# Adaptive Trajectory Design (ATD) / GSFC IRAD

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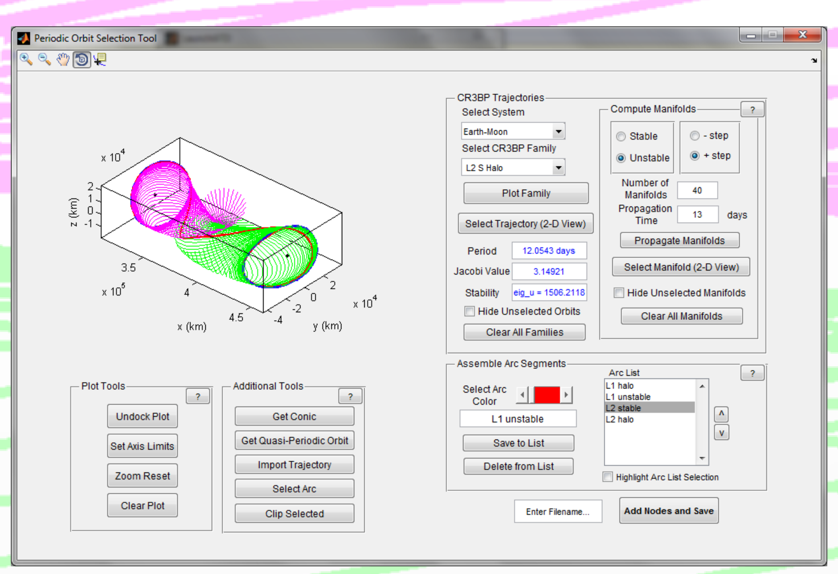
**Innovation:** An interactive and automated design process is developed that allows mission designers to rapidly explore trajectory options and to efficiently compute mission designs within multi-body regimes.

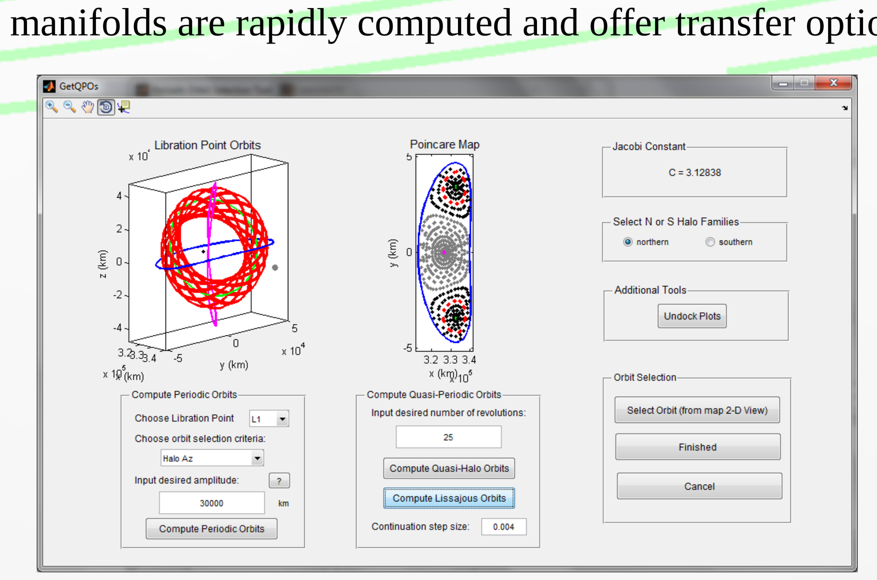
## Description and Objective:

ATD offers expanded mission design capabilities in multi-body regimes

- Provide an efficient and interactive process for mission design in multi-body regimes
- Automate process of blending solutions from distinct dynamical regimes by combining various trajectory design concepts within one design environment
- Synthesize single and multi-body trajectory arcs, e.g., conics, libration point orbits, and stable/unstable manifolds
- Develop and apply numerical corrections algorithms to blend discrete trajectory arcs from various dynamical models
- Transition final design into GSFC's General Mission Analysis Tool (GMAT)



