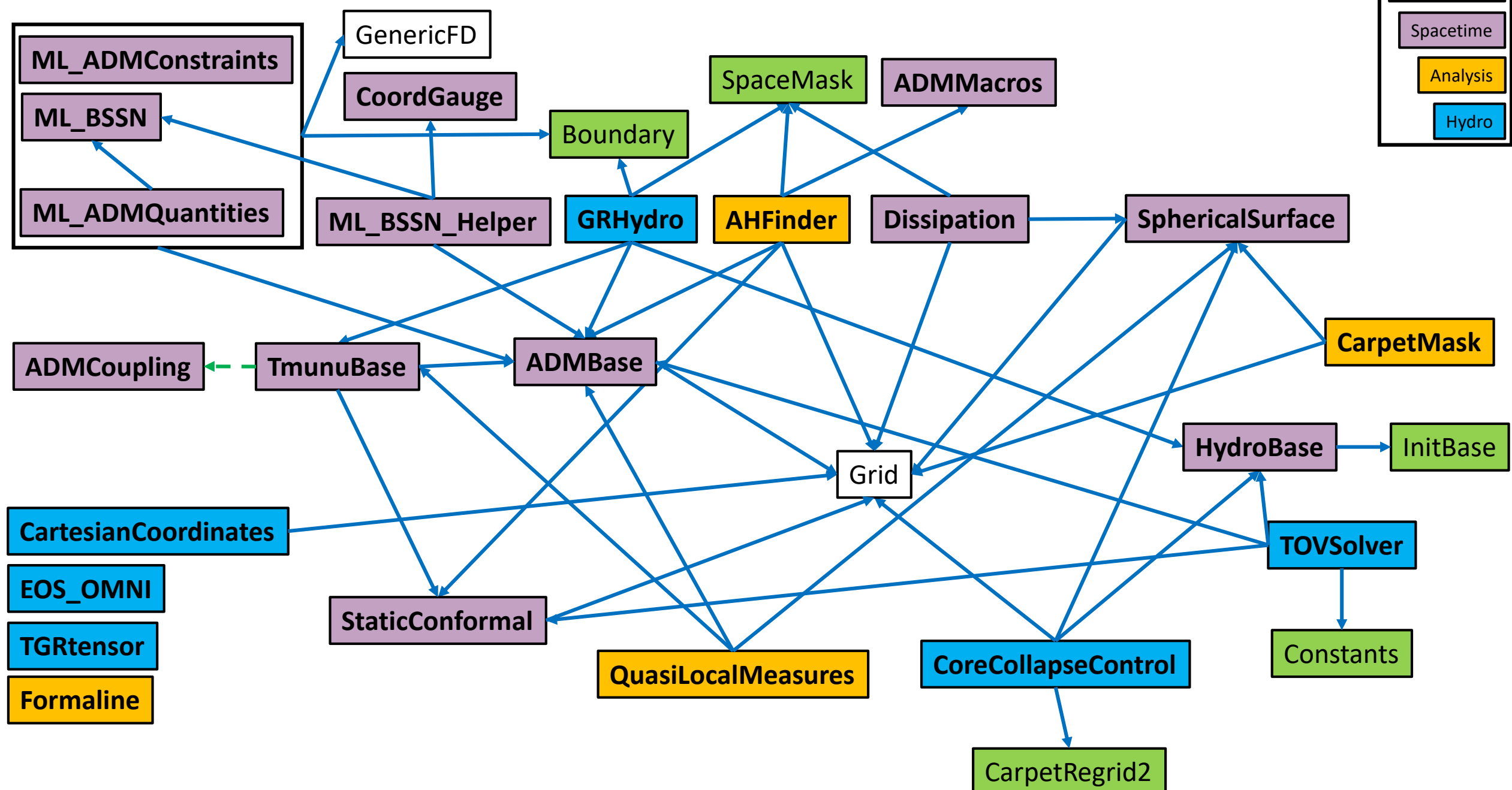
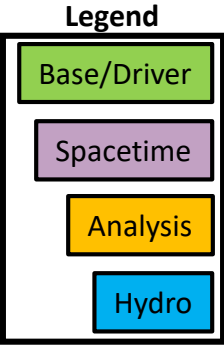
