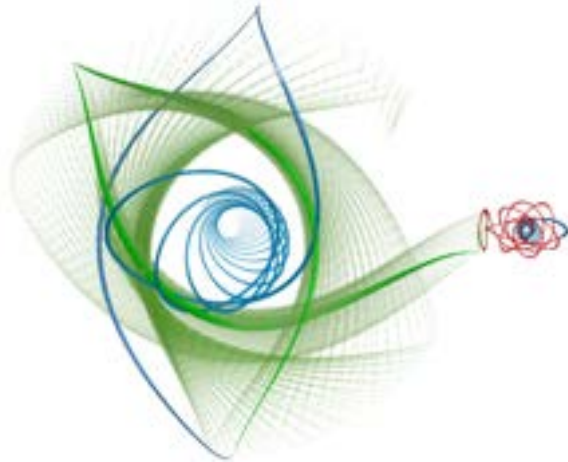


## OVERVIEW

- A C++ object oriented software for macOS, Linux, and Windows for solution of spacecraft trajectory problems in multibody domains (e.g. Earth-Moon, Jovian system)



- **DyLAN leverages dynamical systems theory** to find optimal spacecraft trajectory solutions.
- DyLAN is an **automated trajectory optimization tool**: the user only has to supply the high-level mission details and DyLAN will search the design space unassisted for an optimal solution.
- DyLAN takes into account multibody dynamics when searching for trajectory solutions.

## DYNAMICAL MODELS

- Circular Restricted Three-Body Model
- Four Body-Models
- n-Body modeling with NAIF SPICE

## DYNAMICAL STRUCTURES

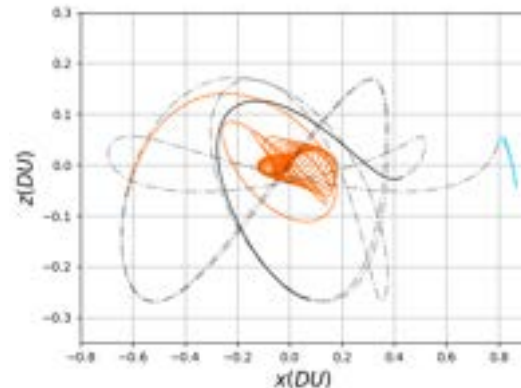
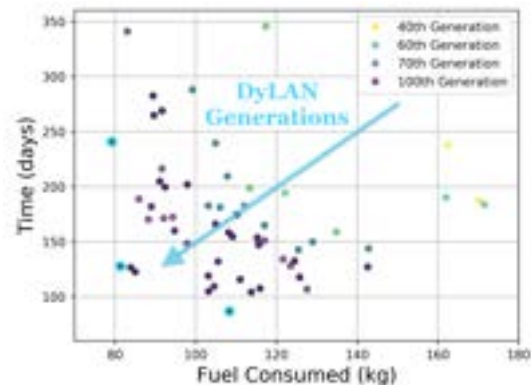
- Lyapunov, Halo, NRHO, Resonance orbits and associated manifolds.
- Poincaré, Weak Stability Boundary (WSB), periapsis, and apoapsis maps.
- **Automated** detection dynamical structures and heteroclinic and homoclinic intersections.

## GLOBAL OPTIMIZATION

- Is a **global optimization tool**: it can solve both local and global optimization problems by combining genetic algorithms (GA) with nonlinear program (NLP) formulations.
- Uses **Monotonic Basin Hopping (MBH)** to efficiently search the domain space.

## MULTIPLE OBJECTIVE OPTIMIZATION

- The ability to solve multiple objective spacecraft trajectory problems (e.g., find solutions that minimize time-of-flight and fuel consumed), using NSGA-II.

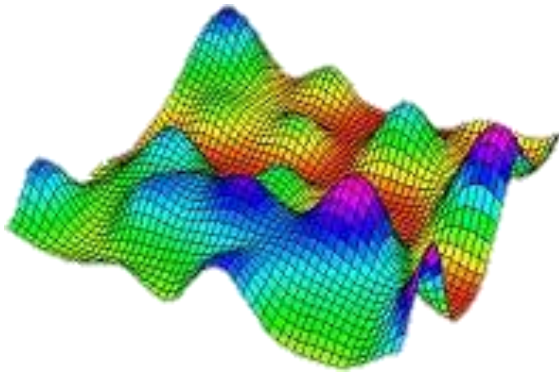


## ADDITIONAL FEATURES

- **Impulsive** and **low-thrust** engine modeling
- **Q-Law** solution for many revolution spirals

## OVERVIEW

- NLPAROPT/COMPNOT are nonlinear programming solvers, *designed to exploit parallel computing architectures.*



- NLPAROPT:** Exploits parallelism on distributed memory (**MPI**) architectures.
- COMPNOT:** Exploits parallelism on shared memory (**OpenMP**) architectures.
- The solvers scale gracefully to different cluster sizes from single processor, through modern coprocessor solutions, up to multi-node supercomputers.