(a) libration point orbits and associated stable and unstable manifolds are rapidly computed and offer transfer options

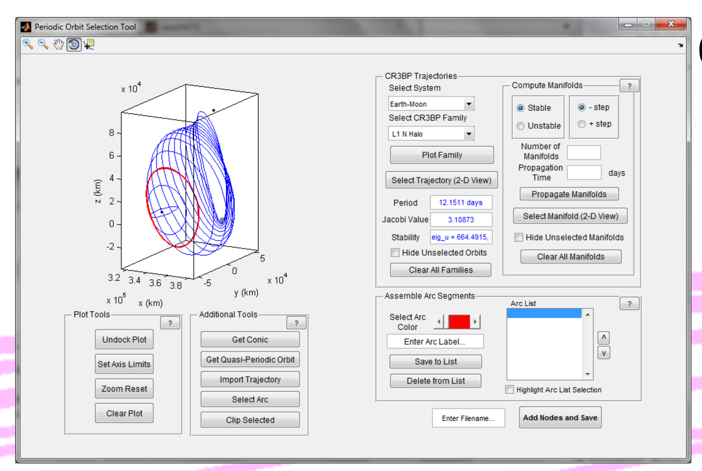


(b) families of orbits with specified amplitudes are computed in real-time

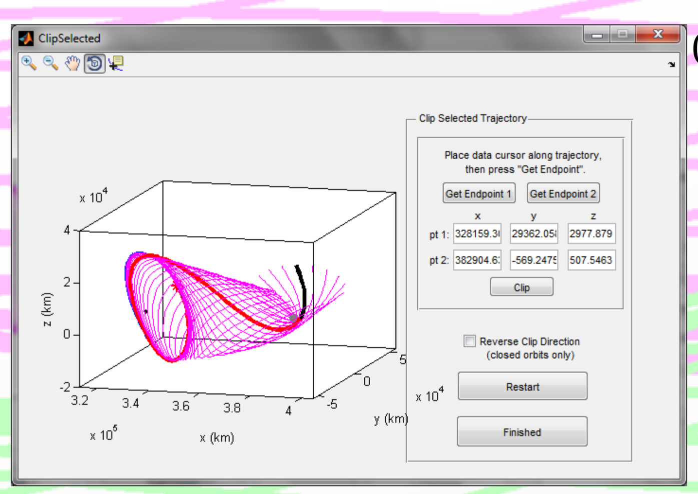
**Fig. 1** Theoretical solutions from three-body regimes are efficient to access within the ATD environment and offer expanded mission design options

## Motivation:

As mission requirements become increasingly complex, improved flexibility in mission design tools is vital. The interactive ATD design environment allows mission designers to exploit theoretical solutions available from dynamical systems theory, and facilitates exploration and design in multi-body regimes.



(a) point-and-click arc selection facilitates user interaction and efficient access to members of orbit families

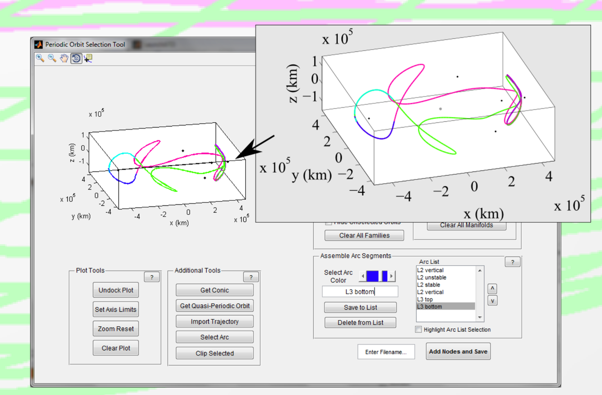


(b) Interactive trajectory arc clipping enables user to isolate desired portion of a trajectory segment quickly and automatically