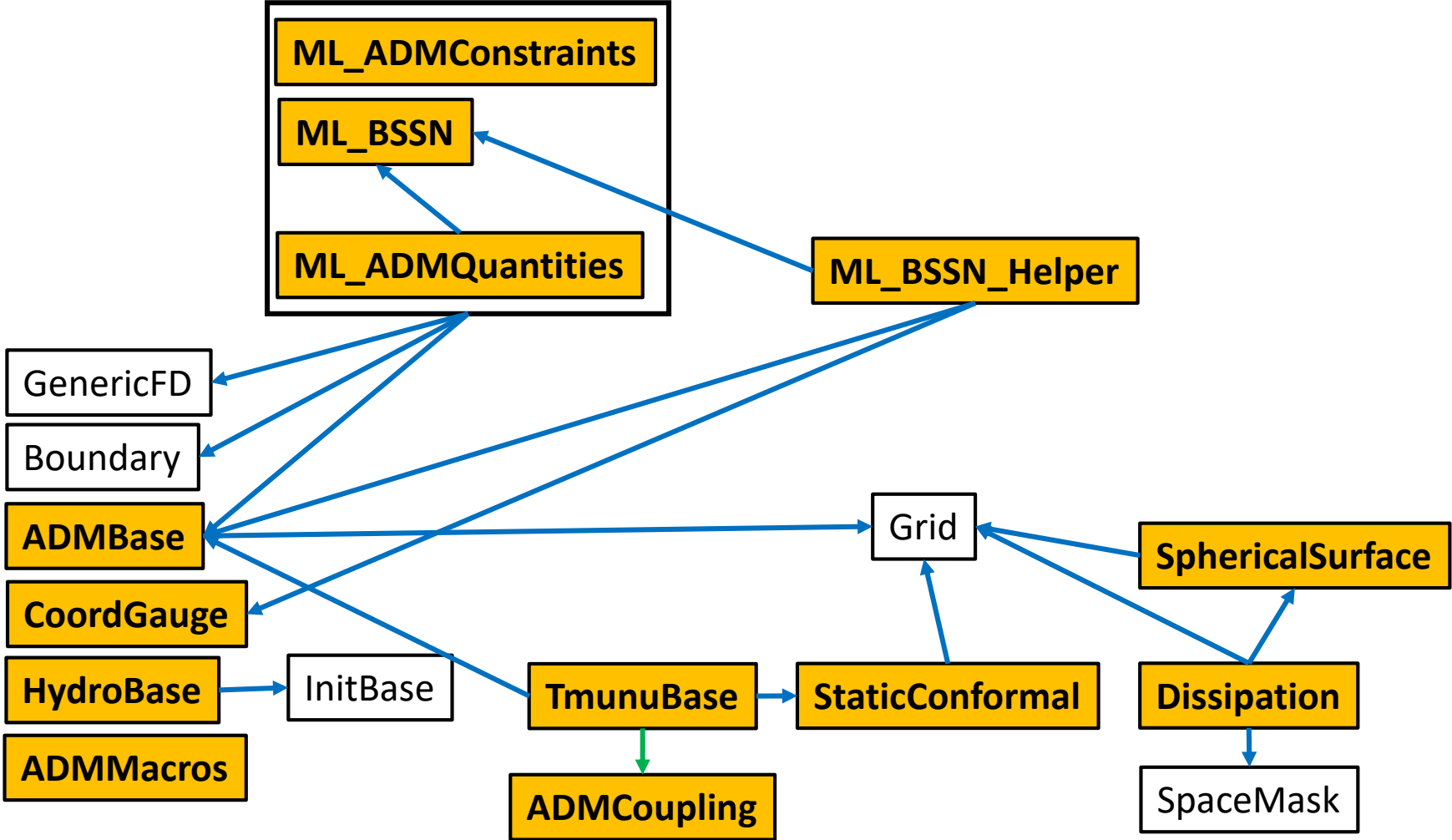


