2**: B1(**A1**)
- **E2**: C1(B1(**A1**), **A1**), **A1**
- **F2**: E1(C1(B1 (**A1**), **A1**), **A1**), D1(B1 (**A1**), C1(B1 (**A1**), **A1**), **A1**

Release Set 3: => Can't all use A2!

- **A3**
- **B3**: **A2**
- **C3**: B2(**A1**), **A2 => A1**
- **D3**: B2(**A1**)
- **E3**: C2(B1(**A1**), **A1**), **A2 => A1**
- **F3**: E2(C1(B1(**A1**), **A1**), **A1**), D2(B1(**A1**), C2(B1(**A1**), **A1**), **A2 => B2, A1**

Release Set 4: => Most stuck with A1 or A2!

- **A4**
- **B4**: **A3**
- **C4**: B3(**A2**), **A3 => A2**
- **D4**: B3(**A2**)
- **E4:** C3(B2(**A1**), **A1**), **A3 => A1**
- **F4**: E3(C2(B1(**A1**), **A1**), **A1**), D3(B2(**A1**)), C3(B2(**A1**), **A1**), **A3 => B2, A1**

Release Set 5: => Five versions of A in use!

- **A5**
- **B5**: **A4**
- **C5**: B4(**A3**), **A4 => A3**
- **D5**: B4(**A3**)
- **E5:** C4(B3(**A2**, **A2**), **A4 => A2**
- **F5**: E4(C3(B2(**A1**), **A1**), **A1**), D4(B3(**A2**)), C4(B3(**A2**), **A2**), **A4 => D3, C3, B2, A1**

- **Developers for Package A have to support current and 4 prior releases!**
- **Some downstream customers stuck with <u>very</u> old versions of some packages!**