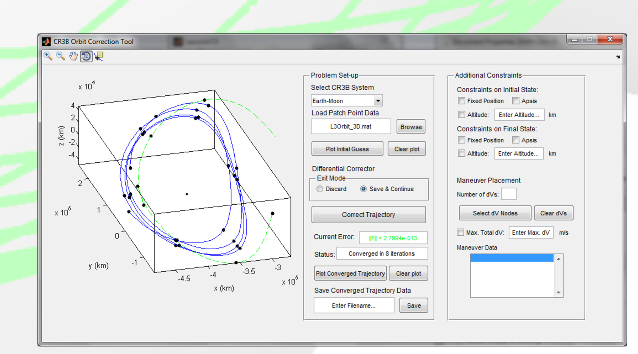
**Fig. 2** Interactive arc selection and "clipping" enables rapid and efficient trajectory design

## Design Environment Features:

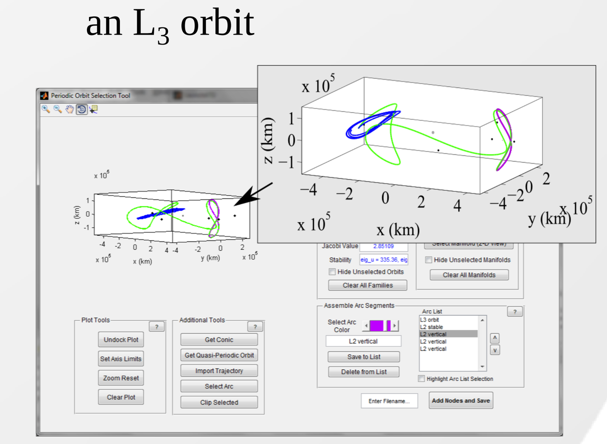
- Interactive and automated design environment provides access to solutions various dynamical regimes
  - conic arcs
  - libration point orbits
  - stable and unstable manifolds
  - patched three-body arcs to blend trajectories transporting between Sun-Earth and Earth-Moon systems
  - point-and-click arc selection
  - interacting trajectory "clipping"
  - Poincaré maps for orbit selection
- Automated design environment
  - computation of stability information for periodic orbits
  - real-time computation of stable and unstable manifolds associated with periodic orbits
  - point-and-click arc selection
  - interactive trajectory clipping to isolate desired segments
  - desired arc segments easily labeled and stored within the ATD environment
  - with all trajectory components assembled, interactive sorting strategies allow user to assemble the end-to-end mission from the individual components
  - interactive node placement strategies to discretize trajectory arcs in preparation for differential corrections processes



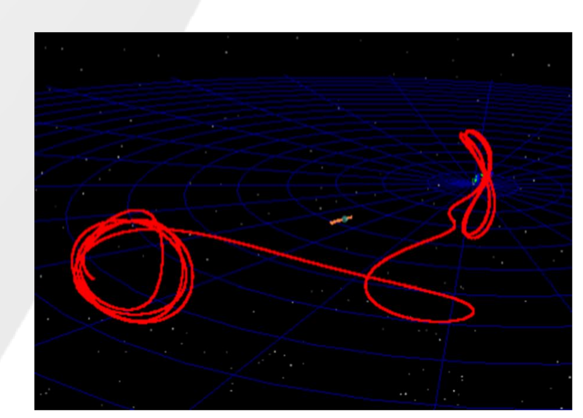
(a) portions of $L_2$ vertical orbit manifolds sampled to construct an $L_3$ orbit



