**Title:** Effects of Different Left-turn Policies on Crashes - A Feasibility Study

**Sponsor Technical Contact:**
- Howard S. Stein
  - Transportation Engineer
  - Insurance Institute for Highway Safety
  - Watergate Six Hundred
  - Washington, DC 20057

**Sponsor Admin/Contractual Matters:**
- Allan F. Williams, Ph.D
  - Vice President, Research
  - Insurance Institute for Highway Safety
  - Watergate Six Hundred
  - Washington, DC 20057

**Harvard Citation:**

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**Travel:**
Foreign travel must have prior approval — Contact OCA in each case. Domestic travel requires sponsor approval where total will exceed greater of $500 or 125% of approved proposal budget category.

**Equipment:**
Title vests with N/A

**Copies To:**
- Project Director
- Research Administrative Network
- Research Property Management
- Accounting
- Procurement/GTRI Supply Services
- Research Security Services
- Reports Coordinator (OCA)
- Research Communications (2)
- Other A. Jones

**Comments:**

---

**Defense Priority Rating:** N/A

**Military Security Classification:** N/A

**Restrictions:**
See Attached N/A Supplemental Information Sheet for Additional Requirements.
Project No. E-20-G07

Includes Subproject No.(s) N/A

Project Director(s) Dr. P.S. Parsonson

Sponsor Insurance Institute for Highway Safety

Title Effects of Different Left-turn Options on Crashes - A Feasibility Study

Effective Completion Date: 9/2/86 (Performance) 10/2/86 (Reports)

Grant/Contract Closeout Actions Remaining:

X None

Final Invoice or Final Fiscal Report

Closing Documents

Final Report of Inventions

Govt. Property Inventory & Related Certificate

Classified Material Certificate

Other

Continues Project No. ____________________________ Continued by Project No. ____________________________

COPIES TO: Project Director

Research Administrative Network

Research Property Management

Accounting

Procurement/GTRI Supply Services

Research Security Services

Library

GTRC

Project File

Other

Duane H.

Angela DuBose

Russ Embry

FORM OCA 69.285
PROPOSAL
for a
Sponsored Research Project Entitled

EFFECT ON CRASHES OF CHANGING
TRAFFIC-SIGNAL PHASING
FROM PERMISSIVE TO PROTECTED/PERMISSIVE
December 18, 1986

Insurance Institute for Highway Safety
Watergate Six Hundred
Washington, D.C. 20031

Attention: Mr. Howard S. Stein

Subject: Research Proposal Entitled, "Effect on Crashes of Changing Traffic Signal Phasing from Permissive to Protected/Permissive"

Dear Mr. Stein:

The GEORGIA TECH RESEARCH CORPORATION desires to submit for your consideration the subject proposal prepared by Dr's. Peter S. Parsonson and Russell Heikes, Georgia Institute of Technology.

A description of the research program, the time required and estimated costs are included in the proposal. Should additional information be desired, please do not hesitate to contact Dr's. Parsonson or Heikes at 404/894-2244 or 2331 regarding technical matters or the undersigned at 404/894-4817 for administrative concerns.

In the event of an award, we propose that the work be authorized by either a grant or a cost-reimbursement (no fee) type of contract drawn in the name of the GEORGIA TECH RESEARCH CORPORATION.

Should you determined that the appropriate funding mechanism is an award document the same as the document you forwarded on June 20, 1986, please delete paragraph 8 as Georgia Tech cannot accept any indemnity language.

We appreciate the opportunity of submitting this proposal and look forward to working with you on this project.

