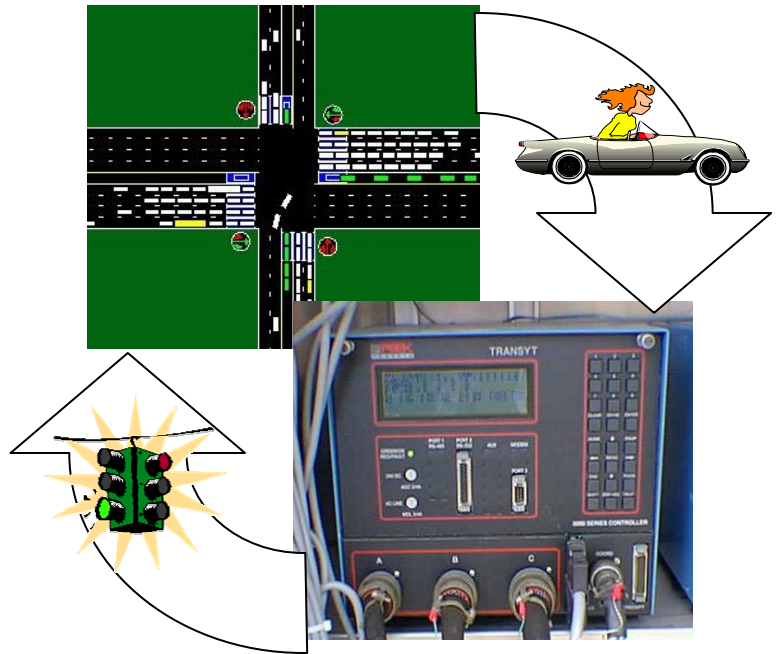




# Hardware in the Loop Traffic Simulation

## Final Report

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| 16. Abstract<br><p>Traffic simulation has become an increasingly practical approach to estimation of performance measures for all types of highway facilities. Simulation is used to some extent in most FDOT districts to address unusual traffic control problems that are not amenable to more simplistic analytical treatments. Recently a new class of devices has been developed to allow actual traffic control equipment to replace the controller emulation built into a traffic simulation model. The "Controller Interface Device" (CID) opens new horizons for the use of traffic simulation as a problem-solving tool.</p> <p>In spite of its potential utility, hardware in the loop simulation (HILS) has not been deployed extensively in Florida, mainly because it represents new technology, the benefits of which are not widely understood. The goal of this project was to apply the CID to create a new traffic analysis tool with many applications for the Department. The specific objectives were to facilitate the implementation of HILS in Florida, and to develop guidelines for future deployment by FDOT</p> <p>Six CID units were purchased and made available to district and local agencies for experimentation. It was found that, in spite of its utility, the CID is somewhat complex and requires substantial training for potential users, who must become familiar with traffic simulation, controller operations and the CID itself. Two software tools were therefore developed to facilitate the training process and to reduce the required workshop schedule to half a day. A series of these workshops was presented around the state. Those who attended expressed a strong interest in applying HILS in the future.</p> <p>The most promising future HILS applications were found to be cross-training of traffic engineering and signal operations personnel in the broad aspects of traffic control; investigation and proof of concept for proposed major traffic control system improvements involving advanced traffic control (adaptive) systems; factory acceptance testing for new and complex traffic control systems after delivery but prior to installation in the field and general controller testing in the shop.</p> |                                                     |                                                                                                                                                                        |          |
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### **Disclaimer**

The opinions, findings and conclusions presented in this report are those of the authors and not necessarily those of the Florida Department of Transportation or any other government agency.

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# 1 INTRODUCTION

Traffic simulation has become an increasingly practical approach to estimation of performance measures for all types of highway facilities. Simulation is used to some extent in most districts to address unusual traffic control problems that are not amenable to more simplistic analytical treatments. The principal limitation of simulation models has, up to this point, been the rigid emulation of basic traffic control equipment and mechanisms, accomplished by internal routines within the simulation model itself. This limitation has placed severe constraints on the utility of traffic simulation as a problem solving approach.

Recently a new class of devices has been developed to allow actual traffic control equipment to replace the controller emulation built into a traffic simulation model. The “Controller Interface Device” (CID) opens new horizons for the use of traffic simulation as a problem-solving tool.

## 1.1 PROJECT OBJECTIVES

Recognizing the potential of this breakthrough in technology, the Florida Department of Transportation (FDOT) has initiated a project to identify and explore potential areas of application that could support the FDOT mission. The University of Florida Transportation Research Center performed this work. The specific objectives were to facilitate the implementation of hardware in the loop simulation in Florida, and to develop guidelines for future deployment by FDOT. This report describes the work that has been carried out and the results that have been achieved.

## 1.2 SUMMARY OF ACTIVITIES AND RESULTS

The principal activities involved in this project are as follows

### 1.2.1 CID Procurement and Testing

Six CID units have been purchased and made available to other agencies for testing and deployment. The current deployment of the six units is as follows:

- One unit is at the FDOT Central Office in the traffic control laboratory.
- One unit is at the Traffic Control Systems Laboratory at the University of Florida.
- One unit is in the hands of the Center for Urban Transportation Research (CUTR) at the University of South Florida. CUTR is working with local area agencies on deployment
- One unit is in the FDOT 4<sup>th</sup> District office.
- Two units are undeployed, currently used to support workshop activities.

Each of the CIDs was tested to ensure its proper functioning. Tests have been conducted with NEMA TS-1 and Type 170 Controllers.

### 1.2.2 Development of Outreach Material

- An internet site has been established at <http://trc.ce.ufl.edu/research/HILS.htm>. This site now contains a description of the project and other related material. The final report document and software will also be placed on the web site

### 1.2.3 Workshops

A series of half-day workshops has been conducted regionally throughout the state. Each workshop involved five sessions:

1. Introduction
2. Simulation as a problem solving tool
3. Simulating an intersection with CORSIM
4. Adding hardware in the loop
5. Suitcase tester features

Workshops have been conducted in Ft Lauderdale, Tampa, Gainesville and Jacksonville. Other workshops scheduled for Tallahassee and Miami had to be postponed because of recent tropical weather problems. These workshops will be rescheduled within the contract period.

Participants who completed this workshop should be able to:

- Perform a simulation run on a sample intersection problem
- Set up a traffic-actuated signal controller for the sample intersection
- Integrate the controller into the simulation loop
- Define more complex problems for analysis

The PowerPoint presentation material and workshop notes will be posted on the HILS web site

### 1.2.4 Development of Tools

Two software tools have been developed to support the workshop presentations and the assimilation of the CID technology by personnel throughout the state:

- The Hardware in the Loop Component Integrator (HILSCI), a tool that facilitates the creation of data sets and simplifies the transfer of data between the various system components. This tool is described in detail in Section 3 of this report.
- A Script Utility (STScript) that introduces the ability to program the suitcase tester feature of the CID to perform a series of controller tests by manipulating the input functions over time and monitoring the output functions to compare their status with the response that would be expected from a properly functioning controller. This tool is described in detail in Section 4 of this report.

## 2 HILS CONCEPTS AND DEPLOYMENT

Hardware in the loop simulation has been employed for several years, largely in military and industrial applications requiring the design and deployment of large and complex systems. The importance of simulation of such systems prior to deployment has been well recognized. The limitations of emulating the control elements of these systems have also been noted. Several companies focusing primarily on military and industrial HILS applications have emerged. Examples of such applications include vehicle control systems, anti-lock braking, missile defense systems, flight simulators and unmanned aerial vehicles. The following definition of HILS was offered by Gomez on one of the web sites devoted to the topic [1].

*A HILS is a device that fools your embedded system into thinking that it's operating with real-world inputs and outputs, in real-time.*

Traffic control simulation is an ideal application for HILS. The importance of traffic simulation as a problem solving tool has been well recognized, and the limits of software emulation of traffic signal controllers have also become apparent.

### 2.1 Current HILS Development Status

The first known HILS device for traffic was developed in 1977 at the University of Florida using a CompuColor 8051 microcomputer [2] connected through a serial port and a hardware interface to a NEMA TS-1 controller. A graphics display was driven by a primitive intersection simulator that exchanged detector presence and display status information with the controller. This system was used as an instructional tool and as a demonstration of the current state of the art in traffic control. The system toured the country as a part of an FHWA display of advanced technology. Apart from that, it served no real useful purpose, other than to stimulate thinking in this field.

The development of powerful traffic control simulation tools laid the groundwork for the HILS systems that are now available. Most of the development work was done within the academic community. Some of the main contributors to this technology have been Urbanik and Engelbrecht at Texas A&M, Bullock at LSU and later at Purdue, and Kyte at the University of Idaho.

There are four components involved in a HILS system:

1. A traffic simulation software product;
2. A traffic-actuated controller;
3. A hardware interface that connects the controller to the computer system;
4. A run-time software package that exchanges information between the controller and the simulation logic.

One of the byproducts of HILS is a controller testing feature derived from the connection between the controller and the computer (item 3 above). Some of the existing hardware interfaces were developed with controller testing in mind, with the HILS features added later. Because of the usefulness of the controller testing features, this report will cover the broader field of computer-controller connections and not just the HILS component.

There are several alternatives available for each of the HILS components. The commercially available alternatives for each component are summarized as follows:

The following simulation software products include HILS features that have been used in the USA:

- **CORSIM:** A well documented run time extension package has been developed for CORSIM and is available as a part of the CORSIM distribution [3].
- **VISSIM:** Run time extension features for this package have been incorporated by the developer
- **SimTraffic:** Run time extension features for this package have been incorporated by the developer in a special version called SimTraffic CI

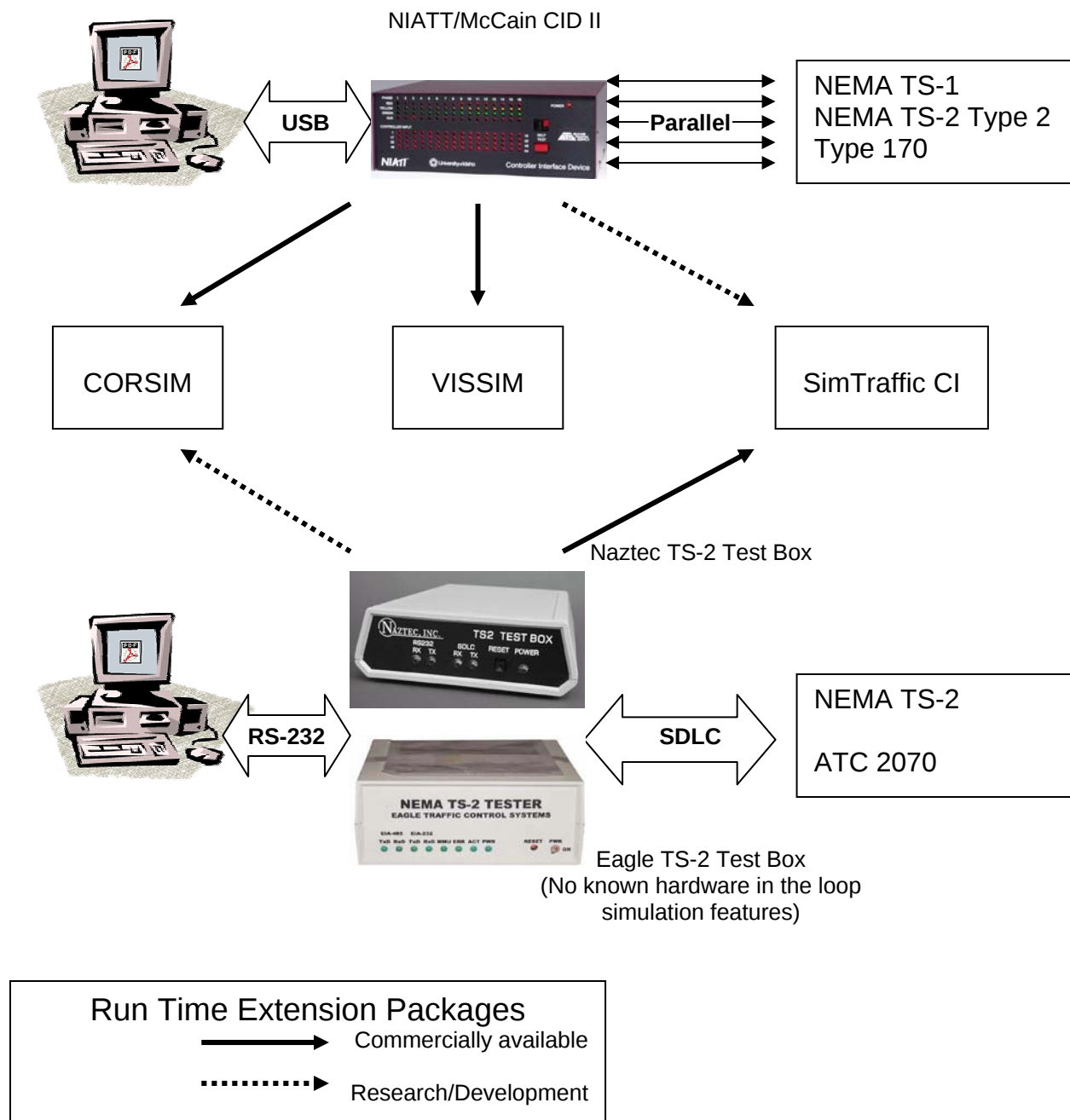
Traffic-actuated controllers are manufactured by several firms. Each controller conforms to one of the following standards:

- **NEMA TS-1:** An earlier standard that is still in widespread use. Individual control and display functions are accessed by multi-pin connectors, with one specific pin assigned to each function
- **Type 170:** Similar for our purposes to NEMA TS-1, except that a different connector arrangement is used for the input and output functions
- **NEMA TS-2, Type 1:** This standard handles the input and output functions with Synchronous Data Link Control (SDLC) technology. Compatible terminal equipment is required to handle the detector and display commands.
- **NEMA TS-2, Type 2:** Connectors are provided for both TS-1 and TS-2 operation. This standard was developed to ease the transition between TS-1 and TS-2
- **ATC-2070:** A more advance version of the Type 170 controller developed for complex ITS applications. Some units provide both SDLC and parallel input/output accommodations.

The following controller interface hardware is commercially available in the USA.

- **NIATT Controller Interface Device:** This unit was developed at the University of Idaho as an extension of some of the academic work mentioned earlier. It is manufactured and distributed by McCain Traffic Supply. This unit works only with controllers with parallel input/output connections
- **Naztec TS-2 Test Box:** Developed originally as a controller tester, this unit connects to NEMA TS-2, Type 1 controllers. Some commercially available connectivity with simulation models has been developed.
- **Eagle TS-2 Test Box:** Also developed originally as a controller tester, this unit connects to NEMA TS-2, Type 1 controllers. At this time, no known commercially available connectivity exists with simulation models.

Figure 2-1 illustrates how all of the various components fit together into HILS systems. This figure includes only those simulation models traffic controllers and interface devices that are commercially available in the USA. The run time packages for information exchange between the controller and simulation logic are represented at two levels: those that are commercially available and those that are known to exist, but are not yet on the market.



**Figure 2-1. Controller interface hardware availability and compatibility with simulation programs**

In addition to the capabilities shown in Figure 2-1, other institutions have developed their own in-house HILS facilities, usually for more advanced applications. The Texas Transportation Institute (TTI) and Purdue University are examples of such institutions.

## 2.2 HILS Deployment Experience

HILS actually accomplishes two things simultaneously. It provides a realistic control environment for the simulator and it provides a realistic field environment for the controller without leaving the office or signal shop. The former is of most use to researchers and traffic engineers and the latter is of most use in the signal shop for testing and training purposes.

In spite of its potential, HILS has not yet been applied extensively to traffic simulation. There are five reasons why this is true:

1. The technology itself is relatively new and many potential users are not aware of (or perhaps not convinced of) its potential usefulness.
2. The controller emulation features of most simulation models are fairly realistic, and most applications, especially those involving routine design and analysis tasks can be carried out without the added complexity of HILS.
3. HILS must be applied in real time as opposed to embedded control emulation, which runs at full computer speed.
4. The technology itself is somewhat complicated to learn and use.
5. The wide range of available traffic control equipment would require some agencies to have multiple HILS systems to cover all of their equipment.