(b) $L_3$ orbit is corrected using ATD corrections tools

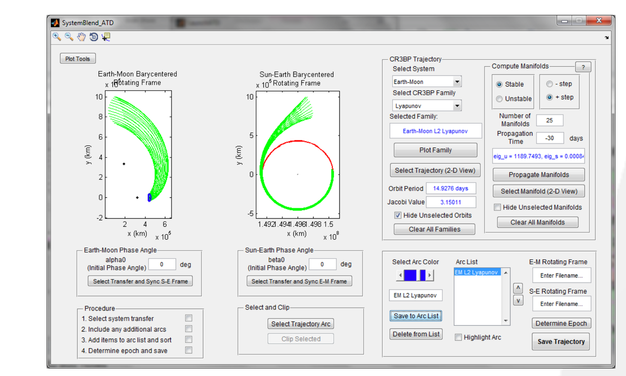


(c) $L_2$ and $L_3$ orbits are connected within the ATD environment

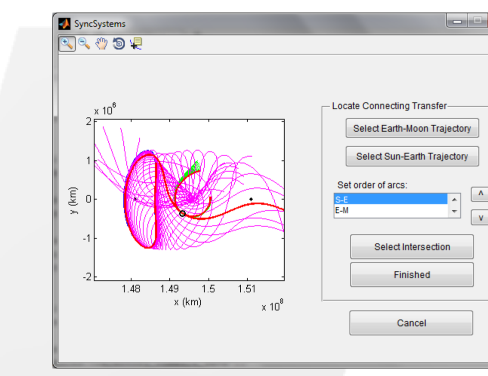


(d) Path is reconverged within GMAT in a Sun-Earth-Moon ephemeris model

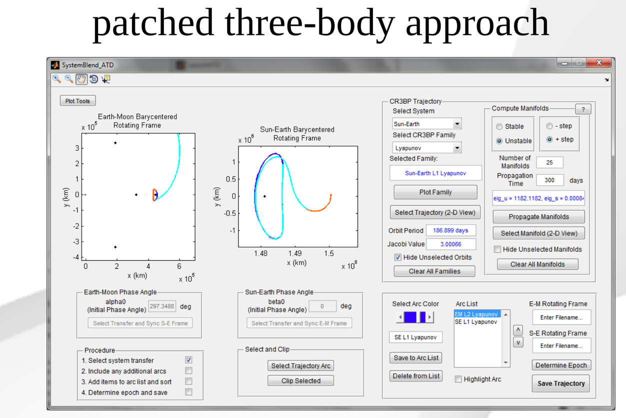
**Fig. 3** A transfer from an $L_3$ orbit to the $L_2$ vertical is designed and corrected in a Sun-Earth-Moon ephemeris model



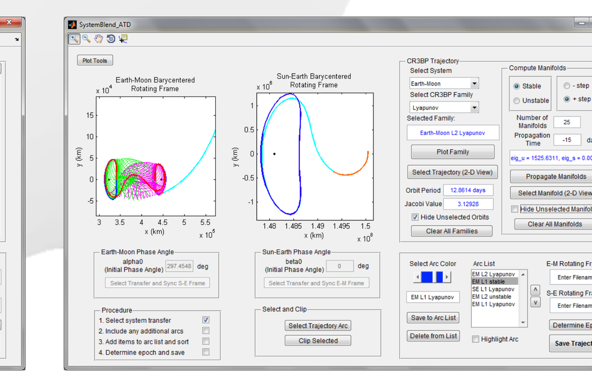
(a) solutions from Sun-Earth and Earth-Moon are blended via a patched three-body approach



(b) trajectory segments from different systems are selected and concatenated



(c) transfer between Sun-Earth $L_1$ Lyapunov and Earth-Moon $L_2$ Lyapunov orbits



(d) additional trajectory arcs are included within each system

**Fig. 4** Mission designs that incorporate multiple three-body systems are facilitated via the ATD system blending environment

- Differential corrections tools allow discrete trajectory arcs to be blended within one uniform dynamical model
  - interactive maneuver placement
  - continuation of corrected solutions via gradual modification of constraints
- Final output includes a script file that facilitates transition of final designs into NASA's GMAT software

## Publications:

A. F. Haapala, M. Vaquero, T. Pavlak, K. C. Howell, and D. C. Folta, "Trajectory selection strategy for tours int he Earth-Moon system", AAS/AIAA Astrodynamics Specialist Conference, Hilton Head, South Carolina, August 11-15, 2013.