Sincerely,

Ralph Grede
Contracting Officer

RG/sdm

Addressee: In triplicate
Enclosure: Proposal - In triplicate
PROPOSAL
for a
Sponsored Research Project Entitled

EFFECT ON CRASHES OF CHANGING TRAFFIC-SIGNAL PHASING FROM PERMISSIVE TO PROTECTED/PERMISSIVE

from the
School of Civil Engineering
Georgia Institute of Technology
to the
Insurance Institute for Highway Safety

SUMMARY

Sponsor
Insurance Institute for Highway Safety
Watergate Six Hundred
Washington, D. C. 20037

Sponsor's Contact Person
Mr. Howard S. Stein
Transportation Engineer
Telephone: (202) 333-0770

Proposing Agency
Georgia Tech Research Corporation
Georgia Institute of Technology
Atlanta, GA 30332

Person Submitting Proposal
Mr. Ralph Grede, Contracting Officer
Office of Contracts Administration
Telephone: (404) 894-4817

Project Director and Principal Investigator
Peter S. Parsons, Ph.D., P.E., Professor
School of Civil Engineering
Telephone: (404) 894-2244

Co-Project Director
Russell G. Heikes, Ph.D., P.E., Associate Professor
School of Industrial and Systems Engineering
Telephone: (404) 894-2331

Dates
Estimated time to conduct: 6 months from award of contract
Estimated project period: January 15 - July 15, 1987
Date of Proposal: December 17, 1986

Budget
$33,114, all from sponsor
STATEMENT OF WORK

This is a proposal to perform work that follows on from an earlier study entitled "Effects of Different Left-Turn Policies on Crashes: a Feasibility Study" performed by Georgia Tech's School of Civil Engineering for the IIHS in 1986. The primary objective of that study was to determine if there are sufficient numbers of intersections, in major cities and suburban areas, with various left-turn policies. Another objective was to determine if there are sufficient intersections that have changed from one type of phasing to another, permitting before/after analyses.

To meet these objectives, questionnaires were sent out to 71 state and local traffic-engineering agencies, nationwide, asking about their policies and the availability of crash data at intersections that have been changed. Thirty-nine agencies responded. The return of over 50 percent of the questionnaires was due to telephone contacts made by Georgia Tech before mailing.

The questionnaires showed that there was a large data base of intersections that had been changed for one reason or another. In order to avoid complications from the effect called "regression to the mean", it was decided that further research should analyze only those intersections that were changed for reasons other than safety. Attached is a three-page Table 1 entitled "Intersections with Signal Phasing Changes Not Caused by Increased Accident Rates". Through follow-up phone calls we found that some of these intersections were changed for the purpose of improving progression by clearing out the left-turning traffic prior to the main flow. The remainder were changed to reduce left-turn delay and excessive queue lengths. It may turn out that these locations will have crash rates higher than average, but the fact that crash-rate was not the reason for change will be our assurance that regression to the mean will not be a factor that could bias our results.

Our phone calls and letters indicate that most of the changes done for non-crash reasons were from P to P/P. That indication is clear from Table 1. We will discuss data availability later herein, but first we would like to address the question of needed sample size.

Sample Size

Agent (1978), in his SSITE Committee Report on Left-Turn Signal Warrants, reported that his questionnaires showed that a representative crash warrant to install left-turn signal phasing calls for four or more left-turn crashes on an intersection approach in a one-year period or six or more in a two-year period.

Warren (1985) reported two locations that were changed from P to P/P for reasons he did not state. Before the change each location experienced six "approach-left-turn" crashes over a
two-year period.

These two findings suggest that an approach changed for non-crash reasons would be expected to show somewhat fewer than six left-turn crashes in two years.

Assume that a typical location has a ADT of 13,000 vpd on the main street, meaning 6,500 vpd in one direction, and that a typical approach-left-turning volume is 1500 per day (derived from 150 vph turning left for four hours per day plus 100 for another six, plus a remainder of 300 vpd). The sum of the two volumes is 8,000 vpd. Over two years this amounts to 5,840,000 vehicles. Now, Cottrell found that his 20 sites with P/P averaged 55.8 left-turn crashes per 100 million vehicles turning left and oncoming, added. For our assumed volume levels the number of crashes in two years is calculated as follows:

\[
55.8 \times \frac{5,840,000}{100,000,000} = 3.26 \text{ crashes in two years}
\]

From all of this we can estimate that the data we will obtain will show a before left-turn crash rate (under P operation) of about five in two years, and an after rate under P/P operation of perhaps three or four.

