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STEREO ELECTRO-OPTICAL TRACKING SYSTEM (SETS)

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SUMMARY

The measurement of deflection of light emitting diodes embedded in aircraft models in the National Transonic Facility is to be provided by the Stereo Electro-Optical Tracking System (SETS). This is a remote, non-contact, high accuracy, digitally controlled measurement system. The resulting capability and flexibility are expected to provide data for accurate and rapid calculation of the deformation and motion of the aircraft model, particularly under the conditions required for model testing at high Reynolds Numbers.

The SETS equipment consists of four trackers mounted in the floor beams of the NTF test section to view a model at angles consistent with stereo measurement techniques. Motions of the target diodes of 0.02-mm are measurable at sample rates reaching 2000 per second. Position data collected from each of the four trackers is stored on magnetic tape for later analysis. Computer control provides for acquisition, data collection and calibration of the desired information.

The total system has been installed in a laboratory at NASA Langley Research Center for training and modification prior to final installation in the NTF.

INTRODUCTION

System Concept

The Stereo Electro-Optical Tracking System (SETS) measures aeroelastic deformation of models at the National Transonic Facility. The system provides data for accurately measuring the deformation of parts of an aircraft model under conditions of high Reynolds number. Real time collection of target location and storage of that information from two or more trackers permits stereo deformation calculations to be performed immediately after a test run.

The SETS system is a non-contact, non-photographic system that detects minute deviation in the position of targets embedded in the model. Targets are monitored repetitively and sequentially at high rates to minimize vibration effects and to permit many position measurements during a test run. The data is fed in digital form to a dedicated computer for collection and later analysis. The SETS is based on a study completed for NASA under Contract NAS1-15629 (Ref. 1) which described the concept and approach to implementation. A second study (Ref. 2) provided a baseline evaluation of factors which could affect the tracking accuracies through disturbance of the optical path. The results of the studies were encouraging for development of a complete system. Under Contract NAS1-16883, the equipment was developed, tested and delivery made to NASA Langley Research Center on July 6, 1984. At this writing, it has been installed in the Instrument Research Division Laboratory and is being operated by NASA personnel.

Positions of individual targets mounted on the model are measured simultaneously from different angles by four trackers. Two trackers are mounted 122-cm (4 ft) up-stream and down-stream from the center of the model. Two others are mounted 61-cm (2-ft) up-stream and down-stream from a point 40-cm (16-in) to the side of center for viewing one wing. Measurement of target location to less than 0.02-mm (0.001-in) in a field diameter of 180-cm (50-in) was accomplished in laboratory tests.

Coordination of the scan of the four trackers is performed in the Target Interface Unit (TIU). During normal data collection, the TIU controls the system timing and directs the trackers. The SETS Computer acts as a program control and data collector only, and does not actively participate in the target selection or data generation. The TIU has, in its memory, an identifying number and a sequence in which the Light-Emitting Diode (LED) targets are to be measured. It turns on only the one LED selected, sends its target number to all four trackers, and waits until they all report back that the target has been located before sending the next target number. This assures that all trackers are viewing the same target at the same time. If a time limit has elapsed for any one tracker to reach the desired accuracy, the TIU will automatically cycle to the next target.

Each tracker receives commands from the TIU to locate and report a target. The tracker retrieves the last known position from its own memory and begins a track scan at that location. Each tracker performs a four point scan sequence and calculates a new center position. If the target has moved significantly since the last measurement, several of these four point sequences may be needed to find the new location. When the target location has been determined, the tracker notifies the TIU. On command from the TIU, each tracker updates its memory and also sends the information to the computer.

System Performance

The SETS system is capable of locating, measuring, and following the positions of 2 to 63 targets. The data rate is related to the time required for capturing the target and determining its location to the desired accuracy.