Spacetime, Hydrodynamics, and Analysis thorns inheritance (A inherits from B: A → B)



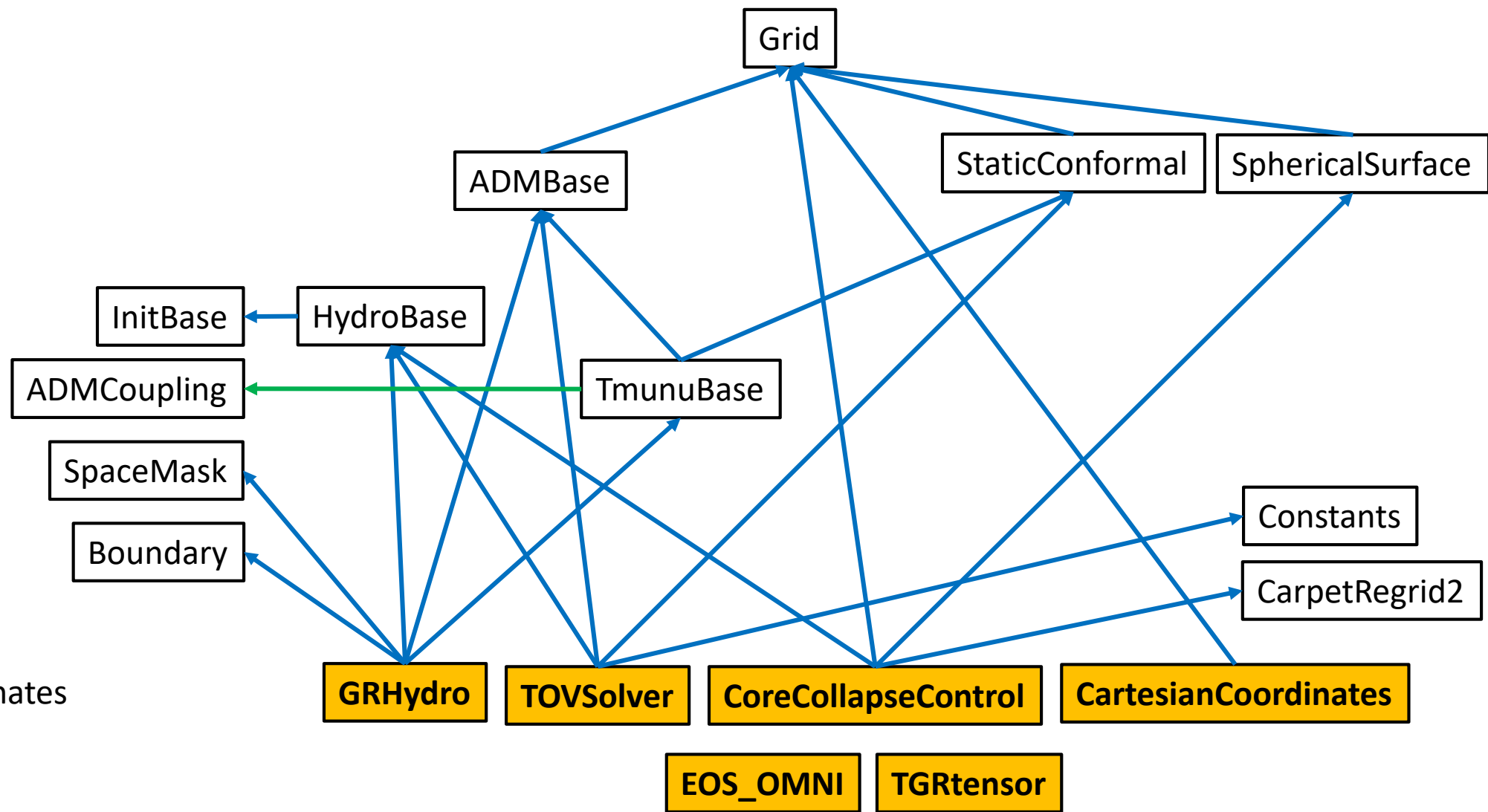
Spacetime

- **EinsteinBase**
 - ADMBase
 - StaticConformal
 - CoordGauge
 - ADMCoupling
 - ADMMacros
 - TmunuBase
 - HydroBase
- **CactusNumerical**
 - Dissipation
 - SphericalSurface
- **McLachlan**
 - ML_ADMConstraints