Having said that, it is important to note there have been several worthwhile applications that have demonstrated the ability of HILS to extend traffic simulation beyond its present horizons. Some recent examples include:

- *Evaluation of Diamond Interchanges:* Diamond interchange controller emulation is somewhat limited, especially in CORSIM, which requires both intersections in the interchange to be controlled by individual controllers. Some of the more advanced strategies for diamond interchange control involve a single traffic actuated controller that covers all of the approaches. One recent example of research on this subject was carried out by Engelbrecht and Barnes [4]. The research evaluated advanced features available in the traffic signal controllers currently used for diamond interchange control in Texas. Eight potentially useful controller features were identified. The effectiveness of these features was evaluated with hardware-in-the-loop traffic simulation.

Another study demonstrated that hardware-in-the-loop simulation can improve the accuracy of traffic operations analysis by removing the inherent differences between emulated controllers and the actual hardware [5]. In that study, a controller enhancement called conditional service was considered for implementation at an actuated diamond interchange. An evaluation of the traffic operations at the diamond interchange was completed using PASSER III-98, CORSIM, and hardware-in-the-loop simulation.

- *Development of advanced adaptive traffic control strategies and migration of adaptive control logic from software to field hardware.* All new traffic control strategies start out as ideas and progress through software emulation into the hardware stage. HILS features can be very effective, especially in the migration stage because of the need to test the

hardware under simulated conditions before field deployment. In Reference 6, the RHODES (real-time hierarchical optimized distributed effective system) real-time traffic-adaptive control system was followed as it progressed from a laboratory project toward the field. HILS played a role in the algorithm development and migration stage.

- *Investigation of emergency vehicle preemption and transit priority:* Traffic simulation models do not emulate the full capabilities of the traffic control equipment for preemption and transit priority. One study analyzed the impact of emergency vehicle traffic signal preemption across three coordinated intersections on a route near Landsdowne, Virginia [7]. Controller Interface Devices were used to link CORSIM with Type 170 controllers programmed with the identical signal plans to those existing in the field with minor modifications to allow signal preemption. Results showed that for the geometric and operational conditions studied, the impact of emergency signal preemption on the signal coordination of the corridor was minor.

Another study dealt with intelligent bus priority strategies [8]. The concept used bus position information to predict when in the cycle a bus would arrive at the bus stop and stop line of a signalized intersection and to determine whether a bus needs priority. Priority was provided by using phase extension, phase insertion, and early return strategies without causing the controller to drop from coordination. Implementation of the strategies was accomplished through normal traffic-signal controller commands. Hardware-in-the-loop simulation studies were performed to evaluate the effectiveness of the concept with real traffic-signal controllers.

- *Development of procedures and guidelines for traffic control system implementation:* HILS has also been used to develop implementation procedures and guidelines because of its realistic representation of the traffic control. One such manual provides a step-by-step procedure for designing the parameters, implementing, testing, and field tuning closed loop systems [9]. The procedure is described for an example closed loop system consisting of five intersections in West Lafayette, Indiana. The testing procedure described in this manual is a hardware-in-the-loop simulation, which uses a controller interface device in conjunction with CORSIM software.
- *Investigation offset transition strategies:* In one such study [10], a traffic signal offset transition algorithm was introduced that can be viewed as an integrated optimization approach designed to work with traditional coordinated-actuated systems. The algorithm was implemented in a hardware-in-the-loop simulation and evaluated with a set of National Transportation Communications for Intelligent Transportation Systems Protocol (NTCIP) National Electrical Manufacturers Association controllers.
- *Major project development:* Because of the significant costs associated with major traffic control system projects, it is often desirable to carry out a full simulation of the proposed improvements before committing to a final design and implementation. If the proposed improvements involve traffic control features beyond the emulation capability of the simulation model, then HILS will probably be required. A good example of a major

project evaluation in Florida may be seen in the area of downtown West Palm Beach, involving the following elements:

- o Two railroads;
    - o Two drawbridges;
    - o Two FDOT roadway projects converting US1 from two one way streets into 2 two-way streets with traffic calming features;
    - o County sewer upgrade projects and
    - o Replacement of Royal Park Bridge connecting Palm Beach to West Palm Beach
- The project staff programmed 10 intersections in a very congested downtown grid with HILS, using Naztec TS-2 test boxes interfaced to SimTraffic CI. The main role of this HILS deployment was to test post pre-emption settings to improve progression
- Pre deployment acceptance testing of advanced traffic control systems: Adaptive systems are said to offer generally superior performance compared to time of day systems, but their complexity and lack of field experience causes concern to some agencies. A successful pre deployment test using HILS technology can be useful in alleviating those concerns. A good example of a recent pre-deployment test was the factory acceptance test (FAT) of a new Naztec system developed for Cupertino, California [11]. The objective of the FAT was to test the response of the local controller and central office software developed for adaptive control using a test bed of 5 controllers that define the critical intersections for the DeAnza Blvd. CORSIM was selected as the simulation model for this project because it models the detector types and locations installed for the project.
- This system was modeled using two master groups using the Naztec SDLC based Test Box interfaced with CORSIM. The run-time extension link to CORSIM was developed by Engelbrecht at the Texas Transportation Institute. Because this package is not available commercially, the link to CORSIM is referenced in Figure 2-1 as a “Research and Development” level run time extension package.
- Several runs were performed under various volume and time of day conditions. Animated graphics outputs were obtained for each run to produce visual comparisons between the existing and proposed operation. This level of testing at the pre-deployment stage helped to give the project staff the confidence required to proceed with the full deployment.
- Education and training: Training of operations and maintenance personnel has always posed a problem for traffic control system managers. Technicians who deal with controllers in the field must be properly trained in their operation, but that training must generally take place in the office. The realistic field environment created for the controller in the office by HILS offers an important new training opportunity for new personnel. The tools that were developed under this project are oriented heavily towards training.

### **3 HARDWARE IN THE LOOP COMPONENT INTEGRATION**

This section describes the integration of the various HILS components and explains the operation of the Hardware in the Loop Component Integrator (HILSCI) program. The components to be integrated were described Section 2 as follows:

1. A traffic simulation software product;
2. A traffic-actuated controller;
3. A hardware interface that connects the controller to the computer system;
4. A run-time software package that exchanges information between the controller and the simulation logic.

The component integrator described in this section is compatible with the CORSIM simulation program and the McCain controller interface device.

#### **3.1 HILSCI OVERVIEW**

A simplified overview of the hardware in the loop concept is shown here. The simulation model, running in real time, communicates with the CID using an industry standard interface. For each second of operation, the simulation model tells the CID what detectors are occupied and asks for the state of each signal phase (red, yellow or green). The CID is connected to a standard traffic-actuated signal controller by the same cables that would normally connect the controller to the detectors and signal displays in the field. The CID passes the detector status from the simulation software to the controller hardware. It also passes the signal display status from the controller hardware to the simulation software. By this method, the CID is able to connect the abstract process of simulation to the real-world process of traffic control.

The CID accommodates a variety of microscopic traffic simulation programs. This document will focus on CORSIM, a publicly developed and maintained software product.

HILSIM studies require detailed operational knowledge of both the simulation model and the controller. A user must be able to create a simulation network in CORSIM and edit the input data to supply the approach configurations, traffic volumes and signal timing parameters. While this is not an onerous task, it does require proper training in the use of CORSIM.

Many of those with adequate CORSIM skills will lack the training required to operate a signal controller. The problem is compounded by the fact that each controller model tends to differ from other models in the way that the controller settings are entered and changed. HILSCI is a software product that attempts to minimize the need for specialized training in CORSIM or controller operations.

The components of HILSCI are presented in Figure 3-1, which also shows the flow of data between the components. Note that HILSCI passes information to CORSIM, the CID and the Controller itself.

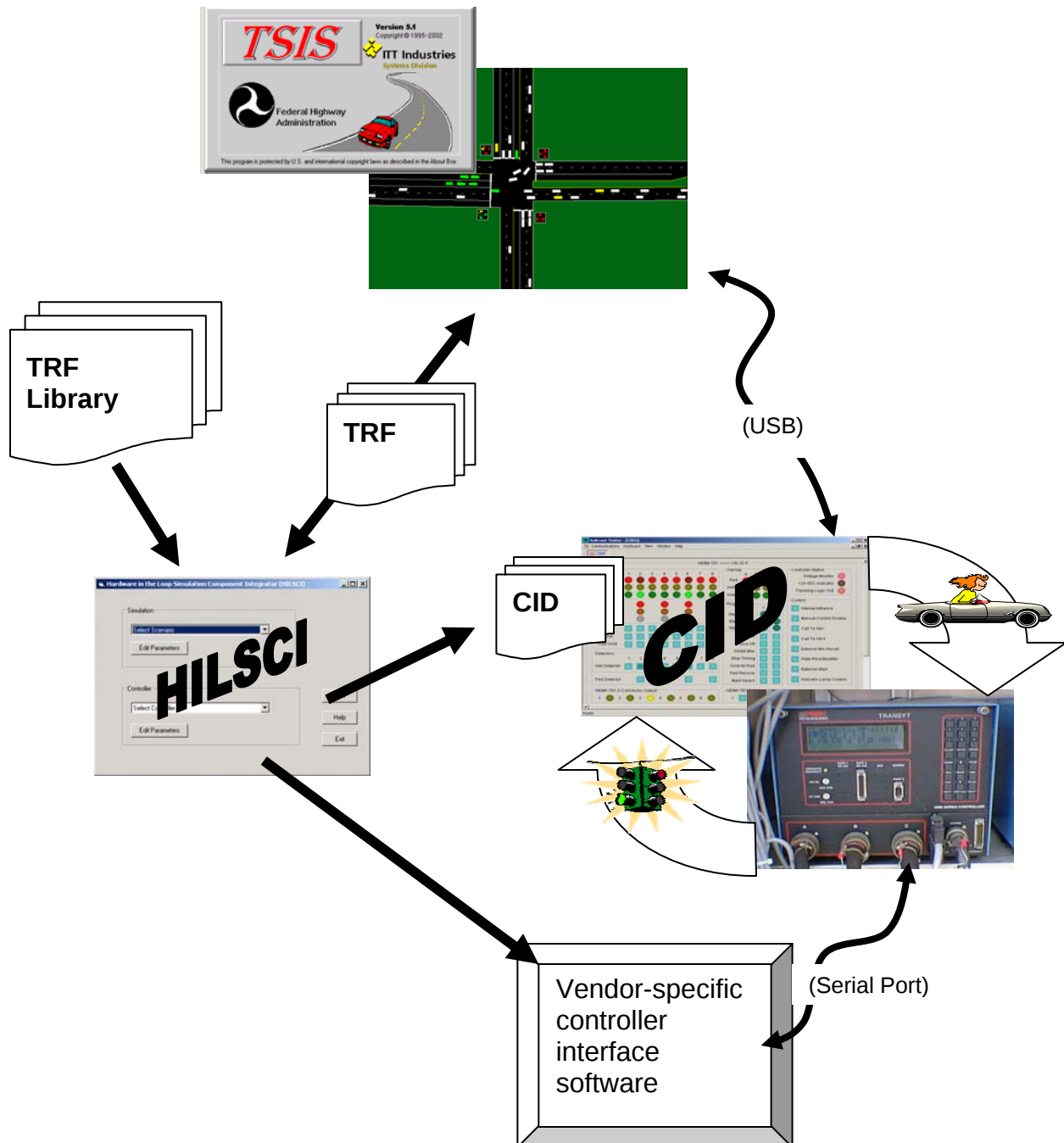


Figure 3-1. HILSCI components and data flow

The HILSCI functions include:

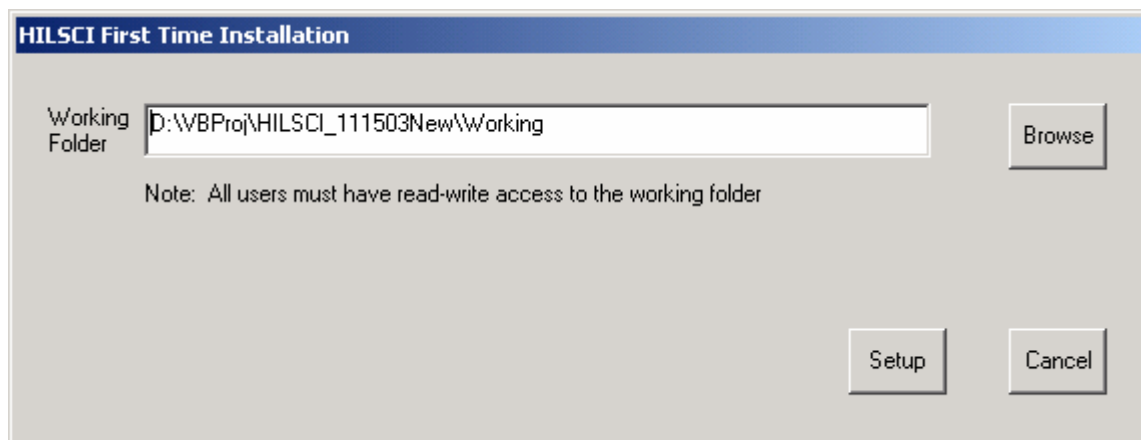
- Loading a CORSIM data file in TRF format
- Identifying the intersections in the file that are operating under traffic actuated control
- Selecting an intersection for hardware in the loop control from a list of the available intersections
- Modifying the CORSIM file to establish hardware in the loop control at the selected intersection
- Generating the configuration file for the CID
- Executing CORSIM
- Executing Vendor supplied software that edits the operating parameters of the controller

While several intersections can be placed under hardware in the loop control simultaneously, the HILSCI program is limited in scope to a single intersection. HILSCI is intended to provide a simplified method of establishing hardware in the loop control with minimum effort. Multiple intersection studies introduce complexities that generally are not amenable to HILSCI-type simplification.

As an example of HILSCI's simplifying features a preset library of 36 intersections with varying configurations is accessible from the HILSCI menu. This feature permits editing of the traffic volumes on each approach to create simulation data with little or no knowledge of CORSIM.

## 3.2 PROGRAM INSTALLATION

HILSCI is installed in the same manner as other windows programs (i.e., by running the Setup.exe program on the distribution disk. The first time the program is run, you will see the following screen that completes the program installation process.



HILSCI requires the designation of a “working folder” for storing parameter files and other temporary information. The default location for the working folder is a “Working” subfolder within the program folder. You may specify any other folder using the “Browse” button.

It is important that all users have read and write access privileges to the working folder. The newer Windows versions contain security features that allow a system administrator to restrict the access of some users to certain parts of the system. If you are not sure about your access privileges, you should consult your system administrator.

When you have selected the working folder, click the “Setup” button and the installation will be complete. You will not see this screen again on future runs. If you need to reinstall the program at some point in the future, you must delete a file called “HILSCI.ini” in the program folder. This will cause the first time installation screen to be displayed the next time that HILSCI is executed.

HILSCI may be run as a stand-alone program or it may be integrated into the TSIS menu as a TSIS tool.

Before the main menu screen is displayed on a first time installation you will be presented with the File Location Screen

### 3.3 THE FILE LOCATION SCREEN

This screen is also displayed when you run HILSCI for the first time. On subsequent runs, it is accessed from the drop-down “Edit” menu on the initial menu screen.

The screenshot shows a Windows-style dialog box titled "HilSci File and Folder Locations". It contains several input fields and buttons for configuring file locations. At the top, there is a "TSIS Program" field with the text "Not Specified" and a "Find" button. Below this is a section titled "Data Folders" which contains two sub-sections. The first sub-section has "TRF Files" and "Controller Settings" fields, both with "Not Specified" text and "Find" buttons. The second sub-section is titled "Controller Settings" and contains a table with four rows. Each row has a "Controller" field (empty) and a "Controller Settings Program Name" field (with "Not Specified" text) and a "Find" button. At the bottom of the dialog, there are four buttons: "Restore From", "Save To", "OK", and "Cancel".

