Donald Rapp -- Additional Background

In the 1960s and 1970s:

I developed a greater understanding of the relationship between classical, semi-classical and quantum calculations of transitions in atomic and molecular collisions, and I applied this understanding to a variety of atomic and molecular systems. A completely quantum calculation would typically be very complex in which the various particles involved would be represented by waves, that interact where they meet. A fully classical calculation treats the particles according to classical mechanics, and they follow deterministic trajectories, and exchange energy in differential amounts, not bound by quantum mechanics. In a semi-classical calculation, the interacting atoms or molecules are assumed to move through space along classical deterministic trajectories, and in so doing, apply forces to one another. The internal properties of the atoms or molecules are treated properly as quantum particles with quantized energy levels. The forces applied by the deterministic classical external motion induce transitions between the quantized internal energy levels.

A diatomic molecule can be approximated as a harmonic oscillator (two masses connected by a spring) with evenly spaced, quantized energy levels. When such an oscillator is hit by an impacting atom, it can drive the oscillator into an excited state by transferring kinetic energy from the atom to the oscillator. I used the semi-classical method to investigate a wide variety of such collisions. I showed that in the classical approximation, a small amount of energy (e) is transferred to the (non-quantized) classical oscillator in every single collision. In the semi-classical model, a full quantum (E) is transferred to the oscillator in only a small fraction (f) of collisions. I showed that e = (E) (f) so that, when averaged over many collisions, the net energy transferred is the same.

Semi-classical models for atomic and molecular collisions existed before I came along, but I clarified aspects of such models, and applied them to a number of specific cases. These are documented in a dozen paper published in peer-reviewed journals.

I also investigated electron transfer between atoms in atomic collisions of ions with atoms. If a charged ion (A+) passes near a neutral atom (B), it can steal an electron, ending up with (A) + (B+). In the model, a high velocity A+ ion passes near a stationary B atom, along a classical trajectory. An outer electron on the B atom is attracted to both its nucleus (B+) as well as the net charge on the A+ ion. There is a probability that the electron, originally on (B), will “jump” to A+, ending up with (A) + (B+). A special case occurs when A and B are the same atom. This is called “resonant charge transfer” because there is no energy required for the electron jump. The beginning and ending energy levels are the same. When A and B are different atoms (asymmetric charge transfer), there is usually a difference in the energies of the initial and final states. A very special case can occur where A and B are different, but their energies are nearly the same; this is called “accidentally resonant”.

At the time that I worked in this field, each case of charge transfer between atoms was viewed individually, and there was no overall model that encompassed many such processes. Furthermore, resonant charge transfer was treated as a very different process than nonresonant charge transfer. In a landmark paper written in 1962, I developed a model that expressed the cross section for charge transfer of resonant system vs. collision velocity as a function of the first ionization potential of the atoms involved. For asymmetric charge transfer, I developed a model that showed it acted like symmetric charge transfer at high enough collision velocities, but the cross section decreased sharply below a certain threshold velocity. The comparison of this model with data available at that time was good.

In subsequent years, I carried out more sophisticated models of specific charge transfer processes. Of particular interest was the use of pseudo-potentials for the alkali atoms in which the outer electron is modeled quantum mechanically to move in the electric field represented by the nucleus plus an electron cloud of the inner electrons. With such pseudo-potentials assigned to each alkali atoms, charge transfer between various alkali atoms can be modeled as transfer of a single outer electron from one atom to another where the electric fields of the alkali atoms are the pseudo-potentials. This work was done in the early 1970s.

One of the most important, and most fundamental processes in plasma physics is electron impact on an atom or molecule, knocking out one or more electrons from the atom, leaving the atom ionized. Back in the 1930s, some astute scientists made measurements of this ionization process for a number of atoms and molecules. In the 1960s, I decided to reinvestigate ionization of atoms and molecules by electron impact using more modern technology. Our team made important measurements that are still used today, including ionization and electron attachment by electron impact on atoms and molecules.

As a Professor of Physics, I decide to write textbooks on quantum mechanics and statistical mechanics in 1971 and 1972. These books went out of print about 20 years later, but I reissued them as self-published in 2012-2013.

The JPL Years: 1979-2002:

In 1979, I joined JPL where I no longer did research but worked in technology management. During my time at JPL I carried out a number of studies; A few of these are briefly summarized here.

With the advent of parallel processing computers, I developed parallel processing algorithms for matrix inversion and predictor-corrector integration of differential equations.

I worked with others to develop active structures using piezoelectric actuators.

I co-authored a landmark paper on design and applicability of telescopes for IR and sub-mm astronomy.

I co-authored a paper on sue of C-60 as a propellant in ion propulsion.

I was Proposal Manager on several proposals to NASA for large-scale space missions. These included Suess-Urey (which won) to measure composition of the solar wind, OMEGA for gravitational wave detection (which lost), Kitty Hawk to fly gliders on Mars (which lost), and Deep Impact to explore the interior of a comet (which won). The total investment in Suess-Urey and Deep Impact was about 500,000,000 dollars.

I led an experimental study of an absorption compressor to compress Mars gas to usable pressures.

Post-2002:

I analyzed beaming solar power down from space to earth.

I published two papers on life support systems and radiation effects for human missions to Mars.

I acted as Proposal Manager for a proposal to NASA on “Mars Ground Penetrating Radar Proposal to Mars Science Laboratory” but it was not funded.

Acting as a consultant to JPL, I published a number of reports on topics such as: power system in space, a study of available water on Mars, a model of transfer trajectories from earth to Mars, solar energy on Moon and Mars, transporting hydrogen to Mars.

I wrote several papers published in the Mars Journal, dealing with life support and radiation effects.

Because of my reputation as a Proposal Manager, Stanford University asked me lead preparation of a proposal: “Interfacial Chemistry and Energy at SLAC and Stanford University (ICESS) Center".

Post-2008:

My work during this period was mainly divided between analysis of human missions to Mars, climate change, ice ages, and use of extraterrestrial materials in space missions.

My book on human missions to Mars was republished as a second edition in 2016 (582 pages) and a third edition in 2023 (614 pages).

My book on climate change was republished as a third edition in 2014 (816 pages).

My book on ice ages was republished as a third edition in 2019.

My book on extraterrestrial materials was republished as a second edition in 2018.

I also got interested in financial bubbles, and wrote a book on the subject. I also wrote chapters in encyclopedic compendiums.

Working as a consultant for MIT, I was a co-investigator on the Mars MOXIE Project from 2015 through 2023, to convert Martian CO_2 into O_2. I provided continuing documentation of work on the Project, I provided an end-to-end computer model of the end-to-end system, I cataloged the test data and analyzed it, and I provided an analysis of prospects for scaling up to full -scale proportions.

Working with Ralph Ellis and Clive Best, we developed a model for ice ages over the past 2.7 million years and showed how the pacing of ice ages changed across the Mid-Pleistocene transition.