Assuming Poisson with a mean of five crashes in two years, we can calculate the number of approaches needed to give adequate statistical confidence in our conclusions as to whether the change from P to P/P reduced crashes. The expression for the number of approaches is

\[
n = \frac{2(Z^2 s^2)}{E^2}
\]

where \(Z\) is the coded deviate in the normal distribution and is 1.65 for 95% confidence in our one-tailed test; \(s^2\) is the variance of the distribution and is equal to the mean of 5 when Poisson is assumed; \(E\) is the allowable error and is here taken as one-half accident over two years. The 2 is needed because we are testing for a significant difference in the means, and there is uncertainty in both the before and after data. So,

\[
n = \frac{2(1.65)^2 (5)}{0.5^2} = 109 \text{ approaches}
\]

Data Availability

We have identified 10 state and local governments that have a total of 80 intersections that have been changed from P to P/P for non-crash reasons. Our updated understanding of availability is shown on the attached Table 2. Crash data for about 46 intersections can be obtained directly from the governments or by only local travel by Georgia Tech personnel. Data for about 34 of the
Intersections would have to be obtained by out-of-state travel by Georgia Tech. We have found that at most intersections both of the main-street approaches were changed from P to P/P, so the 46 intersections for which data is inexpensively available should yield about 90 approaches.

There are two cities—Memphis and Nashville—that have indicated that they have 17 and 13 suitable intersections, respectively; Georgia Tech would have to make trips to retrieve the data. These two cities are such a rich potential source of data that we believe that these two trips are a justified expense.

Therefore we estimate at this time that the project will have 46 + 17 + 13 = 76 intersections (about 152 approaches) as a data base. Any attrition due to misunderstandings probably could be nullified by a few more phone calls and letters to various agencies.

If we analyze data from 152 changed approaches, the statistical significance can be calculated. If we substitute 152 for the 109 used earlier herein, and if we continue to require 95 percent confidence, then it is easy to show that now our allowable error is 0.42 crashes, slightly less than one-half, over a two-year period.

Control Sites

For each approach that is changed, we propose to use as a control location the nearest upstream approach (same street, same direction) that has P operation similar to that at the changed site, considering primarily volume. (Of course, if the left turns at the changed site are made from a shared lane, or an exclusive lane, the control approach must follow suit.)

Proposed Analyses

We plan to obtain for each changed approach, and its control approach, the following crash statistics on a per-year basis: total crashes, approach left-turn crashes, rear-end crashes and injury crashes. The analyses will parallel those done by Warren (1985) to determine the net effects of the phasing changes after allowing for the findings at the control sites.

We also plan to perform linear regression analyses to develop a model that relates crashes to the site-specific conditions such as speed limit, number of lanes, etc. We believe that this regression work will go very quickly, as in previous steps we will have gathered all the required data.

We plan to be alert to city-to-city variance in accident rates, so that we will not be using data from a city that is an outlier. Dr. Heikes suggests that the proper way to approach this is to examine closely the data from any city whose average crash rate is more than two standard deviations different from
Staffing Plan and Budget

An attachment shows the estimated manpower and budget for the project. Graduate student Larry Henson does not show up as his services for the fall, winter and spring quarters are being furnished free of charge to the IIHS because Larry holds a Stelson Fellowship. Dr. Heikes will be needed to work with me and the student employees to clean up the data, organize it, and put it on the computer. We have already furnished Dr. Heikes’ bio-sketch. Chris Squires is one of our own seniors; he will graduate in the winter quarter and enter our graduate program in the spring. He will have time to monitor the project during the winter and will be able to come up to speed right away in the spring. His transcript is attached.
Table 1
Intersections with Signal Phasing Changes Not Caused by Increased Accident Rates