The sensor tube used in each tracker is an electronically scanned image dissector which sequentially views the individual targets. The tube is driven by a high accuracy digital scan control system. The scan is directed to the expected location of the target where measurements determine its latest coordinates. These coordinates are then stored in memory in the tracker and passed through the computer to magnetic tape. This sequence occurs rapidly, with many target locations measured each second. An initial slew of the scan to the target location may require 140-μs, followed by 130-μs for each four-position search pattern and 40-μs between x and y axis scans. The hardware is set for at least two, but not more than ten, search patterns per target. Thus, the number of targets sampled per second depends on the cycles required for the slowest tracker.

Number of Cycles/Target	2	4	6	8	10
Number of Targets/Second	2272	1282	892	685	555

The SETS is expected to average four (4) cycles/target or less, producing a data rate of at least 1282 targets/second. Vibration of the model, poor visibility, shock wave development, turbulent air flow, and other factors will all tend to increase the number of cycles required and thus reduce the data rate.

A target sequence is established by the operator and used during initial target acquisition. The TIU memory is loaded prior to any data run from a data file in the order in which the targets are to be viewed.

For an example case of a model having 30 targets, the tracker might sample the full set 50 times each second. At this repetition rate, the effects of 50 to 200 Hz rigid body motion will be reduced but not necessarily eliminated. Multiple, random or asynchronous sampling of vibrating targets may be used to minimize the effect of harmonic sampling. The list provided to the TIU can be programmed for periodic, repetitive or broken target sequences. The SETS system approach provides significant flexibility in the ability to adapt to different situations and to be programmed for optimal performance as the result of analysis and experience.

Physical Description

Figure 1 shows the general components of the system. The National Transonic Facility installation requires system operation over a wide range of mechanical, thermal, acoustic, and optical conditions. The mechanical design has considered the requirements of the NTF locations, motion limits, target quality, and environment. An arrangement of equipment is provided that will meet the tunnel and model configuration requirements as presently defined. The full list of equipment includes the trackers, housing, cables, interface electronics, control system, computer, and operator display. Key characteristics of the system are listed in Table 1 and described in detail in later sections.

The SETS system performance is based on the use of LED targets that can be as small as 0.5-mm embedded in the model wing or fuselage. Tracker assemblies are located in the floor of the wind tunnel. This protects them from air flow but not from the hot or cold temperatures. The TIU, situated outside the tunnel is the interface for control of the trackers and targets.

The SETS computer, operator control console, tape storage and printer are to be located in the NTF control room. A control cabinet containing tracker-to-computer interface electronics, tracker power supplies and status monitoring circuitry is to be with the computer in the NTF control room. The SETS Equipment Rack, containing the Target Interface unit and Thermal Power Supplies, is to be located outside the tunnel pressure vessel. Tunnel penetrations are through hermetic connectors for the electrical circuits. Air is supplied to a manifold which distributes air through coolers to maintain tracker temperatures in a safe range during ambient and warm conditions.