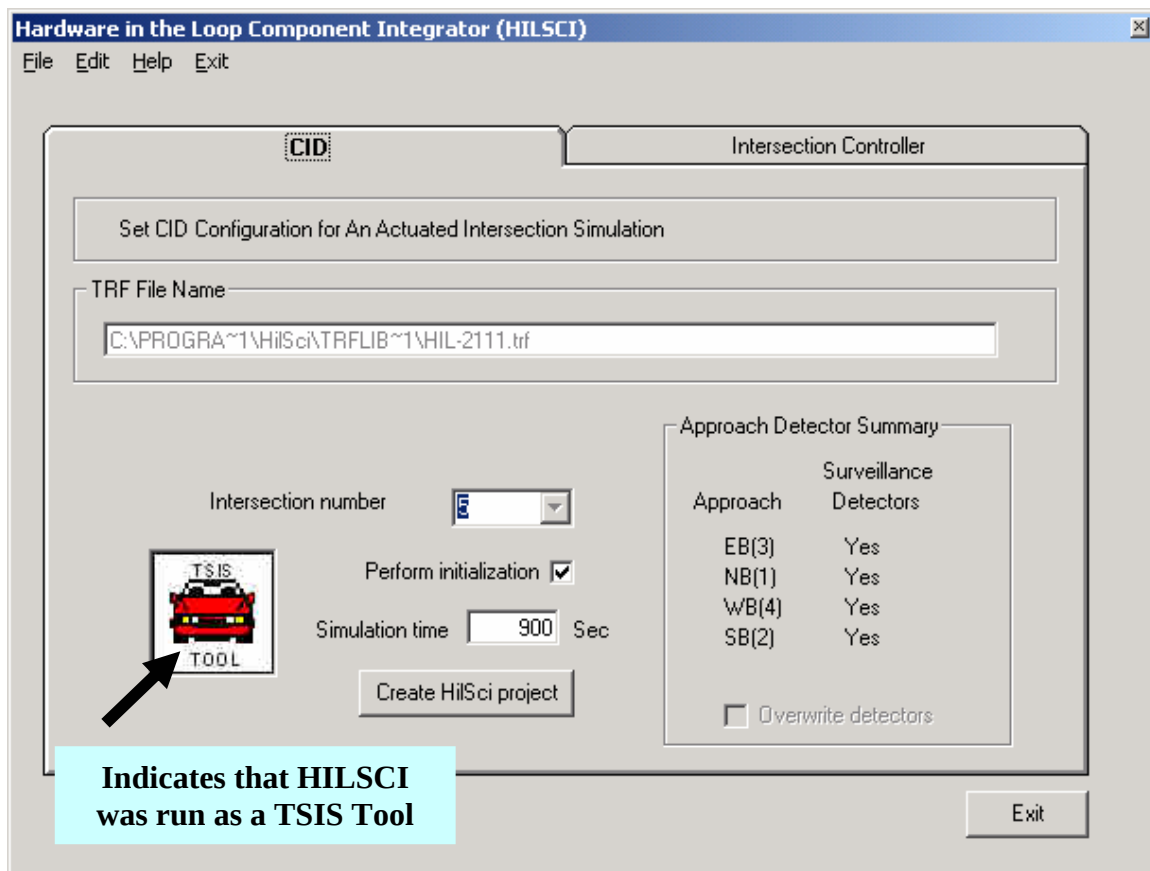
| Controller | Controller Settings Program Name |
|------------|----------------------------------|
|            | Not Specified                    |
|            | Not Specified                    |
|            | Not Specified                    |
|            | Not Specified                    |

There are three file and folder locations that must be specified.

- The full path for TSIS. The HILSCI Installation routine will find this path for you if TSIS has been installed in its own default folder. Otherwise you'll have to browse for it yourself
- The folder for TRF files to be passed to TSIS
- The folder for controller setting files to be passed to the vendor-supplied programs.

### 3.4 PROGRAM OPERATION

When the program is run after the initial installation, the main screen will be displayed as shown below:



**HILSCI Main Screen**

If HILSCI has been installed as a TSIS Tool (See the discussion later for this option), the “TSIS Tool” icon will be displayed.

Note that there are two tab controls at the top of the screen. Only the left tab (CID) is currently operational. The right tab (Intersection Controller) is included as a provision for future expansion.

The drop-down menu includes four items

**File**: which allows you to open an existing TRF file that has been developed externally or to select a TRF file from the library that is included on the installation disk.

**Edit**: which displays the file location screen for editing

**Help**: which displays this document and

**Exit**: which terminates the program.

When you load a file by either opening an existing file or selecting one from the TRF library, the following sequence of events takes place:

1. The specified TRF file is loaded.
2. The data are searched for intersections with traffic-actuated control. If no actuated controllers are found, an error message is displayed. If multiple actuated controllers are found, a drop down list is created to let you select the intersection that you want. CORSIM supports multiple CID units in a network, but HILSCI only lets you specify one intersection for real time control. If you want to run a simulation with multiple CIDs and controllers, you will have to use the full CID configuration program. If only one actuated controller is found in the data, its number is displayed on the screen and the drop-down list is disabled.

When an intersection has been selected, the data are searched again for approaches that supply traffic to this intersection. Each approach is then examined to determine if the surveillance detectors required for CID operation have been specified. The results of this search are displayed in the “Approach Detector Summary” box on the screen.

You are now ready to specify some of the parameters of the CORSIM run that you are about to make.

- **Perform Initialization**: If you don't check this box, no initialization will be performed in the simulation. Without initialization you will be able to view the operation about three minutes earlier, but the numerical simulation results will not be accurate. So if you only want to view the operation you can skip the initialization.
- **Simulation Time**: Specifies the number of seconds to simulate. The time already specified in the TRF file will be displayed here.
- **Overwrite detectors**: Determines whether the surveillance detectors that already exist in the TRF file should be overwritten if some of the detectors are missing. This check box

is disabled if no surveillance detectors have been specified or if all detectors have been specified.

- **Create HILSCI Project:** Click this button to create the required TSIS Project file, a TRF file modified for CID operation at the selected intersection and a CID configuration file with the information required by the CID unit. When these operations have been completed, control will be passed to TSIS and you can begin running the simulation

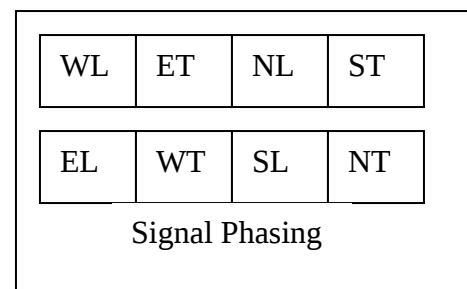
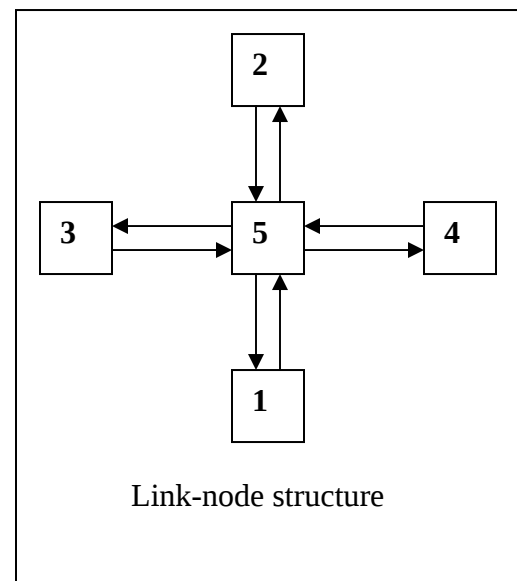
### 3.5 THE HILSCI TRF LIBRARY

The HILSCI TRF Library (TRFLib) consists of 36 single-intersection CORSIM (TRF) data sets with a wide range of characteristics. The TRFLib structure observes the following hierarchy as summarized in Table 3-1:

- Six Basic Layouts
  1. 2EW – 1 NS
  2. 2EW – 2NS
  3. 3EW – 2NS
  4. 3EW – 3NS
  5. 4 EW – 2 NS
  6. 4 EW – 3 NS
- Each basic layout has two configuration choices, the details of which will vary among different configurations
- Each of the configuration choices has three operational choices

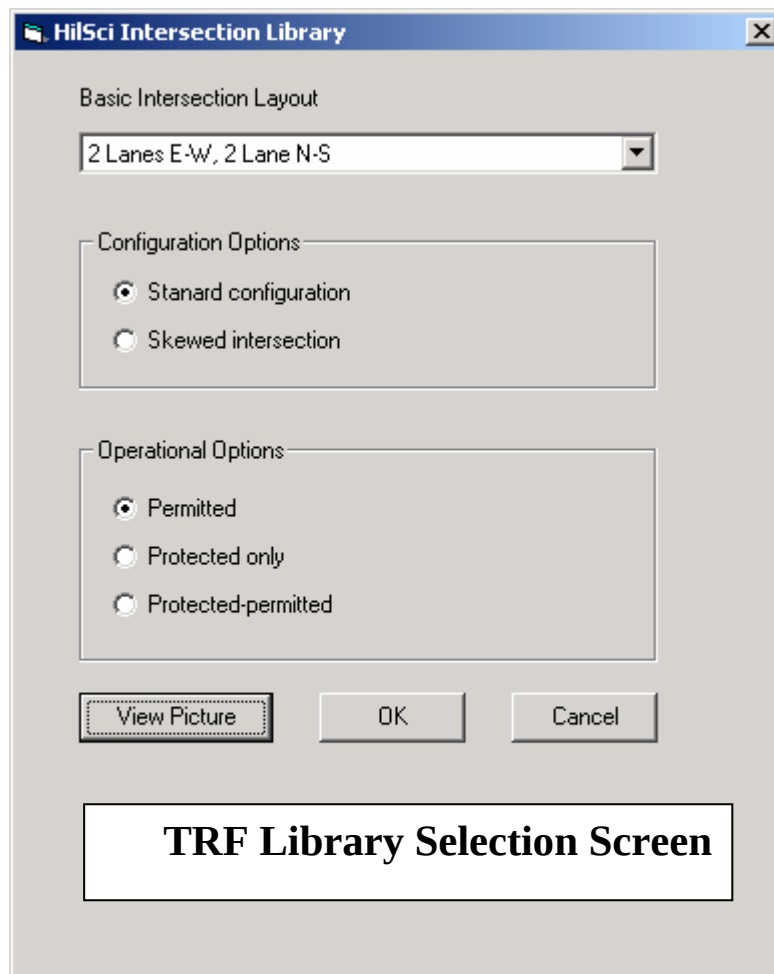
#### Rules for Setting Data Values

- Bays are additional to the indicated number of lanes
- All links are 500 ft long
- All bays are 200 Ft long
- All detectors are 30 ft long with no setback
- Minimum greens:
  - o 15 sec for thru phases
  - o 10 sec for LT phases
- Maximum greens
  - o 30 sec for thru phases
  - o 20 sec for LT phases
- Unit extensions:
  - o 3 sec for single lane approaches
  - o 2.5 sec for 2 lane approaches
  - o 2.0 sec for 3+ lane approaches
- Intergreen: All 4 sec Yellow, 1 sec All Red
- No recall, detector delay or carryover settings for any phase



- No coordination functions
- Traffic Volumes: (2% trucks for all movements)
  - o 50 vph for shared lane permitted turns
  - o 100 vph for exclusive lane permitted turns
  - o 200 vph per lane for protected turns
  - o 400 vph per lane for thru movements
- **Standard Conditions:** Unless otherwise noted, all approaches with more than one thru lane have one left turn bay and no right turn bays. Left turns are leading protected-permitted.

The screen for selecting a TRF file from the library is shown here:

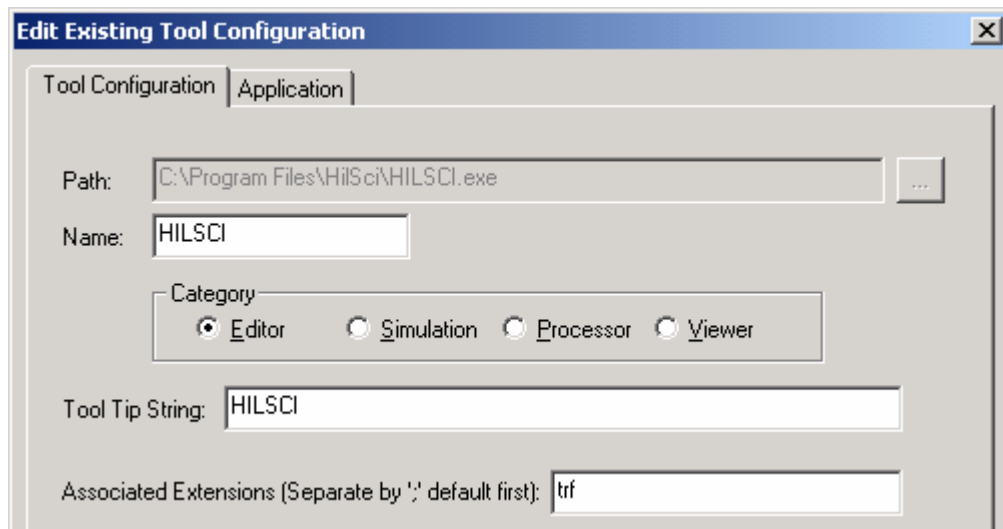


The basic layout, configuration options and operational options are selected from this screen. The *View Picture* button will display a captured TRAFVU image of the intersection layout. The *OK* button will select the file and display a screen that contains the turning volumes for each approach. You may edit these volumes to approximate field conditions. All other parameters are fixed and must be edited with one of the TSIS editors.

### 3.6 INSTALLING HILSCI AS A TSIS TOOL

You may install HILSCI as a TSIS tool by following the directions for creating TSIS tools in the TSIS User Guide. The TSIS tool configuration screen is shown below.

The path name for the executable file must be selected by browsing for the file *HILSCI.EXE*. The associated file name extension should be TRF. You will also be asked to select your choice for an icon from the list of icons supplied with TSIS

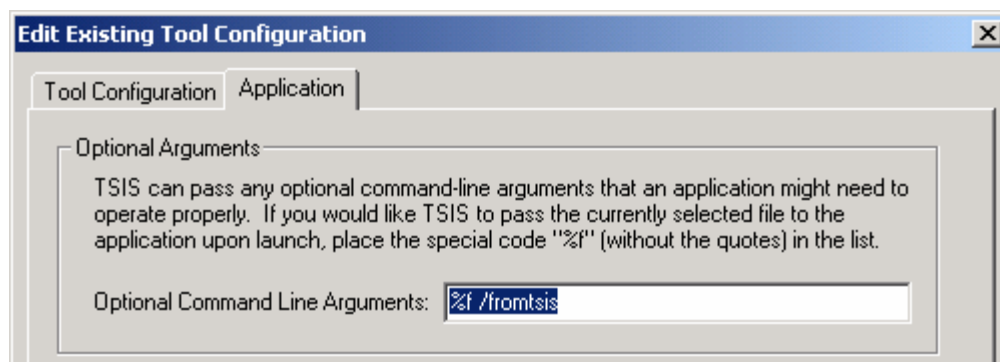


The TSIS tool application screen is shown below. The optional command line arguments should be:

“%f” to pass the name of the selected TSIS file to HILSCI and

“/fromtsis” to tell HILSCI that it is being run as a TSIS tool.

The command line arguments must be separated by one space.



**Table 3-1: TRF Library File Summary**

**Basic Layout: 2 EW – 1 NS**

**Configuration 1: No LT bays**

- HIL-2111:** All shared lane permitted
- HIL-2112:** Exclusive lane permitted on E-W
- HIL-2113:** Split phase N-S

**Configuration 2: LT bays on all approaches**

- HIL-2121:** Protected EW, permitted N-S
- HIL-2122:** Protected EW, protected N-S
- HIL-2123:** Protected EW, split phase N-S

**Basic Layout: 2 EW – 2 NS**

**Configuration 1: Stanard configuration**

- HIL-2211:** Permitted
- HIL-2212:** Protected only
- HIL-2213:** Protected-permitted

**Configuration 2: Skewed intersection**

- HIL-2221:** Permitted
- HIL-2222:** Protected only
- HIL-2223:** Protected-permitted

**Basic Layout: 3 EW – 2 NS**

**Configuration 1: Standard configuration**

- HIL-3211:** All protected LTs
- HIL-3212:** Protected E-W,S
- HIL-3213:** Protected E-W, perm-prot S

**Configuration 2: T intersection NB**

- HIL-3221:** Leading LT protection WB
- HIL-3222:** Lagging LT protection WB
- HIL-3223:** No LT protection

**Basic Layout: 3 EW – 3 NS**

**Configuration 1: Standard configuration**

- HIL-3311:** Leading lefts
- HIL-3312:** Lagging lefts
- HIL-3313:** Lead-lag

**Configuration 2: All with LT bays + RT bays**

- HIL-3321:** Protected only
- HIL-3322:** Protected-permitted
- HIL-3323:** Protected only with RT overlap

**Basic Layout: 4 EW – 2 NS**

**Configuration 1: Standard configuration**

- HIL-4211:** Standard lane use
- HIL-4212:** Double LT bays E-W
- HIL-4213:** LT Bay + trap lane E-W

**Configuration 2: One-way street NB**

- HIL-4221:** Single LT bay EB
- HIL-4222:** Single LT bay + optional lane EB
- HIL-4223:** Double LT bays EB

**Basic Layout 4: EB – 3 NB**

**Configuration 1: E-W triple LT treatments**

- HIL-4311:** Double LT bays + optional TH/LT lane E-W
- HIL-4312:** Double LT bays + LT trap lane E-W
- HIL-4313:** Triple LT bays E-W

**Configuration 2: E-W RT bay treatments**

- HIL-4321:** Single RT bay E-W
- HIL-4322:** RT bay + optional TH/RT lane E-W
- HIL-4323:** Double RT bays E-W with LT overlap

## 4 THE SUITCASE TESTER SCRIPT UTILITY (STScript)

Traffic signal maintenance personnel have traditionally used a “suitcase tester” to test and evaluate the operation of a traffic controller before it is placed in the field. A suitcase tester is a suitcase-like box containing switches that, when linked to a traffic controller, can activate functions on the controller and monitor outputs from the controller. A suitcase tester can provide a controlled environment for verifying that the controller behaves as expected when individual functions are programmed.