 - ML_BSSN
 - ML_BSSN_Helper
 - ML_ADMQuantities



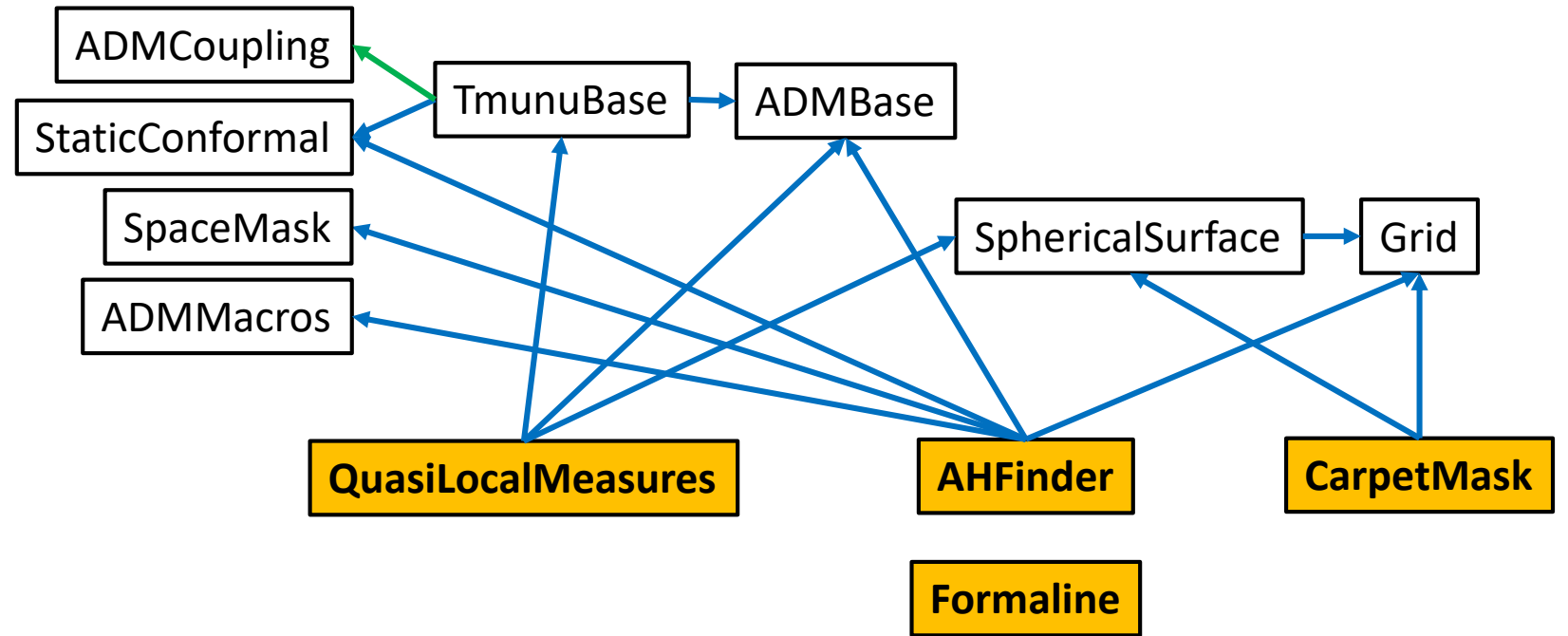
Hydrodynamics

- **EinsteinEvolve**
 - GRHydro
- **EinsteinInitialData**
 - TOVSolver
- **EinsteinEOS**
 - EOS_OMNI
- **EinsteinUtils**
 - TGRtensor
- **CTGamma**
 - CartesianCoordinates
- **CoreCollapseControl**
 - CoreCollapseControl