## NONLINEAR PROGRAM

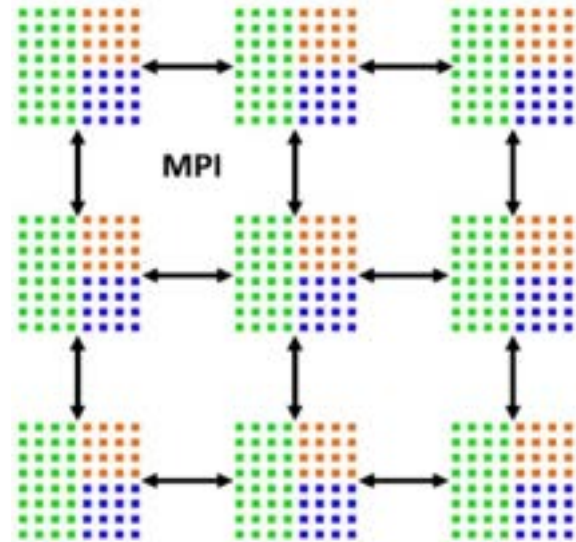
- NLPAROPT/COMPNOT solves nonlinear programs (NLP): mathematical problems of the following type:

$$(NLP) \equiv \begin{cases} \min_x f(x) \\ \text{subject to } b_L \leq Ax \leq b_U \\ g_L \leq g(x) \leq g_U \\ x_L \leq x \leq x_U \end{cases}$$

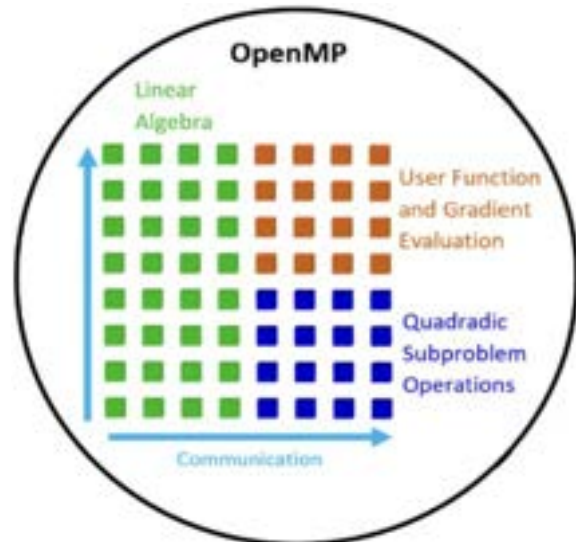
- NLPs arise in e.g., engineering, economics, finance, logistics and operations research.
- NLPs are common in **aerospace engineering** for spacecraft trajectory, attitude and control, structural, materials and design optimization.

## PARALLELIZATION

- NLPAROPT/COMPNOT distributes across multiple nodes (or multiple cores) via MPI:



- Three levels of algorithmic parallelization: 1. linear algebra, 2. quadratic programming operations, 3. user function evaluations.



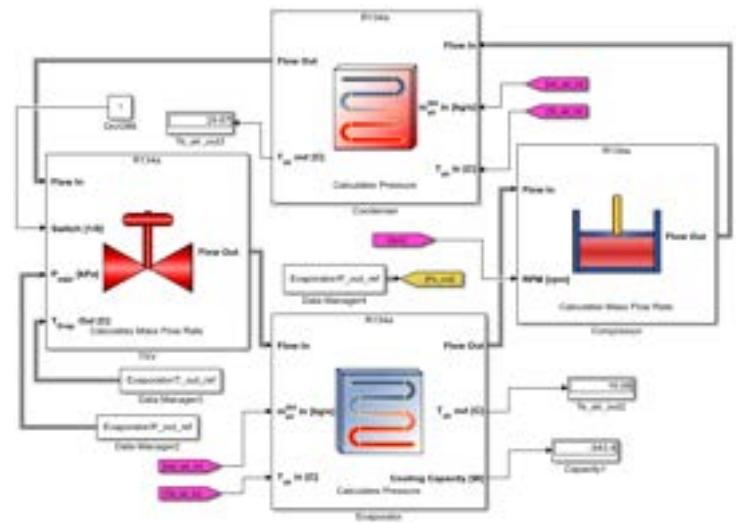
## EASY USER INTERFACE

- C++ object-oriented interface with easy plug-and-play options, parallel finite differencing for Jacobian calculations, and options for advanced users to tune the solver.