This section describes the STScript Suitcase Tester Script Utility, an extension of the HILS concept that introduces the ability to program the suitcase tester to perform a series of controller tests by manipulating the input functions over time and monitoring the output functions to compare their status with the response that would be expected from a properly functioning controller. STScript was developed to work with the McCain controller interface device. It is not compatible with any other products at this time.

### 4.1 STScript OVERVIEW

The *CID Suitcase Tester Emulator* application is one of the applications in the *CID Software Suite*. It provides a convenient way to fully test the most widely used functions of NEMA or Type 170 traffic controllers. The application can test up to 99 controllers at a time, through CIDs connected to the USB port with USB hubs. One CID must be connected to each traffic controller that is being tested.

The controller I/O is arranged in groups of single bit binary functions, with each bit representing the status of an input such as detector presence, or an output such as the condition (on or off) of a specific signal lamp. Most of the input and output functions of a signal controller can be transferred through the CID.

The data flow for a controller being tested with STScript is shown in Figure 4-1. The STScript program performs the following functions:

1. Reads the test instructions from a script that has been prepared for the desired test plan
2. Converts the instructions in the script to a series of input function commands that are understood by the CID. Each command contains an instruction to turn one input function on or off.
3. Interrogates the CID once per second to learn the status of all of the controller output functions.
4. Writes an entry to the monitor log each second to give the status of all inputs and outputs.

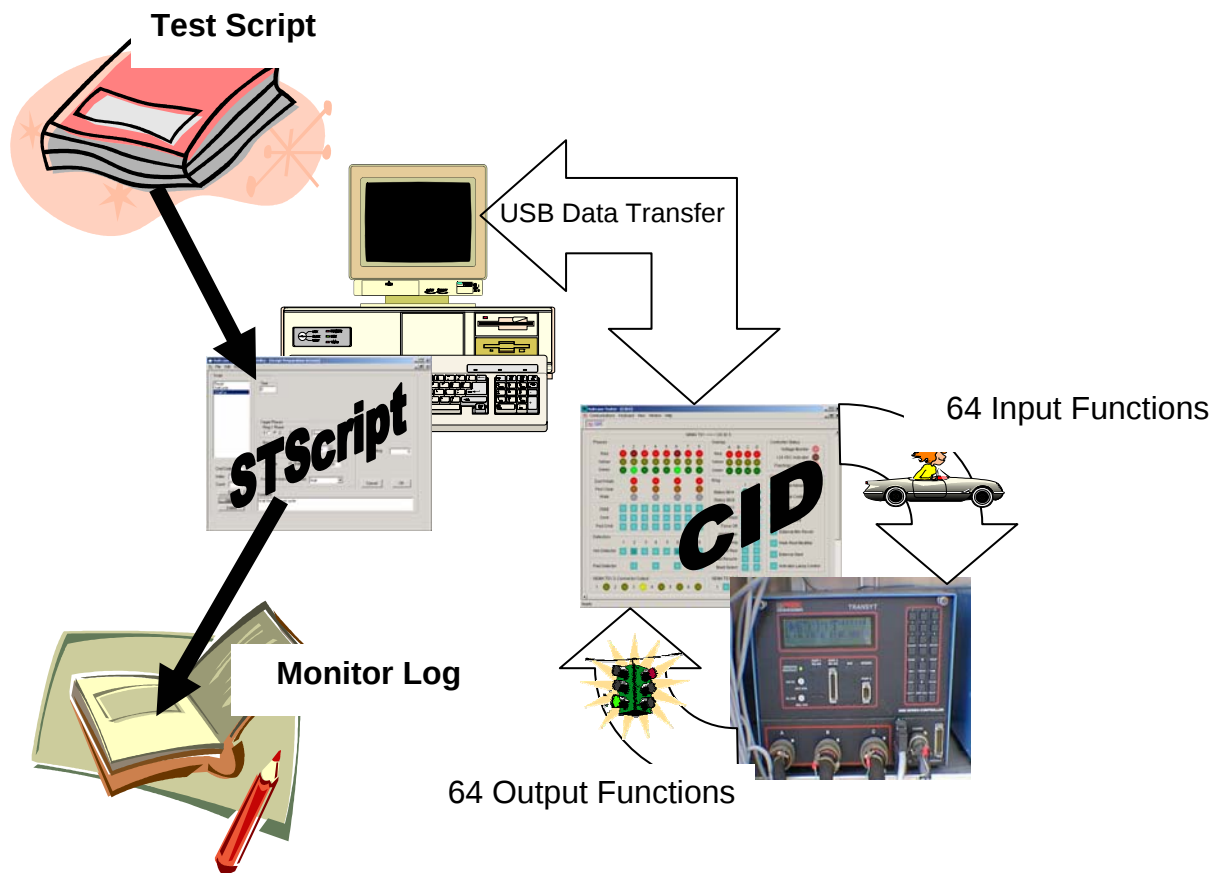
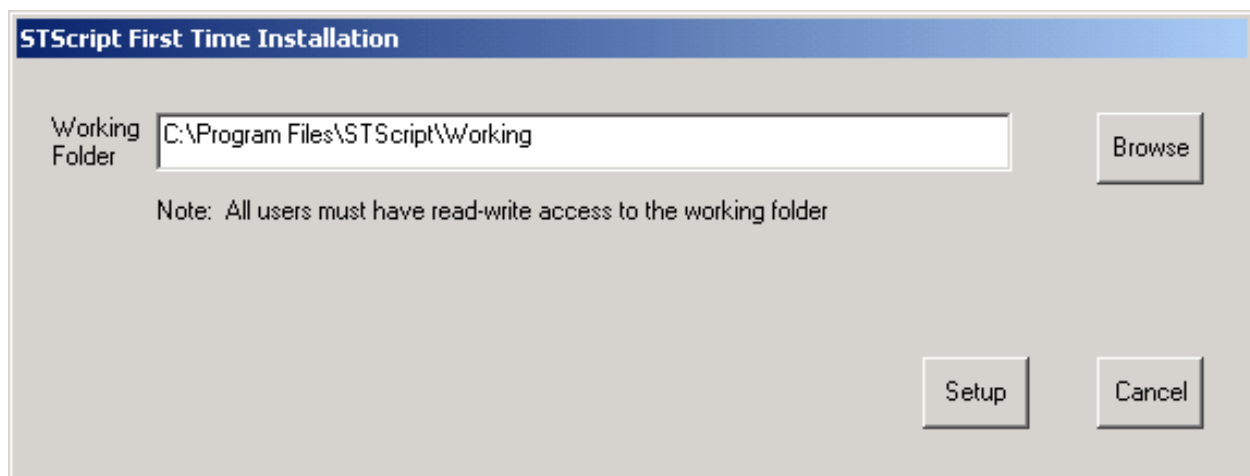


Figure 4-1. STScript Data Flow

## 4.2 PROGRAM INSTALLATION

STScript is installed in the same manner as other windows programs (i.e., by running the Setup.exe program on the distribution disk. The first time the program is run, you will see the following screen that completes the program installation process.



STScript requires the designation of a “working folder” for storing parameter files and other temporary information. The default location for the working folder is a “Working” subfolder within the program folder. You may specify any other folder using the “Browse” button.

It is important that all users have read and write access privileges to the working folder. The newer Windows versions contain security features that allow a system administrator to restrict the access of some users to certain parts of the system. If you are not sure about your access privileges, you should consult your system administrator.

When you have selected the working folder, click the “Setup” button and the installation will be complete. You will not see this screen again on future runs. If you need to reinstall the program at some point in the future, you must delete a file called “STScript.ini” in the program folder. This will cause the first time installation screen to be displayed the next time that STScript is executed.

STScript may be run as a stand-alone program or it may be integrated into the menu of the CID software suite. If you want to run STScript as a CID tool, you must follow the installation instructions for the CID program.

Before the main menu screen is displayed on a first time installation you will be presented with the File Location Screen

### 4.3 THE FILE LOCATION SCREEN

This screen is also displayed when you run STScript for the first time. On subsequent runs, it is accessed from the drop-down “Edit” menu on the initial menu screen.

The screenshot shows a dialog box titled "File and Folder Locations". It has a blue header bar. Below the header, there are four rows of text input fields, each with a "Browse" button to its right. The rows are: "Comparison Utility" with the text "Not Specified"; "Script Files" with the text "C:\Program Files\STScript\Working\"; "Reference Logs" with the text "C:\Program Files\STScript\Working\"; and "Test Logs" with the text "C:\Program Files\STScript\Working\". At the bottom of the dialog, there are five buttons: "Restore from ...", "Save to ...", "OK", "Cancel", and "Help".

There are four file and folder locations that must be specified. The comparison utility program compares the second by second status of the inputs and outputs between the reference and test files. The script files, reference logs and test logs are all loaded from and saved to their own dedicated folders, which must be selected here.

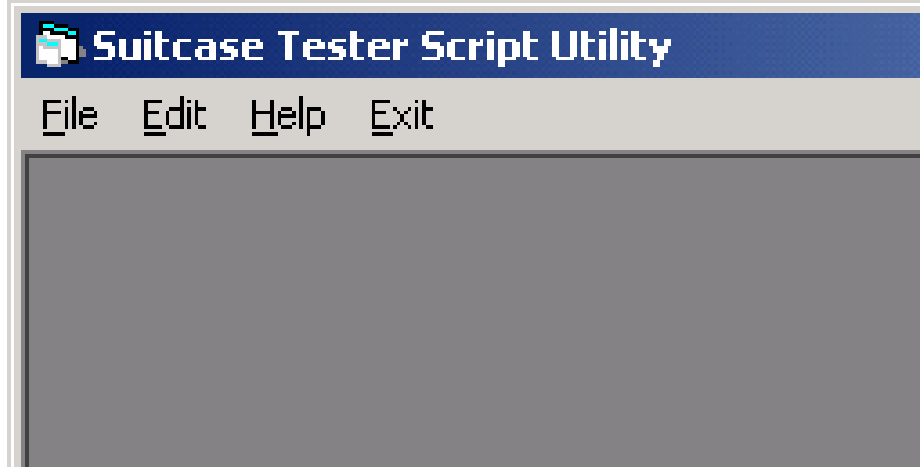
## 4.4 PROGRAM OPERATION

The main tasks of the STScript program are to create script files and to conduct controller tests using the script files. The scripts themselves are stored in a binary data base file. It is not necessary to learn the file format to create the script files, because the instructions and their parameters are created and edited using the type of dialog boxes with which you should already be familiar.

The following discussion assumes that you are generally familiar with the Windows environment and with the operation of eight-phase dual-ring traffic-actuated controllers. Each of the program features will now be explained:

### 4.4.1 The Initial menu

The initial menu will appear when the program is run and whenever you are not preparing or executing a script.



The initial menu commands include:

- File, which lets you open an existing script file, create a new one or compare the log files from two different runs
- Edit which lets you edit two types of information:
  1. The cycle plan specifications, which will be described later
  2. The specified locations for certain data folders and executable files used by the program
- Help, which displays this document
- Exit, which closes all files and terminates the program

#### 4.4.2 The Cycle Plan Specifications

The cycle plan specifications are very important to the operation of STScript. The cycle plan creates an underlying operation that keeps the controller cycling in a prescribed manner by supplying detector calls, coordination commands, etc. So we will examine the cycle plan specifications before we look at the script instructions themselves.

The Cycle Plan Specification Screen is accessed from the initial menu under the “Edit” command. When you choose this option the form shown in Figure 4-2 will be displayed. The detailed appearance of the screen will vary slightly depending on certain conditions that will be explained

The detector status information to be sent cyclically to the CID for each phase conforms to the scheme shown in Figure 4-3. There are only two parameters to specify for vehicle detection:

1. *The startup presence time*: which determines how long the detector will remain occupied following the beginning of green.
2. *The number of vehicles in the queue discharge interval*: The specified number of vehicles will be sent to the CID immediately after the startup presence time. The queue discharge pattern includes a series of two second gaps with 1 second presence time. Figure 4-3 shows three vehicles in the queue discharge interval.

Following the queue discharge interval, the gaps between successive vehicles will be increased by 1 second per vehicle. Depending on the controller settings, the phase will eventually be terminated by the allowable gap time or the maximum green time.

**Cycle Plan Specifications**

Plan # **4**

|         | Startup presence time | No. of vehicles in queue discharge interval | Ped Call                            | Coordination |           |
|---------|-----------------------|---------------------------------------------|-------------------------------------|--------------|-----------|
| Phase 1 | 6                     | 2                                           | <input type="checkbox"/>            | 85           | Force off |
| Phase 2 | 10                    | 3                                           | <input checked="" type="checkbox"/> |              |           |
| Phase 3 | 6                     | 2                                           | <input type="checkbox"/>            | 35           | Force off |
| Phase 4 | 10                    | 3                                           | <input checked="" type="checkbox"/> | 65           | Force off |
| Phase 5 | 6                     | 2                                           | <input type="checkbox"/>            | 85           | Force off |
| Phase 6 | 10                    | 3                                           | <input checked="" type="checkbox"/> |              |           |
| Phase 7 | 6                     | 2                                           | <input type="checkbox"/>            | 35           | Force off |
| Phase 8 | 10                    | 3                                           | <input checked="" type="checkbox"/> | 65           | Force off |

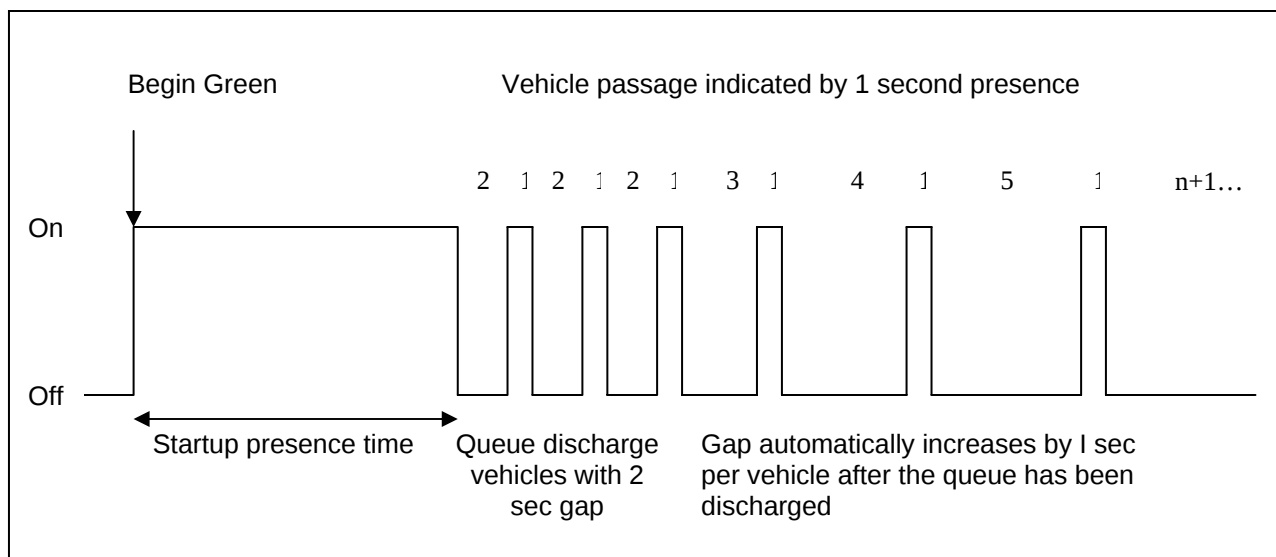
☒ Coordinated Operation Paste

Description:

Cycle Length  
 Yield Point

Cycle plans 0-4 are fixed Copy Cancel

**Figure 4-2. The Cycle Plan Specification Screen**



**Figure 4-3. Standard detector cycle for each phase**

The additional parameters required for the complete cycle specification include:

3. *Ped calls*: If this box is checked for a specific phase, a continuous pedestrian call will be transmitted to ensure that the pedestrian intervals are displayed.
4. *Coordinated operation*: If this box is checked, the coordination data frame will be displayed. Otherwise, it will be suppressed.
5. *Force off*: The force off times for all actuated phases are entered here. These times are reference to the yield point, which is assumed to be time zero in the cycle. Phases 2 and 6 are considered to be non-actuated.
6. *Yield Point*: Only one yield point is specified to indicate the time, referenced to the system zero point, at which the hold will be released on Phases 2 and 6.
7. *Cycle length*: The system cycle length for coordinated operation
8. *Description*: A descriptive label identifying the current phase plan to distinguish it from other phase plans

There are 21 cycle plans (Plans 0 to 20) from which you may choose. The first five plans (Plans 0 through 4) are fixed and may not be changed. The descriptions for the fixed plans are as follows:

- Plan 0*: No detector or coordination functions
- Plan 1*: Isolated cycle without pedestrians
- Plan 2*: Isolated cycle with pedestrians
- Plan 3*: Coordinated cycle without pedestrians
- Plan 4*: Coordinated cycle with pedestrians

The remaining plans (5 through 20) are blank initially and may be specified or changed at any time. Note that any changes made in a given plan could affect the operation of previously developed scripts because the scripts select the desired plan by number and not by parameter values.