Analysis

- **CactusUtils**
 - Formaline
- **EinsteinAnalysis**
 - AHFinder
 - QuasiLocalMeasures
- **Carpet**
 - CarpetMask



Spacetime descriptions

- **EinsteinBase**

- ADMBase – Provides γ_{ij} (`gxx, gxy, gxz, gyy, gyz, gzz`), K_{ij} (`kxx, kxy, kxz, kyy, kyz, kzz`), α, β^i (`betax, betay, betaz`)
- StaticConformal -- Base thorn to provide the variables for the static conformal factor, only need if using conformal metric
- CoordGauge – Provides infrastructure for dynamic gauge selection (possibly avoid by putting in `param.ccl` of new thorn)
- ADMCoupling – CalcTmunu \rightarrow Lets you trivially define $T_{\mu\nu}$
- ADMMacros – Provides macros for common relativity calculations using ADMBase variables
- TmunuBase – Provides T_{00} (`eTtt`), T_{0i} (`eTtx, eTty, eTtz`), T_{ij} (`eTxx, eTxy, eTxz, eTyy, eTyz, eTzz`)
- HydroBase – Provides ρ (`rho`), P (`press`), ϵ (`eps`), v^i (`vel[3]`), Y_e (`Y_e`), T (`temperature`), s (`entropy`), B^i (`Bvec[3]`)

- **CactusNumerical**

- Dissipation – Kreiss-Oliger dissipation term to RHS of evolution equation with order $p \in \{1,3,5,7,9\}$ (`order`) and strength $\epsilon \in \{1,2,3,4,5\}$ (`epsdiss`)
- SphericalSurface – Defines surfaces with spherical topologies. Grid array (`sf_radius`), and grid scalars (`sf_organ_x, sf_organ_y, sf_organ_z`)

- **McLachlan**

- ML_ADMConstraints
- ML_BSSN
- ML_BSSN_Helper
- ML_ADMQuantities

Hydrodynamics descriptions

- **EinsteinEvolve**
 - GRHydro – evolution code for a general-purpose 3D relativistic hydrodynamics code.
 - **Replace (GRScalar)?**
- **EinsteinInitialData**
 - TOVSolver – provides initial data for TOV star(s) in isotropic coordinates
 - **Rewrite (ScalarSolver)**
- **EinsteinEOS**
 - **EOS_OMNI** – Provides a one-fits-all EOS handler. Eoskey control the type of EOS being used
 - **Remove**
- **EinsteinUtils**
 - TGRtensor – modules to calculate things like metric, constants, matrix inverse, covariant derivatives, Ricci tensors, etc.
- **CTGamma**
 - CartesianCoordinates – Complies to an interface for curvi-linear coordinates by implementing cartesian coordinate system with trivial Jacobians
- **CoreCollapseControl**
 - CoreCollapseControl – controls output frequency and grid structure based on the different stages of a core collapse simulation

Analysis descriptions

- **CactusUtils**

- Formaline – collects and preserves meta data about the run
(i.e. par file, date, time, machine, user id, location of output, number of iterations, efficiency summary, etc.)