# THERMOSYS™

## Introducing Thermosys™ 5.1 ...

The THERMOSYS™ 5 Toolbox for MATLAB/Simulink® is a suite of simulation tools for analyzing the behavior of air-conditioning and refrigeration systems (both steady-state and time-dependent). It was developed at the University of Illinois at Urbana-Champaign through sponsorship by the Air-Conditioning and Refrigeration Center (ACRC) and is currently distributed by CU Aerospace.



Vapor Cycle System Model in Thermosys™

### Key features include:

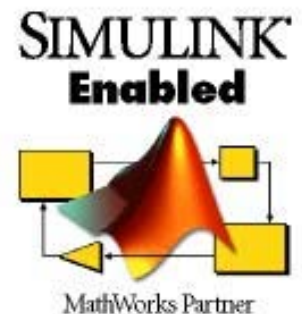
- ❖ Nonlinear models suitable for simulation and control design of multiphase fluid dynamics associated with subcritical air-conditioning and refrigeration systems
- ❖ Capability to simulate transient dynamics, including startup and shutdown dynamics
- ❖ Component models library with user-defined parameters for building customized systems models
- ❖ Approachable and adaptable, with drag 'n' drop functionality and compatibility with MATLAB/Simulink® tools
- ❖ Built-in fluid properties for air, ammonia (R717), carbon dioxide (R744), glycol/water mixtures, R21, R22, R134a, R245fa, R404A, R407C, R410A, R507A, R1234YF, and water
- ❖ Braze plate heat exchanger models for condensers and evaporators
- ❖ Humid air exchanger modeling for condensers and evaporators
- ❖ Improved usability, with application of a bus format to handle data connections between components
- ❖ Newly-developed electro-thermal models for studying motors, generators, and batteries

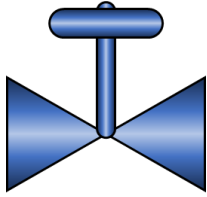
### Pricing options:

Thermosys™ is offered as either a perpetual single-seat license, or an annual multi-machine license package for commercial R&D and academic groups. Special pricing options are offered for educational users, government institutions, and ACRC members.

### Customized support options are available:

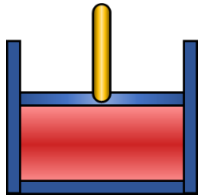
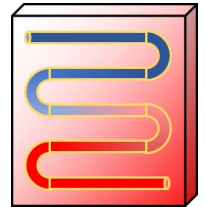
- ❖ Extended maintenance of perpetual license for upgrades and user support
- ❖ Enhanced customer support (hourly or packages)
- ❖ Project support for system design or custom component model development





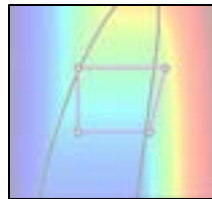
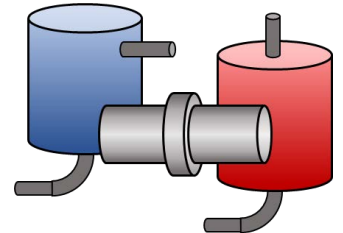
Valves: Thermosys™ includes models for automatic expansion valves, thermostatic expansion valves and electronically controlled throttling valves, with user-defined parameters and performance.

Heat Exchangers: Various options are available for modeling heat exchangers, evaporators, and condensers, including tube-and-fin types and brazed-plate types.



Pump Models: User-defined models for volumetric and adiabatic efficiency are included, as well as thermal dynamics modeling of the compressor housing.

Pipes/Tanks/Junctions/Splits: Flow resistance blocks enable users to account for pressure losses between components; adaptable models for tanks, junctions, and splits are also included.



Advanced Features: The latest release includes updated features such as live P-h plotter blocks, humidity models for heat exchangers, gas coolers with secondary fluids, and electrical component thermal models.

# THERMOSYS™

Go to [www.thermosys.us](http://www.thermosys.us) for details and pricing.

**Features**

- MPI-based scalable parallel multiphysics simulation engine.
- Library of interoperable finite volume models.
- Includes steady-state, pseudo-steady-state, transient, and variable time step transient temporal schemes.
- Compatible with both commercial and free, powerful, open-source grid generation and post-processing software.
- User extendable – create and compile new models to work in tandem with provided engine/models.
- Large demonstration/verification/validation case library.
- Compatible with most modern systems, Windows, Macintosh, Unix/Linux, Distributed Memory Clusters.

