This grant supported basic theoretical research into the derivation (from relativistic field theories) of relativistic equations for few body systems, with practical applications to the properties of 2 and 3 nucleon systems and to the nature of few-quark systems.

The most significant theoretical results are:

- Proof that the instability of field theories of the $\chi^2\phi$-type, known since 1959, are due to the production of $\chi^2$ loops. This explains how such theories can be used successfully in quenched approximation to model one-boson exchange forces.
- Study of the momentum sum rule using the stress-energy tensor and its corresponding Ward identities. This opens a new field of research.
- Demonstration that, to all orders in field theory, cancellations sometimes occur between vertex corrections, self energies, and crossed meson exchange diagrams. For scalar QED describing the interactions of massive scalar particle(s) with a vector field, these cancellations produce some remarkable, unexpected results. In particular (i) the self-energy of the massive scalar particle, when calculated to all orders, is equal to the lowest order self-energy evaluated at the bare mass point, and (ii) the exact (quenched) bound-state energy of two massive scalar particles is equal to the bound-state energy obtained from the generalized ladder sum with no vertex corrections and no self energy corrections, provided only that the (constant) dressed mass of the massive scalar particles is used in the generalized ladder sum. This result justifies a number of approximations commonly used in the construction of relativistic few-body equations.

The most significant practical results for few nucleon systems are:

- Detailed derivation and partial wave decomposition of the covariant three-body Spectator equations that treat relativistic and spin effects exactly to all powers of the nucleon velocity.
- Numerical solution of these three-body equations using a family of realistic two-body interactions. The three-nucleon binding energy was found to be sensitive to the off-shell coupling of the scalar mesons being exchanged between the two nucleons, and it was found that a single value of the parameter that described the strength of this off-shell coupling gave both the exact three-body binding energy and the best fit to the two-body data.
- Derivation, for the first time, of the normalization condition for a relativistic three-body bound state amplitude that is either the solution of the bound-state Bethe-Salpeter equation or the bound-state Spectator equation.
- Study of the gauge invariant current for a two-body system (previously derived) and exploratory numerical studies of deuteron electro-disintegration at high momentum transfer. It was found that these experiments are feasible at the Jefferson Laboratory using existing equipment.
- Derivation of a gauge invariant three-body current for the calculation of both elastic and inelastic electro- or photo-reactions involving three-body nuclei.
In addition to these results, a new method for treating the confinement of quarks in quark-antiquark systems was developed.

This grant partially supported four Ph.D. students and three postdoctoral associates. The research was published and presented in 19 papers in refereed journals and 32 invited talks at international conferences (17 of which were published in proceedings). Included in this list of publications is a major review article on the “Electromagnetic Structure of the Deuteron,” written by R. Gilman and the PI, and a review of “Nonperturbative Dynamics of Scalar Field Theories through the Feynman-Schwinger Representation” written by C. Savkli (postdoctoral associate), the PI, and J. Tjon.