

DRAFT MESA Manifesto

April 29, 2010

Bill Paxton, Lars Bildsten, Aaron Dotter, Falk Herwig & Frank Timmes

ABSTRACT

Project MESA, Modules for Experiments in Stellar Astrophysics, provides state-of-the-art, robust, and efficient open source modules, usable singly or in combination for a wide range of applications in stellar astrophysics. It includes modules for various aspects of the physics, such as nuclear networks, opacities, and equation of state, as well as modules for various algorithmic components such as high order implicit solvers for stiff ODEs. Each module is constructed as a separate Fortran 95 library to facilitate independent use and development, and each includes a test suite and an explicitly defined public interface. The modules are designed to be thread-safe for use with shared memory parallel processing, a mode of operation that promises to become dominant with the advent of multi-core processors

MESA was developed through the concerted efforts of Dr. Bill Paxton over a six year period with the engagement and deep involvement of many theoretical and computational astrophysicists. This founding group is writing the first paper describing MESA and its realm of applicability (Paxton et al. 2010) and will soon officially released MESA-1, a publicly available version for education, scientific research, outreach, and exploration of improvements. This document describes the scientific motivation for MESA, the philosophy and rules of use for MESA-1, and the path forward on stewardship of MESA-1 and advanced development of future research and education tools.

1 Motivation for a New Tool

Stellar evolution calculations (i.e. stellar evolution tracks and detailed information about the evolution of internal and global properties) are a basic tool that enable a broad range of research in astrophysics. Areas that critically depend on high-fidelity and modern stellar evolution include astero-seismology, nuclear astrophysics, galactic chemical evolution and population synthesis, compact objects, supernovae, stellar populations, stellar hydrodynamics, and stellar activity. New observational capabilities are emerging in these fields that will place a high demand on exploration of stellar dependences on metallicity and age. So, even though one dimensional stellar evolution is a mature discipline, we continue to ask new questions of stars and use them as archeological probes of galaxy evolution.

This emergence of demand requires the construction of a general, modern stellar evolution code that combines the following advantages:

- **Performance:** should parallelize on present and future shared-memory, multi-core/thread and possibly hybrid architectures so that performance continues to grow within the new computational paradigm (flops are not in cycles but in threads).
- **Modularity:** should provide independent, reusable modules of lasting legacy value.
- **Openness:** should be open to any researcher, both to advance the pace of scientific discovery, but also to share the load of debugging, fine-tuning and advanced development.
- **Wide Applicability:** should be capable of calculating the evolution of stars in a wide range of environments, including low- and massive stars, binaries, accreting, mass-losing stars, early and advanced phases of evolution etc. This will enable multi-problem, multi-object physics validation.
- **Modern techniques:** should employ modern numerical approaches, including high-order interpolation schemes, advanced AMR, simultaneous operator solution; should support well defined interfaces for related applications, e.g. atmospheres, wind simulations, nucleosynthesis simulations, and hydrodynamics.
- **Microphysics:** should allow for up-to-date, wide-ranging, flexible and modular micro-physics.

A tool that combines the above features would be a significant research and education resource for stellar astrophysics and related fields, and is presently not available. We appreciate that some important aspects of stars are truly three-dimensional, such as rotation and magnetism. Those applications remain in the realm of research frontiers with evolving understanding and insights, quite often profound. However, much remains to be gained scientifically (and pedagogically) by accurate one-dimensional calculations, and this is the present focus of MESA.

2 MESA Philosophy

The MESA code library project is open. It explicitly invites participation from anybody (researcher, students, interested amateurs). Participation in MESA can take a wide range of forms, from just using a MESA release for a science project, to testing and debugging (i.e. report bugs, find fixes and submit them for inclusion into the next release) as well as taking on responsibility for the continued stewardship of certain aspects (modules) of the code. The participation of experienced stellar evolution experts is very welcome.

Users are encouraged to add to the capabilities of MESA between releases. MESA-1 and all future releases of MESA will remain a community resource (source code). However, use of MESA-1 requires adherence to the rather simple “MESA code of conduct”:

- That all publications and presentations (research or educational or outreach) which derive from the use of MESA fairly acknowledge the Paxton et al. (2010) publication and MESA website.
- That users not distribute the code nor develop disconnected branches of MESA.
- That users alert the MESA Council (see below) about their publications, either pre-release or at the time of publication.
- That users make available in a timely fashion (e.g. online at the MESA website) all information needed for others to recreate their MESA results – “open know how” to match “open source”.
- That users agree to help others learn MESA, giving back as the project progresses.

As well as an acknowledgment of intent to adhere to the MESA code of conduct, release of MESA-1 to a user is contingent upon that user identifying themselves by name, email contact and home location.

3 Establishment of the MESA Council

The MESA project began as an initiative to construct a reliable computational tool for stellar structure and evolution that takes full advantage of modern processor architectures, algorithms and community engagement. The ensuing release of MESA-1 has forced some explicit thinking of what structure is needed so as to achieve the mission of stewarding MESA-1 in its use for scientific research, education and outreach, while also enabling the development of new tools and ideas. The MESA operating principles are simple: be open in your scientific discussions, give credit to all contributors, and be prepared to give back to the community of users. We hope that this creates an environment where the young are encouraged to become engaged in a career-enhancing manner.

We have established the MESA Council that consists of those engaged in working towards the shared missions outlined here:

- **Steward the Current MESA Release and Update** There are many ways this will be done, including seeking enabling funding, supporting the contributors, maintaining the web access and web page updates. Holding yearly working groups that allow for continued engagement. Leading the paper writing that is required for each additional release.
- **Interface with the User Community** This starts with answering questions from users, developing a way to accept new code in an integrated fashion, maintain a user registry, and identify new MESA Council members from those most active and engaged in the intelligent use of MESA.

Help to 'call the question' when a new release is needed, or simple bug fixes. Identify members of the MESA council best able to get engaged with a user interested in collaborating.

- **Enable Scientific Research and Education with MESA** The first piece of this is simple marketing, such as ensuring that all relevant conferences have a MESA talk, that a powerpoint is always available for consistent messaging. Work to get the word out that this tool is available. Work within the MESA Council to be sure that the low-hanging scientific fruit is getting picked! Track (if possible) the science carried out by the community with MESA
- **Ensure Advanced Development of MESA** This is basically Bill's sandbox, and the interface we need to install (not a diode, but something with some impedance!) so that Bill can do his thing.

The strategies and approaches for the MESA Council to achieve each of these missions is still under discussion.