<table>
<thead>
<tr>
<th>Intersection</th>
<th>Type of Change</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knoxville, Tenn.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Broadway &amp; Central St.</td>
<td>P/P Lag to PO</td>
<td>High left-turn Volumes</td>
</tr>
<tr>
<td>- Western Ave &amp; University</td>
<td>P to PO</td>
<td>High left-turn Volumes</td>
</tr>
<tr>
<td>- Chapman Hwy &amp; Young High Pike</td>
<td>P/P Lag to P/P</td>
<td>Wrong Driver Expectancy</td>
</tr>
<tr>
<td>- Clinton Hwy &amp; Tillery Rd.</td>
<td>P to P/P</td>
<td>High left-turn Volumes</td>
</tr>
<tr>
<td>- PapERMill Rd &amp; Northshore Dr.</td>
<td>P/P to PO</td>
<td>Dual Left-turn Lanes</td>
</tr>
<tr>
<td>- Kingston Pike &amp; Alcoa Hwy</td>
<td>P/P Lag to P/P</td>
<td>Construction</td>
</tr>
<tr>
<td>Virginia Beach, Vir.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Vir. Beach Blvd &amp; Birdneck Rd</td>
<td>PO to P/P</td>
<td>To Decrease Delay</td>
</tr>
<tr>
<td>- Rosemont Rd &amp; S. Plaza Trail</td>
<td>P to P/P</td>
<td>High left-turn Volumes</td>
</tr>
<tr>
<td>- Rosemont Rd &amp; Holland Rd.</td>
<td>PO to P/P</td>
<td>To Decrease Delay</td>
</tr>
<tr>
<td>Memphis, Tenn.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Walnut &amp; Perkins</td>
<td>P to P/P</td>
<td>High Left-turn Volumes</td>
</tr>
<tr>
<td>- Park &amp; Pendleton</td>
<td>P to P/P</td>
<td>High Left-turn Volumes</td>
</tr>
<tr>
<td>- Peabody &amp; Bellevue</td>
<td>P to P/P</td>
<td>High Left-turn Volumes</td>
</tr>
<tr>
<td>- Park &amp; White Station</td>
<td>P to P/P</td>
<td>High Left-turn Volumes</td>
</tr>
<tr>
<td>- Winchester &amp; Mendenhall</td>
<td>P to P/P</td>
<td>High Left-turn Volumes</td>
</tr>
<tr>
<td>- Raleigh LaGrange &amp; Covenington</td>
<td>P to P/P</td>
<td>High Left-turn Volumes</td>
</tr>
<tr>
<td>- Lentil &amp; Highland</td>
<td>P to P/P</td>
<td>High Left-turn Volumes</td>
</tr>
<tr>
<td>- Frayser &amp; N. Walkins</td>
<td>P to P/P</td>
<td>High Left-turn Volumes</td>
</tr>
<tr>
<td>- I-240 EB Ramp &amp; Mt. Moriah</td>
<td>P to P/P</td>
<td>High Left-turn Volumes</td>
</tr>
<tr>
<td>- Winchester &amp; Swinnea</td>
<td>P to P/P</td>
<td>High Left-turn Volumes</td>
</tr>
<tr>
<td>- Quince &amp; Ridgeway</td>
<td>P to P/P</td>
<td>High Left-turn Volumes</td>
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<tr>
<td>- Quince &amp; Lynnfield</td>
<td>P to P/P</td>
<td>High Left-turn Volumes</td>
</tr>
<tr>
<td>- Knight Arnold &amp; Larmor</td>
<td>P to P/P</td>
<td>High Left-turn Volumes</td>
</tr>
<tr>
<td>- Lamar &amp; Semmes</td>
<td>P to P/P</td>
<td>High Left-turn Volumes</td>
</tr>
<tr>
<td>- Poplar &amp; Kirby Pkwy</td>
<td>P to P/P</td>
<td>High Left-turn Volumes</td>
</tr>
<tr>
<td>- Summer &amp; Stratford</td>
<td>P to P/P</td>
<td>High Left-turn Volumes</td>
</tr>
<tr>
<td>- Crump &amp; East</td>
<td>P to P/P</td>
<td>High Left-turn Volumes</td>
</tr>
<tr>
<td>Greensboro, N.C.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Battleground &amp; Westridge</td>
<td>P to PO</td>
<td>High Left-turn Volumes</td>
</tr>
<tr>
<td>- Highpiont &amp; Meadowview</td>
<td>P to PO</td>
<td>Line of Sight Deficiency</td>
</tr>
<tr>
<td>- Market &amp; College</td>
<td>P to PO</td>
<td>Line of Sight Deficiency</td>
</tr>
<tr>
<td>- Friendly &amp; New Garden</td>
<td>P to PO</td>
<td>Line of Sight Deficiency</td>
</tr>
<tr>
<td>- Market &amp; Muirs Chapel</td>
<td>P to PO</td>
<td>High Left-turn Volumes</td>
</tr>
<tr>
<td>Quincy, Ill.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- 24th &amp; Broadway</td>
<td>P to P/P</td>
<td>To Decrease Delay</td>
</tr>
<tr>
<td>- 33rd &amp; Broadway</td>
<td>P to P/P</td>
<td>To Decrease Delay</td>
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<tr>
<td>- 36th &amp; Broadway</td>
<td>P to P/P</td>
<td>To Decrease Delay</td>
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<tr>
<td>- 36th &amp; Maine</td>
<td>P to P/P</td>
<td>To Decrease Delay</td>
</tr>
<tr>
<td>- 3rd &amp; Broadway</td>
<td>P/P to PO</td>
<td>Road Geometries</td>
</tr>
</tbody>
</table>
### Tallahassee, Fl.
- Duval & Tennessee  
  P to P/P  
  To Decrease Delay
- Bronough & Tennessee  
  P to P/P  
  To Decrease Delay
- Capital Cir & Centerville Rd  
  P to P/P  
  To Decrease Delay
- Thomasville Rd & Betton Rd  
  P to P/P  
  To Decrease Delay