You will see a vertical scroll bar to the right of the data entry form. This feature lets you scroll through the plans one at a time. Several command buttons will also appear on this screen, depending on the current conditions.

- The *Edit* button will be visible if the current plan may be edited. It will disappear when you are viewing Plans 0 through 4.
- The *Reset Plan* button will appear for plans 5 through 20. Clicking this button will cause all parameters to reset to their null state.

- The *Save Cycle Plans* button will also appear for plans 5 through 20. Clicking this button will make all cycle plan changes permanent. Changes that are made without saving the cycle plans will revert to their previous values the next time the program is executed.
- *Copy* and *Paste* buttons are also provided to facilitate editing of cycle plans.

## 4.5 THE SCRIPT PREPARATION SCREEN

The Script Preparation Screen will be displayed whenever you open a script file or begin a new file from the Initial Menu Screen. This screen has a menu of its own with the commands differing slightly from the Initial Menu Screen

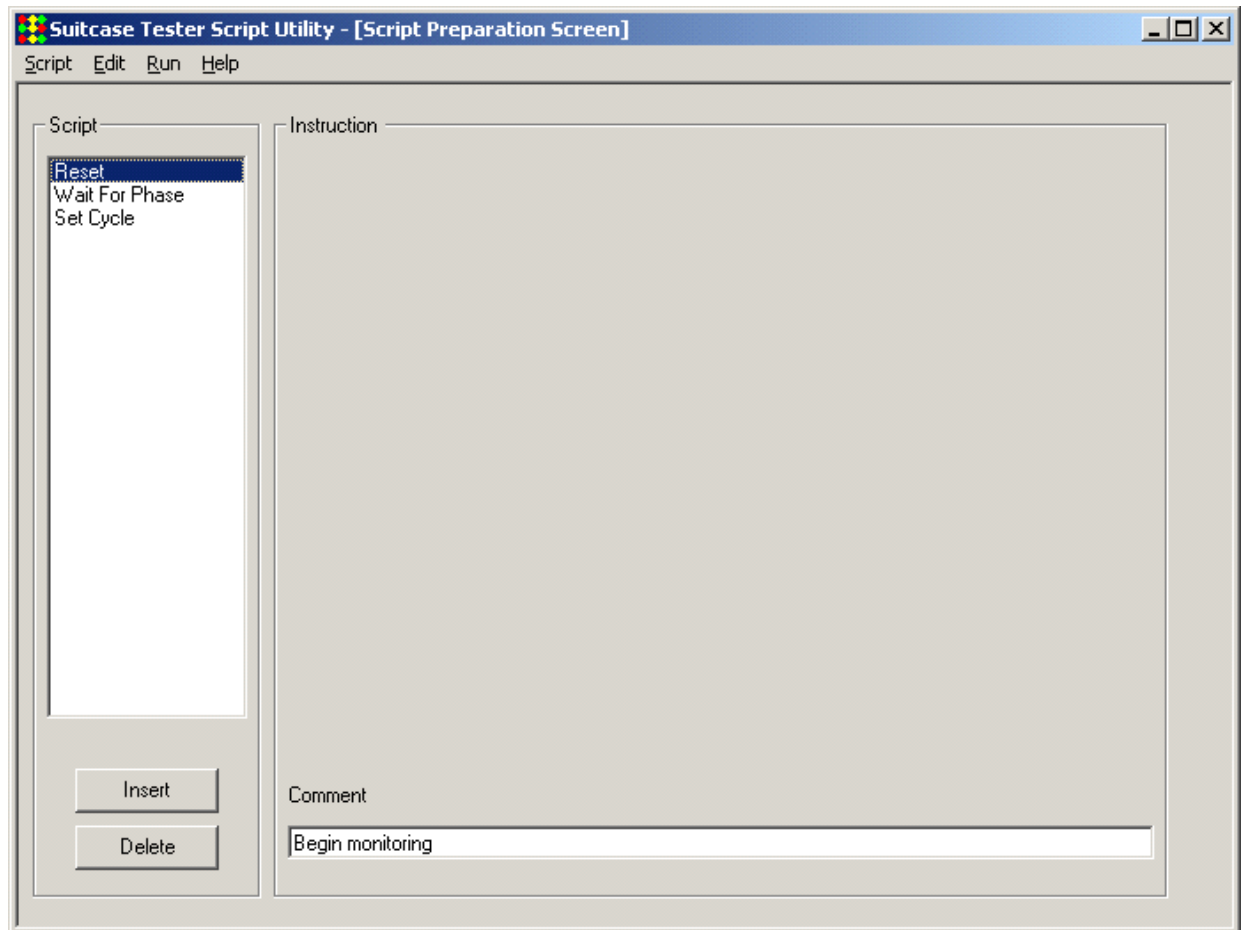
The following discussion assumes that you have accessed the Script Preparation Screen by starting a new script from the Initial Menu. This action loads the “seed script” containing a few instructions that normally appear at the beginning of every script. The resulting screen display is shown in Figure 4-4.

Note that this screen is divided vertically into two large frames. The frame on the left is labeled “Script” and the frame on the right is labeled “Instruction.” Only one of these frames will be active at any time. The label for the inactive frame will be subdued.

When the Script frame is active, you may browse through the instructions in the script that is displayed in the vertical list box in this frame. You may also use the command buttons to insert a new instruction in the script or to edit or delete the currently selected instruction. New instructions are always inserted below the selected instruction. If the selected instruction is the last instruction in the script, the label in the “Insert” button will change to “Append.”

As you browse through the current script, the contents of the instruction frame will change to reflect the parameters of the current instruction, but you will not be able to edit these parameters until you click the “Edit” button. When you click this button, the Instruction Frame will activate and the Script Frame will deactivate. You will now be able to edit the parameters of the currently selected instruction, but you will no longer be able to browse through the script. To return to the Script Frame, you must click either the “OK” or “Cancel” button. If you click “OK” all changes you made to the parameters of the selected instruction will be saved. If you click “Cancel” they will not be saved.

As you enter the Script Preparation Screen from the initial menu, the Script Frame will be active, the Instruction frame will be inactive and three instructions will be contained in the script list as shown in Figure 4-4. When a new script is created, it is seeded with these three instructions because they constitute the logical way to begin a new script.



**Figure 4-4. Script preparation screen with “seed” script**

If you browse through the other two instructions, you will notice that the contents of the Instruction frame will change, and different data fields will be visible. Only the data fields that apply to a specific instruction are visible when that instruction is selected.

## 4.6 STSCRIPT INSTRUCTIONS

The STScript vocabulary includes several instructions that will enable you to perform routine tests on a traffic-actuated signal controller. Each of the instructions has a different set of parameters. The only parameter that is common to all instructions is the *Comment*, which is simply a label that makes the instructions in the script easier to follow.

In the following discussion, a distinction will be made between *instructions* and *commands*. The STScript vocabulary includes several *instructions* for carrying out the tests. The STScript program translates these *instructions* into *commands* that are sent to the controller. A single *instruction* might cause several *commands* to be issued by the CID.

The full instruction set is described as follows:

#### 4.6.1 The Reset Instruction

The Reset instruction invokes an external reset of the controller. A controller testing script will usually start with a Reset instruction to force the controller into a predictable state. As seen in Figure 4-4, the only parameter is a *Comment*. This instruction resets the local time. It also purges any commands that are waiting to be executed.

#### 4.6.2 The Wait For Phase Instruction

The screenshot shows a dialog box titled "Wait For Phase". It has a "Target Phases" section with two sub-sections: "Ring 1 Phase" and "Ring 2 Phase". Each sub-section has four radio buttons labeled 1 through 4 for Ring 1 and 5 through 8 for Ring 2. In both, the second radio button (2 and 6) is selected. To the right of each sub-section is a dropdown menu currently set to "Green". Below these are two radio buttons for "Logic": "Either" and "Both", with "Both" selected. To the right of these is a "Max wait time" field containing the value "90". At the bottom is a "Comment" text box containing the text "Wait through reset cycle". At the bottom right are "OK" and "Cancel" buttons.

The Wait For Phase instruction causes the program to wait until the controller reaches a certain state, at which point the local time is reset. This instruction is usually included in the script as a prelude to other instructions that require knowledge of where the controller is supposed to be. For example, the Wait For Phase instruction follows the Reset instruction in the seed script because the Reset instruction will force the controller into a specified state.

The Wait For Phase Parameters include:

- *Target Phase:* Separate target phases are specified for Ring 1 (Phases 1-4) and Ring 2 (Phases 5-8).
- *Target State:* A target state (Green, Yellow or Red) is associated with each target phase.
- *Logic:* This parameter specifies whether the target condition requires both targets to be achieved (Logical AND) or whether it will be satisfied if either target is achieved (Logical OR).

- *Max wait time*: Specifies how long the program should wait for the target condition to be achieved. If the max wait time is exceeded, the program will halt.

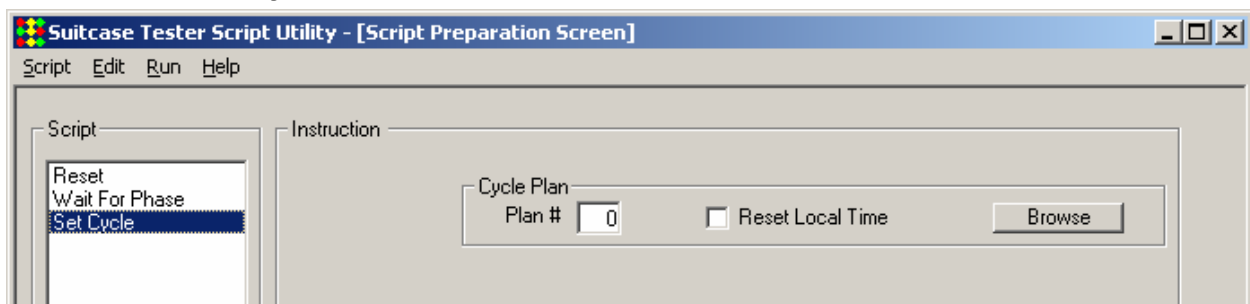
### 4.6.3 The Go To Phase Instruction

The Go To Phase instruction is similar to the Wait For Phase instruction with three exceptions.

1. The Go To Phase instruction forces the controller to the target state by placing calls on the detectors associated with the target phases and removing calls from all other phases.
2. The target state for the Go To Phase instruction includes only the Green interval, while the target state for the Wait For Phase instruction includes both a phase and interval (Green, Yellow or Red).
3. The Go To Phase instruction suspends the detector and coordination cycle operations and purges all commands that have not yet been sent to the controller. The Wait For Phase instruction leaves the background operation intact.

The Go To Phase instruction data entry form is the same as the Wait For Phase instruction except that the interval choice fields are disabled.

### 4.6.4 The Set Cycle Instruction



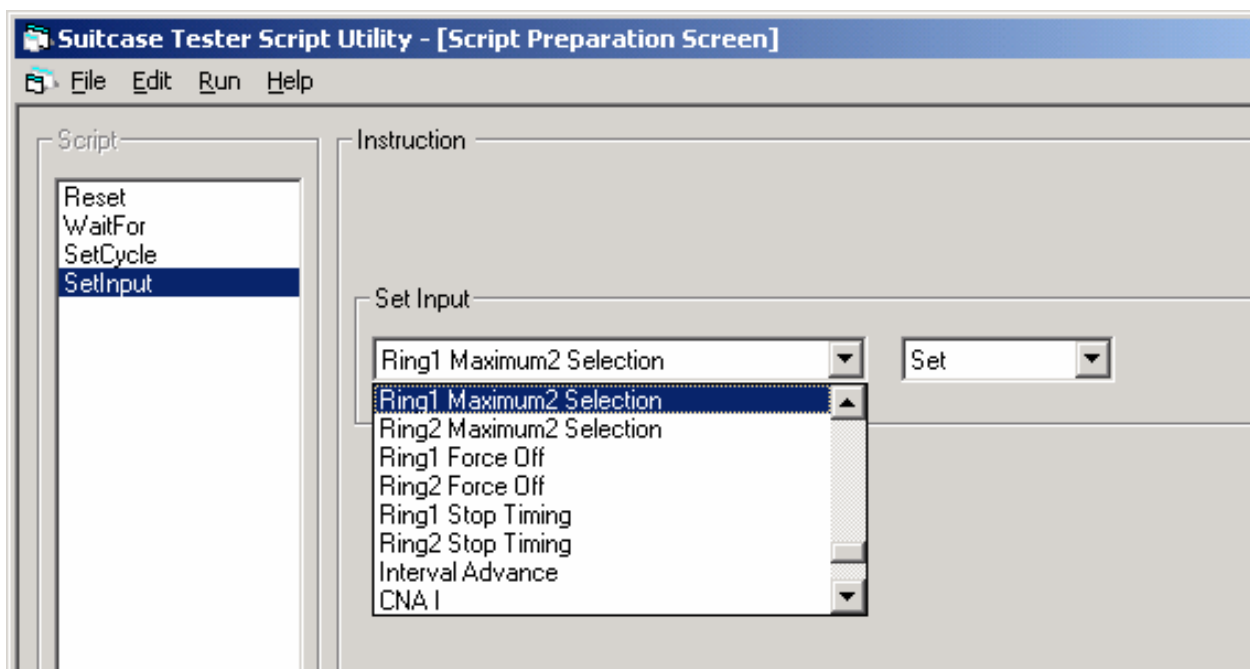
The Set Cycle instruction establishes the background operation that keeps the controller cycling. The parameters for this instruction are as follows:

- *Plan #*: Specifies which of the 21 available plans (Plans 0 through 20) should be established for the background operation.
- *Action*: offers an option to reset various timers, including:
  - the *local time*, which is the elapsed time since the last Go To Phase or Wait For Phase or StandBy event was satisfied, or since another event reset this timer.
  - The *cycle time*, which is the time with respect to the zero reference point in the cycle

Either or both times may be reset with this instruction

A “Browse” button is also included on the form for this instruction. Clicking this button will display the Cycle Plan Specification frame described previously and shown in Figure 4-2. It will not be possible to modify any of the plans at this point. You may, however, review the specifications for each plan and select the plan you want by clicking the “OK” button.

#### 4.6.5 The Set Input Instruction



The Set Input instruction lets you control any of the controller inputs accessible through the CID. The data form for this instruction is shown below.

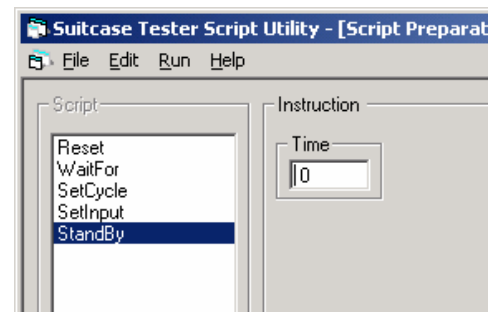
The two parameters for this instruction are:

- *Input selection:* The desired input is selected from a list of available input functions as shown above.
- *Action:* There are three possible actions for this instruction:
  1. *Set:* Which will turn the function on
  2. *Reset:* Which will turn the function off
  3. *Pulse:* Which will turn the function on and then off after a specified duration

If the selected function is a part of the current background operation for any phase (e.g., turning a detector on) this instruction will cancel the background operation for that phase only.

