The Rare Isotope Accelerator (RIA):

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Involved Scientists:

RIA is a project supported by the nuclear and nuclear astrophysics community. The project has been endorsed by numerous workshops and town meetings including the RIA workshop at Raleigh-Durham, NC, July 24-26,2000, and the Oakland, CA, DNP Town meeting on Nuclear Structure and Nuclear Astrophysics, November 9-12, 2000. The pool of users was estimated by the NSAC ISOL Task Force as over 600 scientists in the US and 1000 overseas.

In the recent 2001 Nuclear Science Advisory Committee Long Range Plan recommendations, RIA was listed as the highest priority for major new construction.

Project:

RIA is a bold new facility concept for the production of accelerated exotic nuclear beams. RIA's capabilities will far exceed those of any other facility that is now on the horizon for the production of rare isotopes. Its goal is to provide access to the nuclides important for understanding how nuclear structure changes with neutron to proton ratio and to provide complete access to astrophysical important nuclei. It will therefore offer unprecedented opportunities for progress in our understanding of unstable nuclei and their role in the cosmos. This information is needed to solve some of the most important questions in nuclear astrophysics.

The RIA concept is to allow for a variety of production mechanisms and to choose the optimum one for the nuclide of interest. High energy light-ion beams (1-3 GeV total energy) will be available for standard target spallation and fission production and isotope-separation-on-line. Heavy ion beams of more than 400 MeV/nucleon will be available for projectile breakup and fission production of nuclides. After electromagnetic separation the fast ions can be stopped in helium buffer gas where they remain singly charged, and can be quickly extracted and then reaccelerated. Thus, by this combination of techniques, rare isotope beams are available with beam energies of a few keV to 400 MeV/nucleon.

RIA's primary accelerator is planed to be a flexible superconducting linac capable of providing beams from protons to uranium at energies of at least 400 MeV/nucleon at power deposition rates of at least 100 kW. With the possibility to optimize the production method for each nuclide and the high available beam power, RIA will provide orders of magnitude improvement in rare isotope yields over existing facilities.

There are no serious technical risks or developments necessary to implement RIA. The superconducting linac technology is closely related to that used at existing accelerators and the Spallation Neutron Source. The various isotope separation technologies are extenisions of techniques currently used or in development at laboratories around the world. R&D for the RIA project is underway at several laboratories under the guidance of a RIA R&D Coordinating Committee.

The RIA community has begun working on the experimental equipment necessary for RIA. Modest extensions of existing technology appear to be adequate. A full complement of experimental devices is planned and initial conceptual designs have been made. The RIA project cost quoted below includes funds to build the required experimental equipment.

Science questions addressed:

Nuclei far from stability play a key role in the physics associated with a number of astrophysical sites. These include the rapid neutron capture process (r process), supernova explosions, the interiors of neutron stars, the surface and crust processes of accreting neutron stars in X-ray binaries, and Nova explosions. For all these scenarios recent progress in astronomy has yielded unprecedented new observational data. These include, for example, the discovery of r process element enhanced ultra metal poor halo stars (Keck, HST, and others), the detection of a variety of oscillations in X-ray binaries (RXTE), and new high quality data on the composition of nova ejecta (Chandra X-ray observatory). These observations together with new data expected from next generation observatories like INTEGRAL, NGST, Constellation-X, GLAST, EXIST and others hold the key for answering some of the most important questions in nuclear astrophysics. However, interpretation of the observational data requires a quantitative understanding of the underlying nuclear physics processes, and many of the experimental data needed can only be provided by RIA.

The open questions in nuclear astrophysics that require input from RIA are at the heart of two of the key science questions identified in the CPU Phase 1 report:

(1) *How were the elements from iron to uranium made* ? Half of the elements heavier than iron are made in the rapid neutron capture process, yet we still don't know where in the universe this process operates. RIA will provide the unique opportunity to measure the properties of most r process nuclei leading to a dramatic improvement in our understanding of this process. This is a prerequisite for identifying the r process sites, and for using r process observations in the solar system, in metal poor stars, and maybe in the future in supernova ejecta, to obtain constraints on stellar conditions and possibly on neutrino properties. In addition, experimental data on weak interaction rates from RIA will also lead to a better understanding of the explosion mechanism in supernovae. Supernovae play a key role in the synthesis of heavy proton rich (p process) and most likely also neutron rich (r process) nuclei, but self consistent modeling is severely hampered by the lack of understanding of the explosion mechanism.

(2) *Are there new states of matter at high density and temperature* ? Data from RIA will provide new constraints on the equation of state in neutron rich matter. At RIA one will be able to explore the isospin dependence of the equation of state which plays an important role in neutron stars. Data from RIA will also provide the connection between observations in X-ray binary systems and the properties of neutron stars by putting our understanding of the nuclear processes on the surface and in the crust of accreting neutron stars on a solid experimental basis.

The better understanding of supernova explosions and the r process that we can expect from combining advances in supernova modeling, experimental data from RIA, and new astronomical observations will also play an important role in addressing two additional science opportunities identified in the CPU Phase I report:

(3) *What are the masses of neutrinos, and how have they shaped the evolution of the universe* ? Once they are better understood, supernovae can possibly be used as unique neutrino laboratories, either by directly observing neutrinos from supernovae, or via r process abundance observations.

(4) *What is the nature of the dark energy ?* One of the most important indications for the existence of dark energy relies on using type Ia supernovae as standard candles. A better understanding of the explosion mechanism is needed to address possible systematic errors in this assumption.

Cost and Schedule:

RIA will be a multi-laboratory project. The project construction cost, as reviewed by an NSAC subcommittee, is estimated to be 644 M$. The total project cost, which includes research and development and operation of the facility during construction and commissioning is 844M$. It is expected that the construction time is approximately 6 to 7 years. Hence, if started in 2004 RIA would be operational in 2010.

Multi-agency involvement:

RIA could be a collaborative effort between the Department of Energy and the National Science Foundation.