### Albany, Ga.
- Oakridge Dr & Radium Springs Rd  
  P to P/P  
  High Left-turn Volumes
- Oakridge Dr & Elappley Blvd  
  P to P/P  
  High Left-turn Volumes
- Stuart Ave & Dawson Rd  
  P to P/P  
  High Left-turn Volumes
- Oakridge Dr & Newton Rd  
  P to P/P  
  Provide cont. Progression

### Gwinnett County, Ga.
- Jimmy Carter & Atlantic Blvd  
  P to P/P  
  To Decrease Delay
- US 78 & Hewatt Rd  
  P to P/P  
  High Volumes
- US 23 & Beaver Ruin  
  P to P/P  
  High Volumes
- Indian Trail & Singleton Rd  
  P to P/P  
  High Volumes
- Holcomb Bridge Rd & Spalding Dr  
  P to P/P  
  High Volumes
- Holcomb Bridge Rd & P'tree Corn  
  P to P/P  
  High Volumes
- US 23 & SR 120  
  P to P/P  
  High Volumes
- US 23 & Pleasant Hill Rd  
  P to P/P  
  High Volumes
- US 23 & Button Gwinnett Dr  
  P to P/P  
  High Volumes
- Jimmy Carter & Best Friend Rd  
  P to P/P  
  High Volumes
- Jimmy Carter & US 29  
  P to P/P  
  High Volumes
- S. Norcross & Tucker Rd  
  P to P/P  
  High Volumes
- Indian Trail & Dickens Rd  
  P to P/P  
  High Volumes
- Pleasant Hill Rd & Old Norcross  
  P to P/P  
  High Volumes
- Pleasant Hill Rd & Club Dr  
  P to P/P  
  High Volumes
- US 29 & Beaver Ruin  
  P to P/P  
  High Volumes
- US 29 & Pleasant Hill  
  P to P/P  
  High Volumes
- Killian Hill Rd & Arcado Rd  
  P to P/P  
  High Volumes
- 5 Forks Trickum & Killian Hill  
  P to P/P  
  High Volumes
- 5 Forks Trickum & Oak Rd  
  P to P/P  
  High Volumes
- US 78 & Killian Hill Rd  
  P to P/P  
  High Volumes
- SR 20 & SR 124  
  P to P/P  
  High Volumes
- Indian Trail & I-85 N.B.  
  P to P/P  
  Dual Left-turn Lanes
- US 78 & East Park Pk  
  P to P/P  
  Geometry
- 5 Forks Trickum & Pound Rd  
  P/P Lag to P/P  
  Queuing Problems
- Pleasant Hill Rd & Burns Rd  
  P/P Lag to P/P  
  Queuing Problems
- Indian Trail & I-85 S.B.  
  P/P to PO  
  Intersection Change