#### 4.6.6 The Standby Instruction

The standby instruction causes the background cycle operation to proceed on its own for a specified number of seconds. When the specified time is reached, the local time is reset, generally as a prelude to starting a new series of instructions.



#### 4.6.7 The Start Log Instruction

The Start Log instruction causes the monitoring log to be initiated and resets the time. This instruction should be given when the controller has reached its desired startup conditions following the first Reset instruction. There are no parameters to be specified for this instruction.

#### 4.6.8 The Set Yield Point Instruction

The Set Yield Point instruction establishes the current time as the zero reference point in the cycle. The “hold” on Phases 2 and 6 will be released at this point for three seconds every cycle. This instruction is normally given after a Wait For Phase instruction that waits for the yellow interval on Phases 2 and 6. There are no parameters to be specified for this instruction.

#### 4.6.9 The Clear Calls Instruction

The Clear Calls instruction resets all vehicle and pedestrian calls. There are no parameters to be specified for this instruction.

#### 4.6.10 The Clear All Instruction

The Clear All instruction resets all commands that are currently set. There are no parameters to be specified for this instruction.

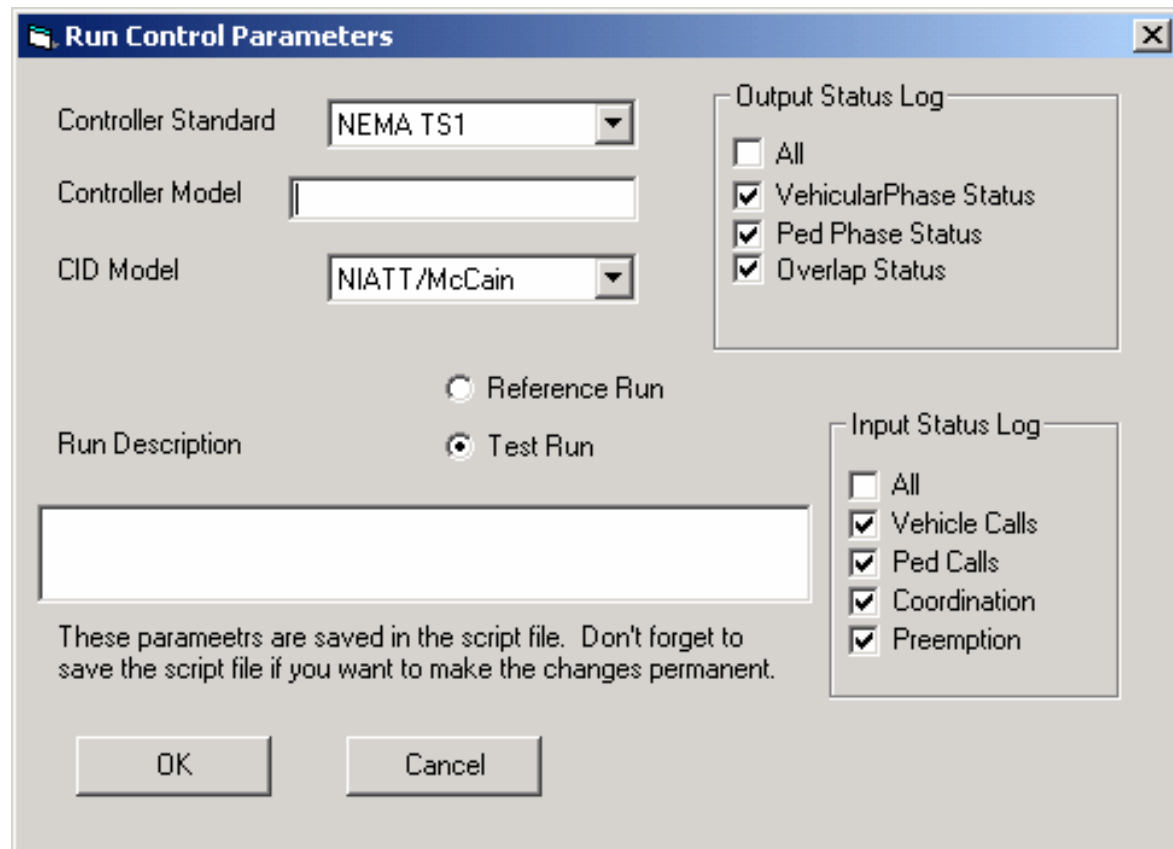
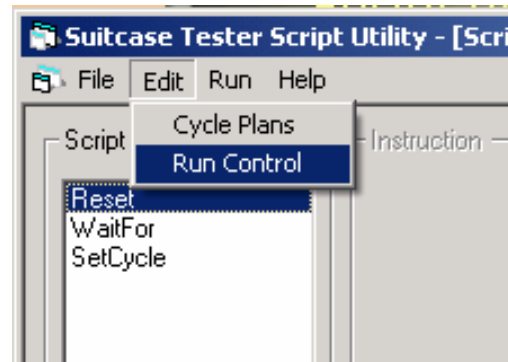
#### 4.6.11 The End Instruction

The End instruction will terminate the test. There are no parameters for this instruction.

### 4.7 RUN CONTROL PARAMETERS

The run control parameters are embedded in each script file. The default values are inserted in the script each time a new script file is created. The parameters may be edited by choosing “Run control” from the drop-down “Edit” menu on the script preparation screen.

When you make this choice the Run Parameters Screen will be displayed.

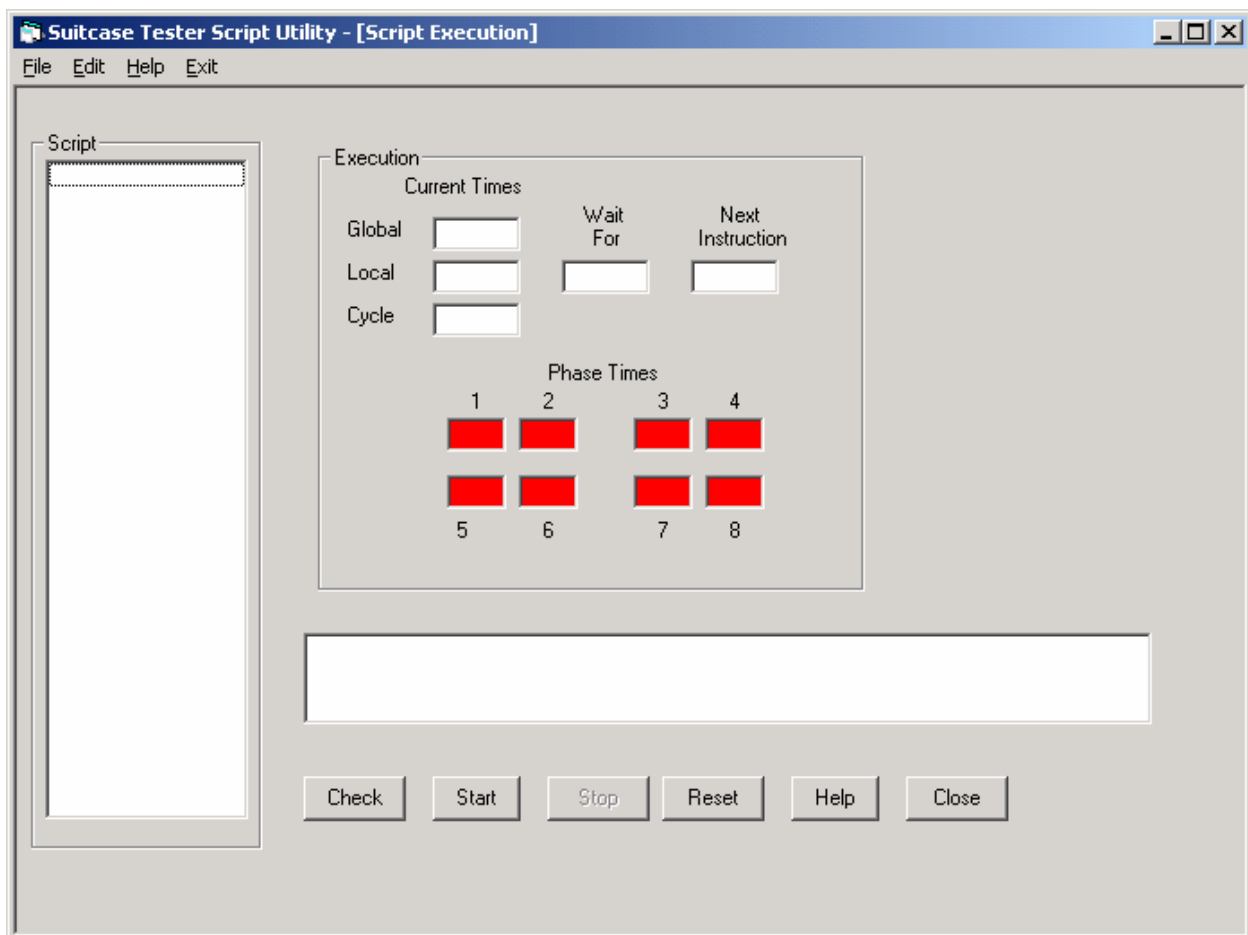


The data fields on the Run Parameters Screen are described as follows:

- *Controller Standard*: Distinguishes between the various standards that the CID accommodates. This version of STScript only deals with the NEMA TS1 standard
- *Controller Model*: A label identifying the controller that is being tested.
- *CID Model*: This version of STScript deals only with the NIATT/McCain CID unit
- *Reference/Test run*: File comparisons will generally be made between a “reference” run using a known configuration, and a “Test” run on a configuration being investigated. This choice determines whether to store the results in the Reference or Test file folder.
- *Input/Output Status Logs*: These boxes lets you choose what items should have their status entered in the output log every second. The comparison task may be simplified by eliminating items in which you are not interested in comparing for a specific run.
- *Run Description*: This is just a label to help you identify the run.

Since these parameters are saved in the script file, you must save the script file if you want any changes to be permanently attached to the current script

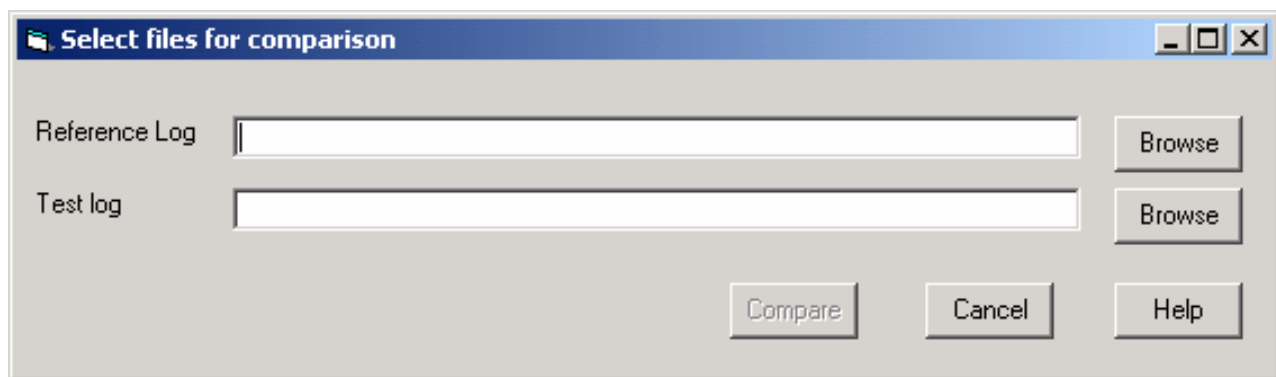
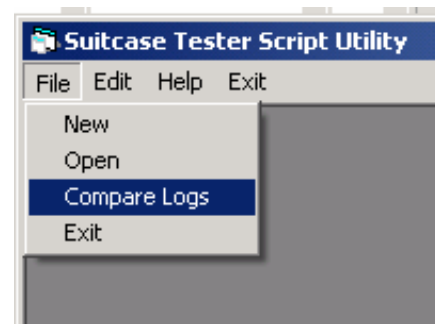
## 4.8 THE SCRIPT EXECUTION SCREEN



The script execution screen displays the current instruction from the script and the current status of the controller. By watching this screen you will be able to observe the progress of the test in real time. Several command buttons let you start, stop and reset the test. The *Check* button lets you perform a rapid check on the script integrity without executing the whole script. The *Close* button will return to the Script Preparation Screen.

## 4.9 COMPARING FILES

The proper functioning of a controller is established by comparing its status log with that of the status log of a controller known to be functioning properly and running the same script. The comparison task is accessed from the drop-down “File” menu on the Initial Menu Screen.

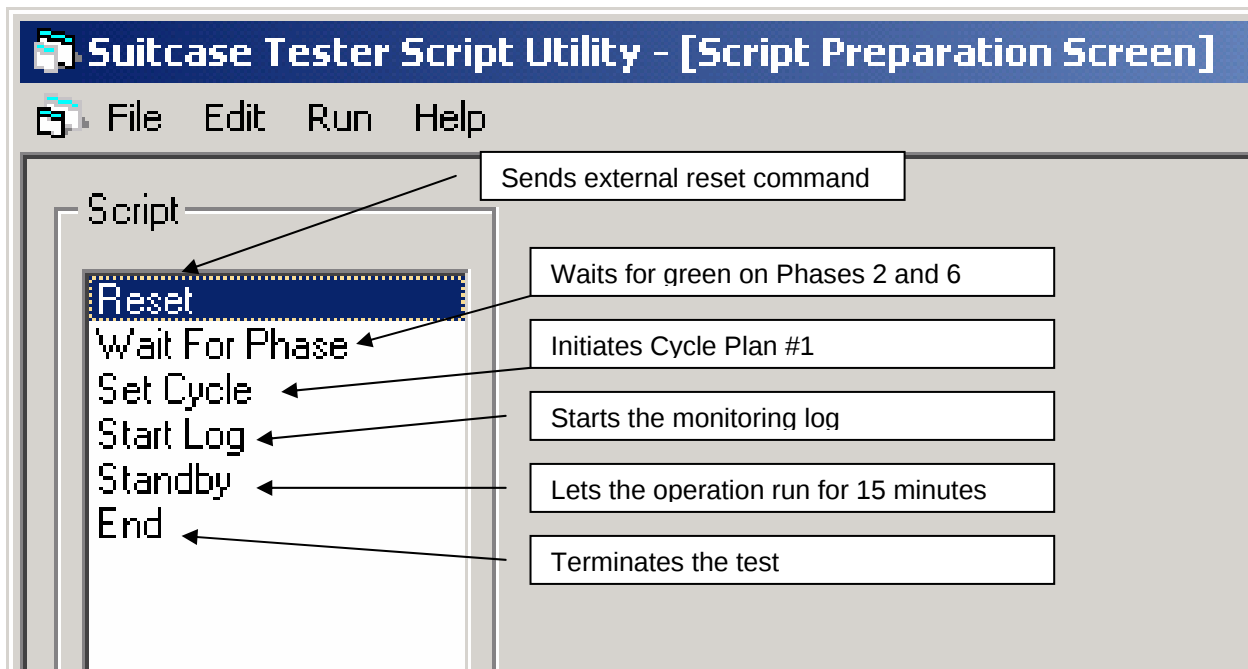


File comparison is performed by a commercial file comparison utility. There are several such utilities from which to choose. Note that STScript does not provide its own comparison utility. It simply executes the program that has already been specified as the comparison utility program in the “File and Folder Location” screen. The names of the two files to compare are sent to the comparison utility as command line parameters. If no comparison utility is specified, this feature will not be accessible from the menu.

To perform the comparison, simply browse for the two files that you want to compare and click the “Compare” button. This command button will only be active when two valid files have been selected.

## 4.10 A SIMPLE SCRIPT EXAMPLE

The full range of STScript instructions will let you give very complex command sequence of commands to a controller. But, before we start thinking about complex sequences we should start with a simple sequence. The script shown below will run the controller for 15 minutes, supplying detector calls for each of the eight phases from Cycle Plan 1 (isolated operation without pedestrians)



This plan is stored as a script file named "STScript.STS" in the "Samples" folder of the program directory.