- **EinsteinAnalysis**

- AHFinder – Finds apparent horizons in numerical spacetimes
- QuasiLocalMeasures – Calculates quasi-local measures such as masses, momenta, or angular momentum and related quantities on closed two-dimensional surfaces, including on horizons

- **Carpet**

- CarpetMask – Remove unwanted regions from Carpet's reduction operations; can be used e.g. to excise horizon interiors

Base/Driver Inheritances

- **CactusBase Arrangement**

- Time
- CoordBase
- Boundary
- SymBase
- IOUtil
- InitBase
- CartGrid3D

- **EinsteinBase Arrangement**

- Constants

- **CactusUtils Arrangement**

- NaNChecker
- TimerReport

- **Numerical Arrangement**

- AEILocalInterp

- **Carpet Arrangement**

- Carpet
- CarpetLib
- CarpetRegrid2
- CarpetReduce
- CarpetInterp
- LoopControl
- CarpetSlab

- **CactusNumerical Arrangement**

- MoL
- SpaceMask
- ReflectionSymmetry
- Slab

Hydrodynamics Inheritances

- **EinsteinEvolve Arrangement**
 - GRHydro
 - **Inherits:**
 - ADMBase
 - Grid
 - Boundary
 - SpaceMask
 - Tmunubase
 - ADMBase
 - Grid
 - StaticControl
 - Grid
 - **Friend:**
 - ADMCoupling
 - HydroBase
 - InitBase
 - **CTGamma Arrangement**
 - CartesianCoordinates
 - **Inherits:**
 - Grid
 - **EinsteinInitialData Arrangement**
 - TOVSolver
 - **Inherits:**
 - ADMBase
 - Grid
 - HydroBase
 - InitBase
 - Constants
 - StaticConformal
 - Grid
- **CoreCollapseControl Arrangement**
 - CoreCollapseControl
 - **Inherits:**
 - CarpetRegrid2
 - HydroBase
 - InitBase
 - GRHydro
 - Grid
 - SphericalSurface
 - Grid
- **EinsteinEOS Arrangement**
 - EOS_OMNI
 - **No inherits**
- **EinsteinUtils Arrangement**
 - TGRtensor
 - **No inherits**

Spacetime Inheritances

- **EinsteinBase Arrangement**

- ADMBase
 - Grid
- StaticConformal
 - Grid
- CoordGauge
 - None
- ADMCoupling
 - None
- ADMMacros
 - None
- TmunuBase
 - ADMBase
 - Grid
 - StaticControl
 - Grid
 - **(Friend)** ADMCoupling
- HydroBase
 - InitBase

- **CactusNumerical Arrangement**

- Dissipation
 - Grid
 - SphericalSurface
 - SpaceMask
- SphericalSurface
 - Grid

- **McLachlan Arrangement**

- ML_ADMConstraints
 - ADMBase
 - Boundary
 - GenericFD
 - Grid
 - TmunuBase
- ML_BSSN
 - ADMBase
 - Boundary
 - GenericFD
 - Grid
 - TmunuBase
- ML_BSSN_Helper
 - ADMBase
 - CoordGauge
 - ML_BSSN
- ML_ADMQuantities
 - ADMBase
 - Boundary
 - GenericFD
 - Grid
 - ML_BSSN
 - TmunuBase

Analysis Inheritances

- **CactusUtils Arrangement**
 - Formaline
 - No inherits
- **EinsteinAnalysis Arrangement**
 - AHFinder
 - ADMBase
 - StaticConformal
 - SpaceMask
 - Grid
 - IO
 - ADMMacros
 - QuasiLocalMeasures
 - ADMBase
 - SphericalSurface
 - TmunuBase
- **Carpet Arrangement**
 - CarpetMask
 - Grid
 - SphericalSurface
 - Grid

Base/Driver Inheritances

- **CactusBase Arrangement**

- Time
- CoordBase
- Boundary
- SymBase
- IOUtil
- InitBase
- CartGrid3D
 - Coordbase

- **EinsteinBase Arrangement**

- Constants

- **CactusUtils Arrangement**

- NaNChecker
 - Reduce
- TimerReport

- **Numerical Arrangement**

- AEILocalInterp

- **Carpet Arrangement**

- Carpet
- CarpetLib
- CarpetRegrid2
- CarpetReduce
- CarpetInterp
- LoopControl
 - CycleLock
- CarpetSlab

- **CactusNumerical Arrangement**

- MoL
- SpaceMask
 - Grid
- ReflectionSymmetry
- Slab