### Tampa, Fl.
- Anderson & Hillsborough  
  P to P/P  
  Provide Progression
- Broadway & 50th  
  P to P/P  
  High Volumes
- Buffalo & Habana  
  P to P/P  
  High Volumes
- Buffalo & Himes  
  P to P/P  
  High Volumes
- Cleveland & Willow  
  P to P/P  
  Reconstruction
- Dale Mabry & Gandy  
  P to P/P  
  High Volumes
- Dale Mabry & Gold Triangle  
  P/P to P  
  Land Use Change
- Busch Gardens & McKinley  
  PO to P/P  
  Delay
- Florida & Yukon  
  P to P/P  
  High Volumes
- Fowler & 15th  
  P/P to PO  
  Multi-lane Crossing
Tampa, Fl.
- Hillborough & I-275
- I-4 & 40th NB
- I-4 & 40th SB
- I-275 & Sligh
- Kennedy & Lois
- Nebraska & Sligh
- North B & Westshore

P to P/P Lag  Volumes onto Freeway
P to P/P  Volumes, Progression
P to P/P Lag  Volumes, Progression
P to P/P  High Volumes
P to P/P  Dual to Single Turns
P to P/P  High Volumes
P/P Lag to P/P  Remove Lag

Charleston, WV
- Lodgeville Rd & Emily Dr
- University Ave & Patterson Dr

P to P/P  Capacity, Delay
P to P/P  Capacity, Delay
Table 2
AGENCIES INDICATING INTERSECTIONS CHANGED FROM P TO P/P FOR NON-CRASH REASONS

<table>
<thead>
<tr>
<th>Location</th>
<th>Intersections</th>
<th>Details</th>
</tr>
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<tbody>
<tr>
<td>Charleston, WV</td>
<td>1 intersection</td>
<td>They would furnish</td>
</tr>
<tr>
<td>Virginia Beach, VA</td>
<td>1 at this time, several more soon</td>
<td>They furnish only one, GT would have to visit for more</td>
</tr>
<tr>
<td>Albany, GA</td>
<td>4 intersections</td>
<td>They would furnish</td>
</tr>
<tr>
<td>Savannah, GA</td>
<td>2</td>
<td>&quot;</td>
</tr>
<tr>
<td>Memphis, TN</td>
<td>17</td>
<td>GT would have to go</td>
</tr>
<tr>
<td>Gwinnett County, GA</td>
<td>24</td>
<td>GT would go, local</td>
</tr>
<tr>
<td>Quincy, IL</td>
<td>4</td>
<td>They would furnish</td>
</tr>
<tr>
<td>Tallahassee, FL</td>
<td>4</td>
<td>GT would have to go</td>
</tr>
<tr>
<td>Tampa, FL</td>
<td>10</td>
<td>Taylor Stukes told us on 11/25 that he would furnish data for the 10, plus 10 control sites</td>
</tr>
<tr>
<td>Nashville, TN</td>
<td>13</td>
<td>GT would have to go</td>
</tr>
</tbody>
</table>