**Modules**

- Pressure-Based Coupled Navier-Stokes Model
- Incompressible Potential Flow Model
- General Diffusion Model
- Gas/Material Property Model
- Electric Field Model
- Various 1- and 2-Equation Turbulence Models
- Nearest Wall Distance Model
- Neutral/Ion/Electron Specie Transport Model
- Non-Equilibrium Gas- Plasma- Photo-Kinetic Model
- Photon Transport Model
- Wave-Optics Model

**Discretization**

- Compatible with multiple grid formats.
- Compatible with single- and multi-block structured / unstructured 2- and 3-D grids.
- Compatible with triangle and quadrilateral first-order, two-dimensional elements, and with the tetrahedron, hexahedron, prism, and pyramid, first-order, three-dimensional elements.
- Automated grid partitioning for parallel simulation.
- Users can sub-divide grids and solve certain models on only user-defined portions, other models on full grid.
- High-order flux schemes with multiple flux blending schemes.

**Temporal Resolution**

- Solve using steady-state, pseudo-steady-state, transient, and variable time step transient temporal schemes.
- 1<sup>st</sup> – 4<sup>th</sup> order fully implicit time accurate schemes available with the fixed time step transient solver.
- CFL time step limiter.

**User Modification**

- Users can create, compile, and call their own parallel finite volume models from BLAZE using a provided API.
- BLAZE simulation engine handles all I/O, parallelism, memory management, parallel sparse linear system solution schemes, etc.
- Users can create, compile and call custom grid parsers.

**Gas Specie & Chemistry Library**

- Large and well validated gas specie database.
- Large and well validated gas- plasma- and photo-kinetic chemistry databases.

**Post-Processing**

- Compatible with multiple post-processing tools including the free, open-source, powerful ParaView and VisIt via open source data formats.
- Users can quickly analyze coupled results from steady-state and transient simulations.

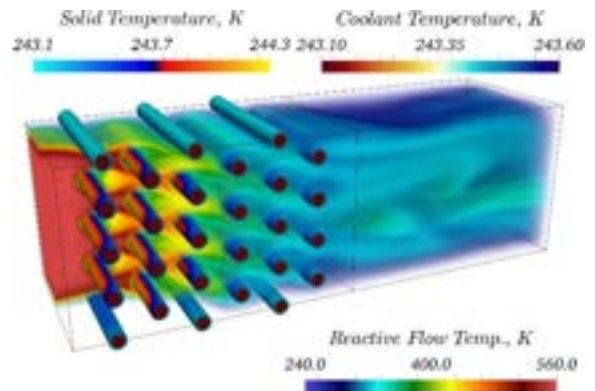


Fig. 1: Multiple Phase Domains

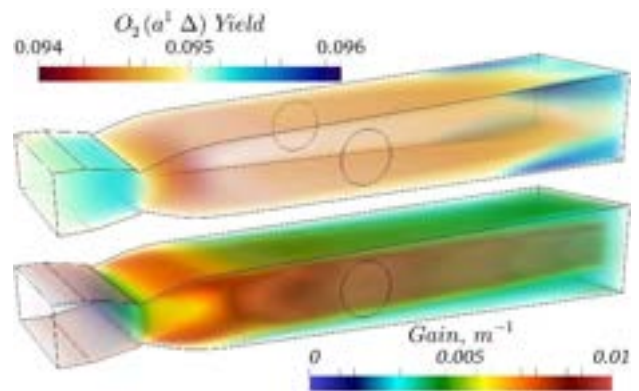


Fig. 2: Gasdynamic Reacting Flows

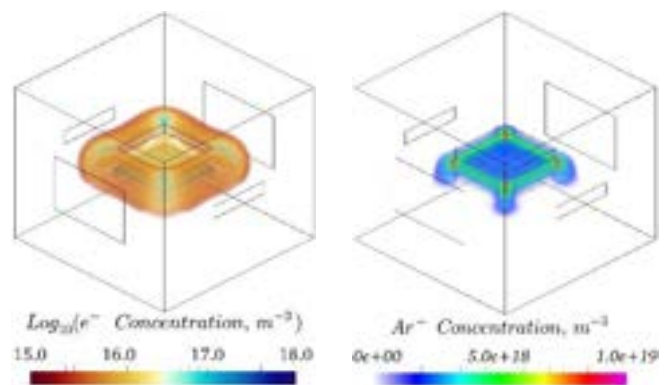


Fig. 3: Nonequilibrium Plasma Discharges