## **5 CONCLUSIONS, RECOMMENDATIONS AND GUIDELINES**

This section summarizes the results of the project in terms of conclusions, recommendations and guidelines for HILS deployment. In general terms, the project was successful in its objective of increasing user awareness of this new technology and in creating tools that will facilitate future applications. The response of operating agencies in the form of HILS deployment was, however somewhat disappointing.

### **5.1 CONCLUSIONS**

Hardware in the loop simulation is still a relatively new concept. As indicated by the literature review presented in Section 2. Some very worthwhile HILS applications have been undertaken in several places around the USA. Collectively, these applications have demonstrated that HILS is an operational technique, and not simply a research tool. The traffic control and simulation industries have responded to a growing market demand with the introduction of new hardware and software products.

Taken individually, all of the project activities described in this report, including the development of tools and presentation of workshops, have been well received throughout the state. Those who have attended the workshops have expressed a definite interest in pursuing HILS projects in the future.

Having said that, it must also be noted that very little actual deployment has taken place to this point. Several reasons for the lack of action on the part of local agencies were noted in Section 2 of this report:

- The technology itself is relatively new and many potential users are not aware of (or perhaps not convinced of) its potential usefulness.
- The controller emulation features of most simulation models are fairly realistic, and most applications, especially those involving routine design and analysis tasks can be carried out without the added complexity of HILS.
- HILS must be applied in real time as opposed to embedded control emulation, which runs at full computer speed.
- The technology itself is somewhat complicated to learn and use.
- The wide range of available traffic control equipment would require some agencies to have multiple HILS systems to cover all of their equipment. The project focused on a HILS system involving CORSIM and a controller interface that accommodated NEMA TS-1 and Type 170 controllers. The practice appears to be shifting away from both of those components towards SDLC-based controllers and other simulation models.

Another complicating factor for this project was the unusually active tropical weather season that coincided with the outreach activities. Three of the scheduled workshops had to be postponed and one was cancelled. This was not a good time to attract the attention of operating agency personnel.

Nevertheless, traffic control systems are becoming more complex as the world of ITS moves forward. The need for HILS increases with system complexity and it is reasonable to anticipate that interest in HILS will grow in the future and that this technology will eventually prove useful to the FDOT and local operating agencies.

## **5.2 RECOMMENDATIONS**

The following recommendations are offered as a result of the study:

1. The FDOT should continue to support the HILS concept. Maximum use should be made of the six CID units purchased for the project.
2. It is premature to seek funding to purchase additional units at this time.
3. The existing units should be deployed at locations where they will be most visible and useful. The current deployment of the six units is as follows:
  - One unit is at the FDOT Central Office in the traffic control laboratory.
  - One unit is at the Traffic Control Systems Laboratory at the University of Florida.
  - One unit is in the hands of the Center for Urban Transportation Research (CUTR) at the University of South Florida.
  - One unit is in the FDOT 4<sup>th</sup> District office.
  - Two units are undeployed.

As an interim measure, these units should remain in their current locations to maximize the opportunity for deployment. The most visible and useful deployments will probably involve multiple CID units. Therefore, all existing CID units should be subject to collection and temporary relocation to support major traffic control system project investigations.

4. Additional deployment should be encouraged. The most promising future HILS applications are
  - Investigation and proof of concept for proposed major traffic control system improvements involving advanced traffic control (adaptive) systems, which are not generally covered by current simulation models.
  - Factory acceptance testing for new and complex traffic control systems after delivery but prior to installation in the field.
  - General controller testing in the shop, using the suitcase tester emulator and STScript tool. While this falls short of an actual HILS application, because no simulation program is involved, it attracted considerable attention and interest in the workshops.
5. The internet site established for this project should be maintained to disseminate the latest information on HILS. The Transportation Research Center is prepared to undertake this task as a service to the profession.
6. The workshop presentation material that has been delivered to FDOT will be placed on the web site. Technology transfer agencies such as McTrans and the T2 Center should be

encouraged to offer future workshops and/or incorporate the presentation material into their existing workshop schedules.

### **5.3 DEPLOYMENT GUIDELINES**

Agencies considering hardware in the loop experiments should consider the guidelines presented here. First, it would be a good idea to consult the UF Transportation Research Center HILS website:

<http://trc.ce.ufl.edu/research/HILS.htm>

to obtain the most up to date information on this topic.

Separate guidelines are offered for agencies who are interested in the controller testing features of the interface hardware, and those who are interested in hardware in the loop simulation itself.

#### **5.3.1 Controller Testing Guidelines**

One of the differences between the controller testing applications and the HILS applications is that the controller testing will generally require a permanent interface unit, and a source for a short term loan of a unit will generally not be an issue. Neither will simulation program acquisition, installation or training be an issue, because no simulation program is involved in controller testing. So, the guidelines for controller testing are much simpler:

1. Consider what types of controllers are deployed, tested and maintained by your agency. If you are not responsible for any of these activities, then you will probably have no use for the test equipment. The currently available interface hardware falls clearly into two categories:
  - Parallel interface for I/O functions (NEMA TS-1 and Type 170).
  - SDLC interface for I/O functions (NEMA TS-2 and ATC 2070)Keep in mind that some controllers offer both types of connectors.
2. Choose a controller interface box that will accommodate your controllers. In general, the McCain unit accommodates controllers with parallel interface connectors and the Naztec and Eagle units accommodate controllers with SDLC connectors.
3. Make sure that your computer has the required serial interface to accommodate the controller interface box. Interface boxes that have parallel I/O use a USB port connection to the computer and those with SDLC I/o use the RS-232 communications port. Most computers have both types of ports installed.
4. Consult the controller interface specification sheets in Appendix A to make sure that your computer meets the stated requirements. You should obtain updated copies of the specifications if possible. The operating system requirements are of particular concern. Some of the specifications in Appendix A are restrictive on operating systems.

5. Procure and install the unit(s) that you have selected. The installation instructions may vary among operating systems but in most cases the installation will be relatively simple.
6. If your controllers and interface box are compatible with the STScript program presented in Section 4 of this report, you should consider installing this program and using the scripting capability. The STScript program may be downloaded from the UFTRC HILS website.

### **5.3.2 HILS Guidelines**

Working with HILS is more complex than using the equipment for simple controller testing, because you will need all of the four HILS components described in Section 1 of this document. You will also need to be familiar with the operation of the simulation program and the traffic controller as well as the configuration requirements for the controller interface. The Hardware in the Loop Component Integrator (HILSCI) program described in Section 2 of this document will facilitate the learning process and relieve you of some of the initial burden for systems using CORSIM with the McCain controller interface.

The guidelines for getting started are presented as follows:

1. Select the simulation program and controller interface to match your controller types and your existing knowledge of traffic simulation. If your simulation knowledge is limited, you might find the HILSCI program useful as an aid to getting started. Keep in mind, however, that HILSCI is only compatible with certain simulators and controller interfaces.
2. Pay particular attention to the simulation program version. In general, you should upgrade your simulation program to the latest version if a newer version is available. This is particularly true of CORSIM, for which the latest version (in 2004) is 5.1. Version 5.0 works differently with the controller interface and you will find version 5.1 to be more satisfactory.
3. Install all software. If you have no software components installed, the preferred installation order is:
  - The simulation program
  - The controller interface configuration program
  - Supplemental programs, such as HILSCI.
4. Revisit each software component to make sure that it is set up properly for HILS. Some programs do this for you automatically. In the case of CORSIM, you must install the run time extension package as a TSIS tool. Be sure to follow the instructions in the controller interface manual. If you are using HILSCI, you may also install it as a TSIS tool, or you may choose to run it as a stand-alone program.
5. If your choice of equipment is compatible with HILSCI, you should run HILSCI first to familiarize yourself with the operation of all of the components.

- If you have any vendor supplied software for transfer of data between a traffic-actuated controller and your computer, you should set that software up in the HILSCI “file location” screen.
  - Choose an intersection from the HILSCI TRF library. Change your controller settings to match the selected intersection
  - Run CORSIM and observe the results.
  - If you have CORSIM data sets of your own, you should now load one of them into HILSCI to let HILSCI modify it for hardware in the loop simulation.
6. You are now ready to take on a full project. The first thing you need to do is define the project. Be sure that you understand why you need to use HILS instead of the internal control emulation built into the simulation program. If the internal control emulation will serve your purposes then you won’t gain much, if anything, from the extra effort of real time simulation.
  7. Summarize the operation of each intersection using the blank form provided in Appendix B.
  8. Prepare the input data for the simulation program using the interface and editing capability that came with the simulation program.
  9. Modify the simulation data for real time simulation at the selected intersection. The modification process depends on the simulation program and controller interface that you have chosen
  10. If you are using CORSIM and have only one intersection for real time simulation, you may be able to use HILSCI to simplify your job. Otherwise you will have to use the native configuration program that came with your controller interface unit. This program will give you access to all of the features of the controller interface, including multiple HILS intersections, but it will take some time to become familiar with its operation. HILSCI uses several default parameters, such as loop detector size and placement to simplify your job, but it limits your flexibility in the process.
  11. Before you create the HILS configuration, it is a good idea to simulate the system with out the features that require HILS, using both HILS and the internal control emulation, to verify that the HILS application is giving approximately the same results as the internal control emulation.

## REFERENCES:

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2. <http://www.old-computers.com/museum>
3. ITT Industries, Inc., Systems Division CORSIM Run-Time Extension (RTE) Developer's Guide, Version 5.1
4. Engelbrecht, RJ; Barnes, KE: "Advanced Traffic Signal Control for Diamond Interchanges" Transportation Research Record 1856
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6. Lucas, DE; Mirchandani, PB; Head, LK, "Remote Simulation to Evaluate Real-Time Traffic Control Strategies." Transportation Research Record 1727, 2000
7. Bullock, D; Morales, JM; Sanderson, B, "Evaluation of Emergency Vehicle Signal Preemption on the Route 7 Virginia Corridor" FHWA-RD-99-070,; Final Report, 1999
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9. Nichols, A; Bullock, D "Design Guidelines For Deploying Closed Loop Systems." FHWA/IN/JTRP-2001/11,; Final Report 2001
10. Abbas, M; Bullock, D; Head, L "Real-Time Offset Transitioning Algorithm For Coordinating Traffic Signals." Transportation Research Record 1748, 2001
11. Naztec, Inc. "City of Cupertino Adaptive Project – Factory Acceptance Test Report), 2004.

# **Appendix A**

## **Controller Interface Device Specification Sheets**



The Power of Ingenuity

**McCain**

2365 Oak Ridge Way  
Vista, California 92081  
Phone (760) 727-8100  
Fax (760) 727-8264  
www.mccaintraffic.com

**New Product Helps Improve  
Traffic Signal Timing**



## Controller Interface Device (CIDII)

### The CID II Allows Real Time Simulation of Signal Timing Plans

The CID II is a communications device that allows traffic engineers to link a traffic simulation program like CORSIM directly to a NEMA, 170, 2070, future ATC traffic controller or any other type of traffic actuated controller. This link between software and hardware is known as real-time hardware-in-the-loop simulation. It allows an engineer to fine-tune a traffic signal timing plan using actual controller hardware, in real time, in the convenience and security of the office, lab or signal shop. The traffic engineer can also fine-tune coordination, systems operation, traffic responsive or traffic adaptive control operation by interconnecting a number of controllers, each under CID II supervision.

### How Does the CID II Work?

CORSIM simulates traffic flow based on traffic demand, street geometry and signal control plans for a given set of intersections. When vehicles approach a signalized intersection in the simulation, CORSIM sends a signal from the PC to the controller that vehicles have been detected. The controller reacts to these signals as it would react to real detector actuations, and sends CORSIM indications of the signal changes at will. Both the simulation and the controller run in real time, i.e. one second of simulation takes one second of actual time. It is the CID II that makes this real-time exchange of data possible.

### Suitcase Tester Function

The CID II can also be used as a "virtual suitcase tester," to test and evaluate the operation of various traffic controller functions. The CID II suitcase tester function is an easy-to-use alternative to the traditional controller tester.

### CID II Specifications

The CID II software (included with the hardware) runs on a PC or laptop computer running *Windows 98, 2000, XP or Me*.

Data transfer between the PC and the CID II is via a Universal Serial Bus (USB) cable. Data transfer between the CID II and the traffic controller is done over cables configured for the various controller input/output connectors or hard-wired to the detector inputs. A version to tie the CID II into the HDLC serial port is under development.

The CID II can connect to 64 inputs and 64 outputs on the traffic controller.

Power..... 120 VAC, 60 Hz (240 VAC, 50Hz optional)  
Dimensions..... Height – 5 inches (13 cm); width – 13 inches (33 cm)  
Depth – 11 inches (28 cm)

Developed by NIATT at the University of Idaho, manufactured by McCain Traffic Supply, Inc.

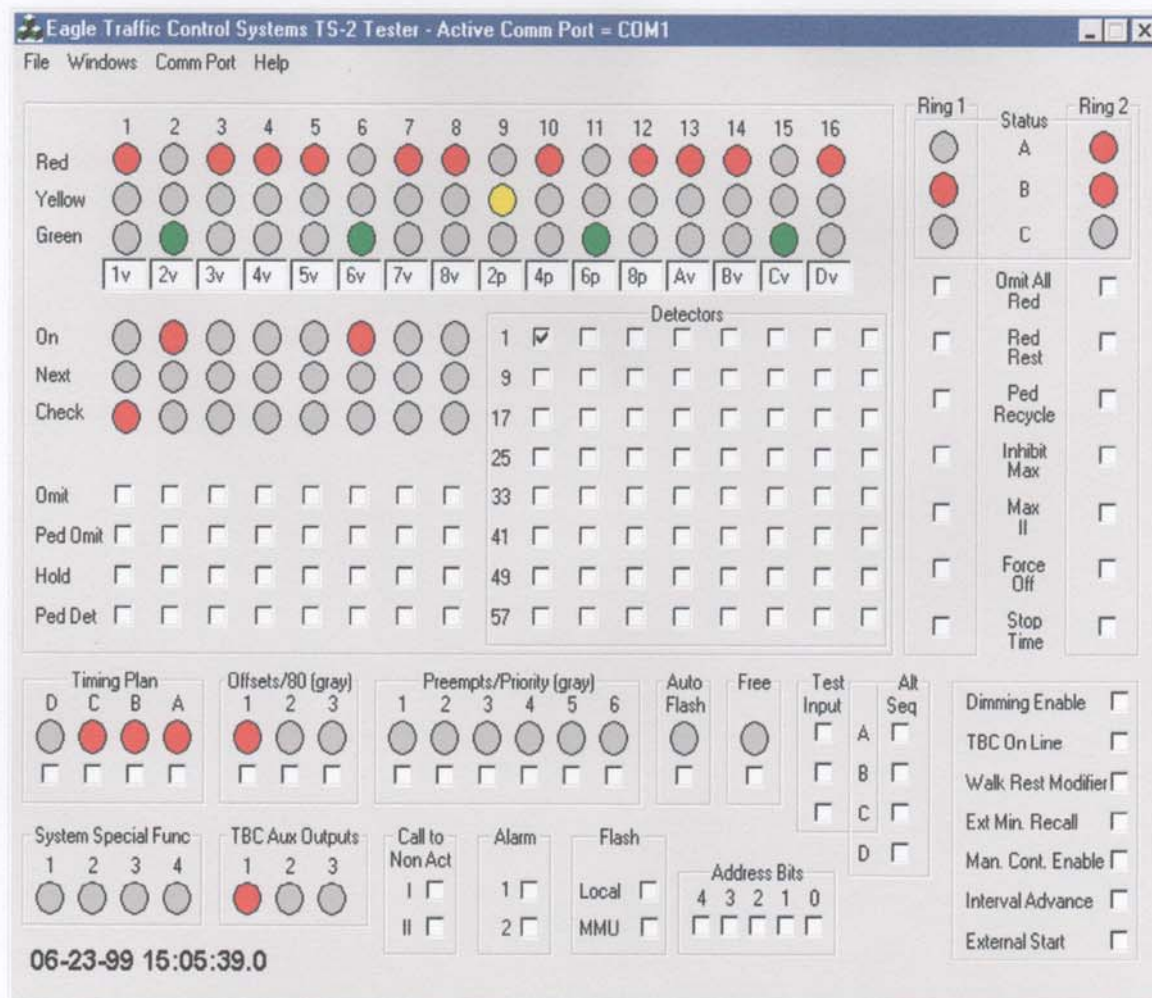
McCain reserves the right to change product specifications without notice.  
McCain 01/04

# SIEMENS

## EAGLE NEMA TS-2 Tester FOR TS-2 Controllers



EAGLE NEMA TS-2 tester allows complete testing of TS2 controllers without a wired cabinet. The tester consists of two main parts: the Box and the Window-driven (GUI) PC Software. The Box listens for messages from the controller and sends the received data, 10 times per second, to the PC Software for GUI update. The Software configures responses to the messages and returns appropriate information to the controller via the Box.