Total 80 intersections

of which 46 would have the crash data furnished by the agency or by only local travel by Georgia Tech personnel, and 34 where GT would have to make an overnight trip. Of the 34, only 30 (Memphis and Nashville) are considered cost-effective to obtain.
<table>
<thead>
<tr>
<th>Course Number</th>
<th>Descriptive Title of Course</th>
<th>Hrs Sched</th>
<th>Grade Earned</th>
<th>Quality Points</th>
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<td>IST 1001 U.S. HISTORY TO 1865</td>
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<tr>
<td>HEM 1101 GENERAL CHEMISTRY I</td>
<td>5</td>
<td>B</td>
<td>5</td>
<td>15</td>
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<tr>
<td>ENGL 3076 FAULKNER</td>
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<td>B</td>
<td>3</td>
<td>9</td>
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<tr>
<td>ESM 3201 DYNAMICS I</td>
<td>3</td>
<td>B</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>ESM 3301 MECH-DEFORMABLE BODIES</td>
<td>5</td>
<td>C</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>MATH 3705 MATH FOR SYS ENGINEERING</td>
<td>3</td>
<td>C</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>MGT 2000 ACCOUNTING</td>
<td>3</td>
<td>A</td>
<td>3</td>
<td>12</td>
</tr>
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<td>OPTICS &amp; MODERN PHYSICS</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>APPLIED DIGITAL COMPUTERS</td>
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<td>3</td>
<td>12</td>
<td></td>
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<tr>
<td>CALCULUS IV</td>
<td>5</td>
<td>A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GENERAL CHEMISTRY I</td>
<td>5</td>
<td>B</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>ACCOUNTING I</td>
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--- CONTINUED FROM PREVIOUS COLUMN ---
EFFECT ON CRASHES OF CHANGING TRAFFIC-SIGNAL PHASING
FROM PERMISSIVE TO PROTECTED/PERMISSIVE

BUDGET ESTIMATE

6-month budget, January 15 to July 15, 1987

1. SALARIES AND WAGES FOR PERSONAL SERVICES

Winter Quarter, 1987

Principal Investigator and Professor
Dr. Peter S. Parsonson, 20% time @ $15,834/qtr 3167

Undergraduate Student Assistants (2), Seniors
One-third time, 266 hrs @ $7.00 1862

Spring Quarter, 1987

Principal Investigator and Professor
Dr. Peter S. Parsonson, 20% time @ $15,834/qtr 3167

Co-Principal Investigator and Associate Professor
Dr. Russell G. Heikes, 25% time @ $14,000/qtr 3500

Graduate Research Assistant
Chris Squires, one-third time @ $7500/qtr 2500

Undergraduate Student Assistants (2), Seniors
One-third time, 266 hrs @ $7.00, .......................... 1862

Total Personal Services 16,058

2. TRAVEL EXPENSES

Three-day trip to Memphis
Round-trip air fare 402
Meals, lodging, ground transportation 300

Three-day trip to Nashville
Round-trip air fare 298
Meals, lodging, ground transportation 300

Total Travel 1300

3. STAFF BENEFITS AND PAYROLL TAXES

Fringe benefits are calculated as 23.6% of earnings of employees participating in retirement (Teachers Retirement System). No fringe benefits are assessed for student employees.

Earnings shown above for Drs. Parsonson and Heikes:
$11,418 x 23.6% 2695

(continued next page)
4. **PRINTING EXPENSES**
   Photocopying of data and Final Report 200
   \[
   \text{Total Direct Costs} \quad 20,253
   \]

5. **OVERHEAD**
   Calculated as 63.5% of all direct costs
   \[
   63.5\% \times \$20,253 \quad 12,861
   \]

6. **FIXED FEE**
   None, as cost reimbursement is proposed
   \[
   \text{Total Proposal} \quad \$33,114
   \]