<u>Proposal Summary</u>:  **Jumpulse and Law of Touch Demonstrated by Prolonged Contact between Ball and Racket during Collision**

This proposed research deals with the new physics concept of jumpulse, which denotes a sudden change of force, as impulse is a sudden change of momentum.  This proposal will investigate prolonged contact due to a force applied during a collision between a ball and a racket.  In order to have two objects moving together, they need to have the same position, velocity, and acceleration.  Sometime during the impact, the velocity and the position of the ball and the racket are the same and, if then the racket acceleration is increased by a finite amount, prolonged contact can be achieved.  Prolonged contact needs the Law of Touch, which states, unlike velocity, acceleration can be changed instantaneously.  Prolonged contact is directly related to touch because a robot finger bounces off a surface like a ball bounces off a racket, and touch can be defined as permanently prolonged contact at low impact velocity.  **Table** below shows that jumpulse is a missing concept central to the description of motion (for touch).

**Table  Terminology and Concept in Describing Motion**

| Velocity | Acceleration | Jerk (ISO) | Snap (?) | Crack (?) | Pop (?) |
|---|---|---|---|---|---|
| Momentum | Force | Yank (?) | Tug (?) | Snatch (?) | Shake (?) |
| Energy | Energy of Acceleration | | | | |
| Impulse | **Jumpulse ?** | | | | |

Some definitive Yes or No questions regarding prolonged contact serve to focus the goal of the proposal:

    (1)  Does prolonged contact exist?
    (2)  Does jumpulse play a role in prolonged contact?
    (3)  Can acceleration or force be increased instantaneously by a finite amount?
    (4)  Should the concept of an instantaneous change of force be emphasized in describing motion?

The feasibility of prolonged contact has been demonstrated in an experiment, where two colliding cars, which can represent the ball and the racket, moving together after the collision, as shown in the video: http://www.youtube.com/watch?v=PixwnjvNlNQ.  Jumpulse can be defined below with infinite $d^3x/dt^3$:

$$\text{Jumpulse} \equiv \int_{t_1}^{t_2} m\, d^3x/dt^3\, dt, \quad \text{where } (t_2 - t_1) \text{ approaches and can equal zero}$$

Jumpulse is desirable in initiating a motion, but is necessary in prolonged contact and robot touch where a finite increase in acceleration must occur within the short time duration of an impulse.  Jumpulse is measured in **w**eight **u**nits, where one wu equals one newton.  This research project will take one year.  Ultraslow 7000-fps motion videos will capture 70 frames in 10 milliseconds with 32 GB of memory to produce 3 seconds of video to study the effect of a force applied during the 4-msec. impact of a collision.

**Intellectual Merit:**  Jumpulse is an extension of impulse.  Jumpulse and the Law of Touch are missing concepts in the description of motion and are necessary in tennis prolonged contact and in robot touch.

**Broad Impact:**  Learning prolonged contact in sports based on jumpulse should be exciting to students around the world.  Textbooks on mechanics and on sports should include the concept of jumpulse.

The proposal challenges physicists world-wide to think *physically* the solution of prolonged contact.

**Key Words:** jumpulse; robot touch; dynamic contact; applied force; collision; impulse; prolonged contact.