**Siemens ITS**  
Siemens Energy & Automation, Inc.  
Business Unit Intelligent Transportation Systems

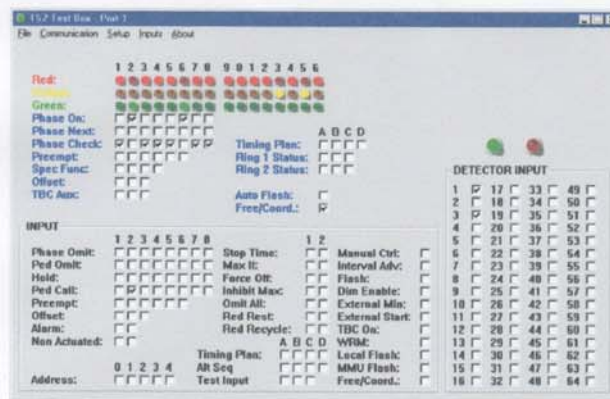
8004 Cameron Road · Austin, TX 78754  
Ph: (512) 837-8310 · Fax: (512) 837-0196  
<http://www.itssiemens.com>

## TS2 Test Box



The TS2 Test Box module simulates a TS2 cabinet (terminal facility) and allows the user to change any BIU input and read all BIU outputs using the SDLC communications port. The TS2 Test Box can also be used with [SimTraffic CI](#) to simulate [Synchro](#) data files before deploying a timing plan to the field.

The size of the TS2 Test Box is only 7" x 5" x 2", but the unit contains 8 terminal facility BIU's and 8 detector BIU's that communicate with the controller over an SDLC cable. The Text Box communicates with a computer over an RS-232 interface (serial port). The TestBox software runs under Windows 95/98/NT and allows you to toggle all controller inputs with a click of your mouse and view 16 load switch channels in real-time.



820 Park Two Drive Sugar Land, TX 77478 (281) 240-7233  
www.naztec.com naztec@naztec.com Additional Offices in Florida and Virginia

## **Appendix B:**

# **Summary Forms and Announcements**

# Hardware in the Loop Simulation

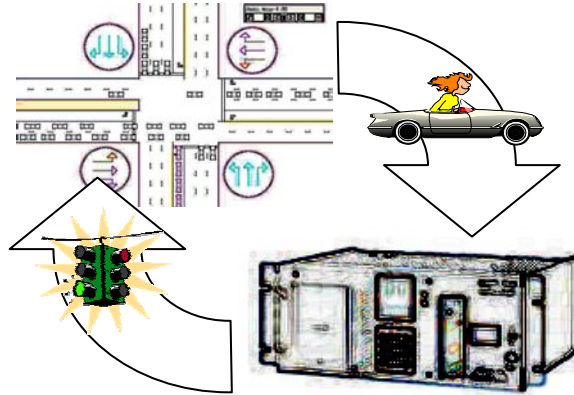
## Workshop Announcement

Traffic simulation has become an increasingly popular traffic analysis tool. Recently a new device has been developed to insert the actual traffic control equipment into the simulation process. The “Controller Interface Device” (CID) opens new horizons for the use of traffic simulation. Recent experiments reported in the literature have demonstrated that the CID is able to create a realistic traffic environment for the controller as well as a realistic control environment for the simulator.

By creating a realistic traffic environment for the controller, the CID supports more comprehensive testing of traffic controllers and control plans in the shop. Because the CID lets a person with minimal training and experience manipulate the controller settings in a risk-free environment, it offers a unique training tool.

By creating a realistic control environment for the simulator, the analyst is able to evaluate innovative control schemes that are beyond the scope of the current simulation models. In this way, the CID can support more efficient handling of traffic with reduced congestion and delay

Recognizing the potential of this breakthrough in technology, the Florida Department of Transportation (FDOT) has initiated a project to identify and explore the areas of application that could support the FDOT mission. The University of Florida Transportation Research Center is performing this work. The specific objectives are to facilitate the implementation of hardware in the loop simulation in Florida, and to develop guidelines for future deployment by FDOT.



One of the tasks in this project involves the presentation of a series of regional workshops to demonstrate the equipment and to instruct state and local personnel in its use. When you have completed this workshop, you should be able to:

- Perform a simulation run on a sample intersection problem
- Set up a traffic-actuated signal controller for the sample intersection
- Integrate the controller into the simulation loop
- Define more complex problems for analysis

Each workshop will cover a full morning with time available in the afternoon to address specific problems with local engineers and technicians.

There are five sessions organized as follows:

1. Introduction
2. Simulation as a problem solving tool
3. Simulating an intersection with CORSIM
4. Adding hardware in the loop
5. Suitcase tester features

Following the formal sessions, the equipment will be made available for interested participants to conduct their own experiments. All participants are encouraged to bring CORSIM data sets and/or NEMA or Type 170 controllers to explore their own unique applications. As a follow up activity, any agency may request the use of a CID unit for a nominal two week period to pursue their applications in greater depth.

Anyone interested in hosting a workshop should contact Prof. Ken Courage ([kcourage@ufl.edu](mailto:kcourage@ufl.edu))

# Suitcase Tester Script Utility (STScript)

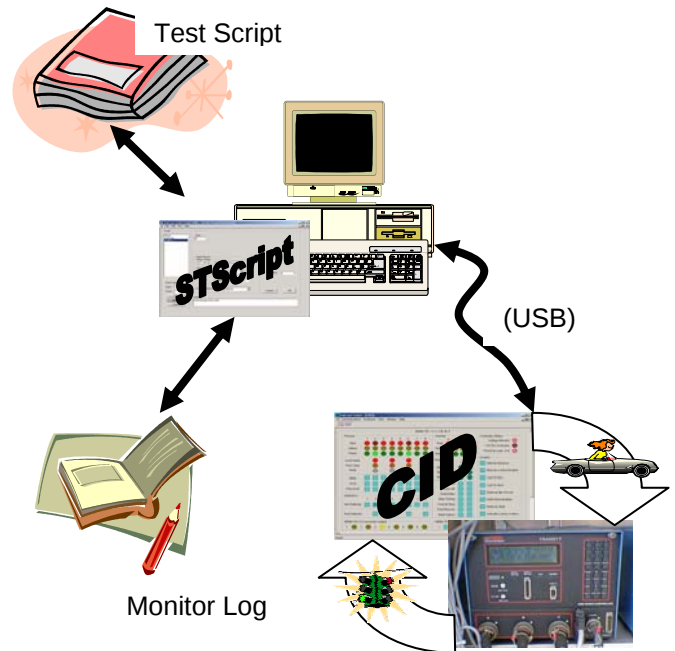
Traffic signal maintenance personnel have traditionally used a “suitcase tester” to test and evaluate the operation of a traffic controller before it is placed in the field. A suitcase tester is a suitcase-like box containing switches that, when linked to a traffic controller, can activate functions on the controller and monitor outputs from the controller. A suitcase tester can provide a controlled environment for verifying that the controller behaves as expected when individual functions are programmed.

Recent developments have created a new instrument known as the Controller Interface Device, or CID, which connects a standard traffic signal controller to a personal computer (PC) through the USB interface port. The CID performs bidirectional transfer of controller inputs and outputs between the controller and the PC. This function has opened several new horizons to the science of traffic control systems operation.

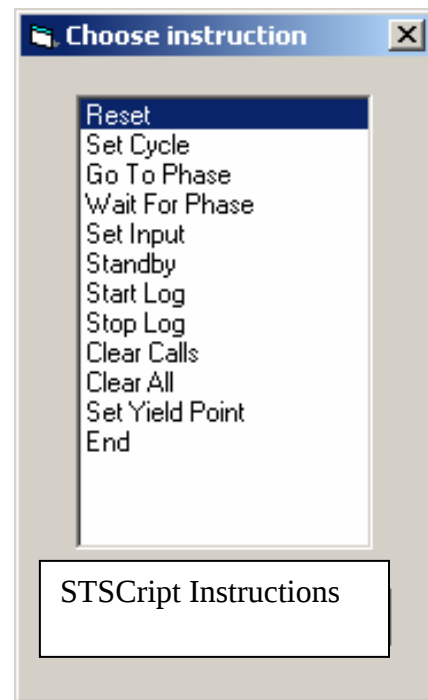
The STScript Suitcase Tester Script Utility introduces the ability to program the suitcase tester to perform a series of prescribed tests by manipulating the input functions over time and monitoring the output functions to compare their status with the response that would be expected from a properly functioning controller.

The data flow for a controller being tested with STScript is shown here. The STScript program performs the following functions:

5. Reads the test instructions from a script that has been prepared for the desired test plan
6. Converts the instructions in the script to a series of input function commands that are understood by the CID. Each command contains an instruction to turn one input function on or off.
7. Interrogates the CID once per second to learn the status of all of the controller output functions.
8. Writes an entry to the monitor log each second to give the status of all inputs and outputs.



**STScript Data Flow**



STScript has been developed for the Florida Department of Transportation by the University of Florida Transportation Research center. The NEMA TS- functions are fully operational. Other functions are under development. For more information, please contact Prof. Ken Courage ([kcourage@ufl.edu](mailto:kcourage@ufl.edu))

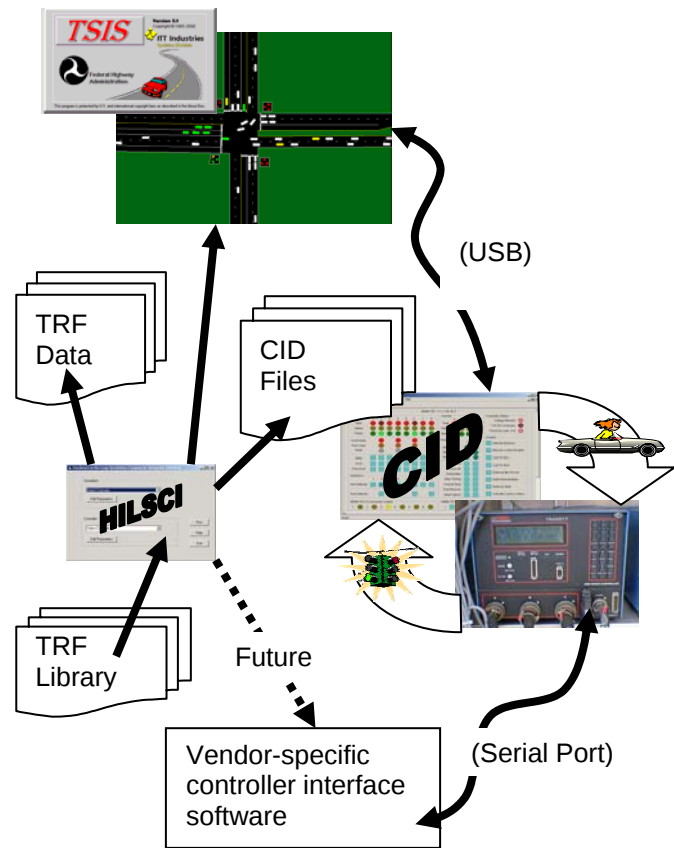
# Hardware in the Loop Simulation Component Integrator (HILSCI)

Traffic simulation has become an increasingly popular traffic analysis tool. Recently a new device has been developed to insert the actual traffic control equipment into the simulation process. The “Controller Interface Device” (CID) opens new horizons for the use of traffic simulation. Recent experiments reported in the literature have demonstrated that the CID is able to create a realistic traffic environment for the controller as well as a realistic control environment for the simulator.

The Hardware in the Loop Simulation Component Integrator (HILSCI) has been developed to facilitate the use of the CID. The components of HILSCI are presented in the figure at the right, which also shows the flow of data between the components. Note that HILSCI passes information to CORSIM, the CID and the Controller itself. HILSCI may be run as a stand-alone program or it may be installed as a TSIS tool and launched from TSIS

The HILSCI functions include:

- Loading a CORSIM simulation data file in TRF format
- Identifying the intersections in the file that are operating under traffic actuated control
- Selecting an intersection for hardware in the loop control from a list of the available intersections
- Identifying the traffic-actuated approaches to the intersection that require detectors.
- Modifying the CORSIM file to establish hardware in the loop control at the selected intersection. This step involves designating the intersection for hardware in the loop control and creating the required surveillance detectors on each approach.
- Generating the configuration file for the CID
- Executing CORSIM
- Executing Vendor supplied software that edits the operating parameters of the controller (Future provision).



HILSCI components and data flow

As an example of HILSCI’s simplifying features, a preset library of 36 intersections with varying configurations is accessible from the HILSCI menu. This feature permits editing of the traffic volumes on each approach to create simulation data with little or no knowledge of CORSIM.

While several intersections can be placed under hardware in the loop control simultaneously, the HILSCI program is limited in scope to a single intersection. HILSCI is intended to provide a simplified method of establishing hardware in the loop control with minimum effort. Multiple intersection studies introduce complexities that generally are not amenable to HILSCI-type simplification.

HILSCI has been developed for the Florida Department of Transportation by the University of Florida Transportation Research center. The features that facilitate access to the simulation program are now fully operational. The features that facilitate access to the controller are currently under development. For more information, please contact Prof. Ken Courage (kcourage@ufl.edu)

| Appendix B: HARDWARE IN THE LOOP SIMULATION CASE SUMMARY |                    |      |  |      |  |            |             |      |        |      |   |            |   |      |           |      |  |
|----------------------------------------------------------|--------------------|------|--|------|--|------------|-------------|------|--------|------|---|------------|---|------|-----------|------|--|
| Agency                                                   |                    |      |  |      |  | Contact    |             |      |        |      |   |            |   |      |           |      |  |
| Project                                                  |                    |      |  |      |  | Direction  | Origin Node | RTOR | Volume |      |   | Full Lanes |   |      | Bay Lanes |      |  |
|                                                          |                    |      |  |      |  |            |             |      | L      | T    | R | L          | T | R    | L         | R    |  |
| Case Description                                         |                    |      |  |      |  | Northbound |             |      |        |      |   |            |   |      |           |      |  |
|                                                          |                    |      |  |      |  | Southbound |             |      |        |      |   |            |   |      |           |      |  |
| TSIS File Name                                           |                    |      |  |      |  | Eastbound  |             |      |        |      |   |            |   |      |           |      |  |
| CID File Name                                            |                    |      |  |      |  | Westbound  |             |      |        |      |   |            |   |      |           |      |  |
| <b>Phasing Scheme Name</b><br><div></div>                |                    | Ph 1 |  | Ph 2 |  | Ph 3       |             | Ph 4 |        | Ph 5 |   | Ph 6       |   | Ph 7 |           | Ph 8 |  |
| <b>Yield Point</b> <div></div>                           |                    |      |  |      |  |            |             |      |        |      |   |            |   |      |           |      |  |
| Minimum Green                                            | Maximum Green      |      |  |      |  |            |             |      |        |      |   |            |   |      |           |      |  |
| Extension                                                |                    |      |  |      |  |            |             |      |        |      |   |            |   |      |           |      |  |
| Yellow                                                   | Red Clearance      |      |  |      |  |            |             |      |        |      |   |            |   |      |           |      |  |
| Recall                                                   |                    |      |  |      |  |            |             |      |        |      |   |            |   |      |           |      |  |
| Walk                                                     | Ped Clearance      |      |  |      |  |            |             |      |        |      |   |            |   |      |           |      |  |
| Detector 1 Type                                          | Detector2 Type     |      |  |      |  |            |             |      |        |      |   |            |   |      |           |      |  |
| Detector 1 Lanes                                         | Detector 2 Lanes   |      |  |      |  |            |             |      |        |      |   |            |   |      |           |      |  |
| Length                                                   | Setback            |      |  |      |  |            |             |      |        |      |   |            |   |      |           |      |  |
| Detector 1 Setback                                       | Detector 2 Setback |      |  |      |  |            |             |      |        |      |   |            |   |      |           |      |  |
| <b>Comments</b>                                          |                    |      |  |      |  |            |             |      |        |      |   |            |   |      |           |      |  |

**Volume II: Workshop Presentation Material (on CD-ROM)**

**Volume III: Software Tools (on CD-ROM)**