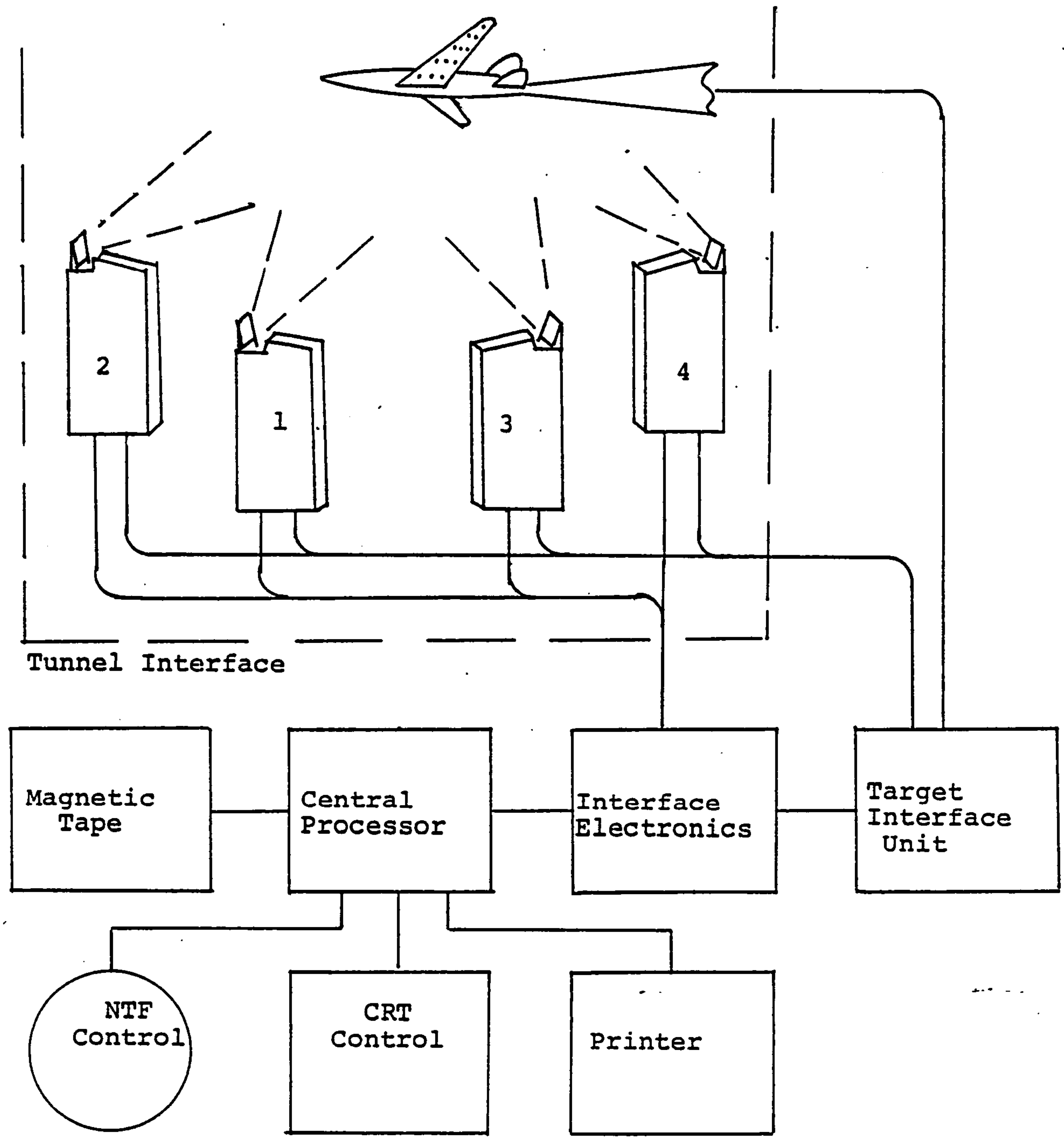


Figure 1. The Sets Components Comprise a Total Position Data Collection and Processing System.

Instrumentation Room Components

The SETS computer console and related equipment are shown in Figure 2. Key items in the group are the computer, disk unit, magnetic tape unit, and the SETS control cabinet. The SETS control cabinet is built to match the appearance of the commercial computer equipment. The SETS computer is similar to other computers in the NTF but is dedicated to the SETS. The computer consists of four cabinets, a printer, and a control CRT and keyboard. The cabinets must be physically located together due to data bus cable lengths, while the printer and CRT may be located some distance away. Cable lengths have been established based on the planned layout in the NTF Instrumentation Room.

The four racks of computer equipment were furnished to the SETS configuration. Interface logic cards in the control cabinet provide the data transmission, reception, and buffering necessary to match the computer input system. An alarm circuit monitors and indicates over-temperature, under-temperature, and over-pressure, (voltage and current limits are monitored by a software program). Power supplies for the tracker electronics are included in this cabinet. Control of the tracker heaters are here but the power supplies are in the Equipment Rack near the tunnel. Other than for initial setup and observation, the operator will not be operating the heater controls during normal tunnel operation. Information monitored by this cabinet is converted to digital form and is included in the stored data.

Trackers

The SETS trackers, one of which is shown in Figure 3, are to be located in the test section floor. A layout of a tracker is given in Figure 4. The trackers are designed to operate in the pressure and temperature environment of the tunnel and require phy-

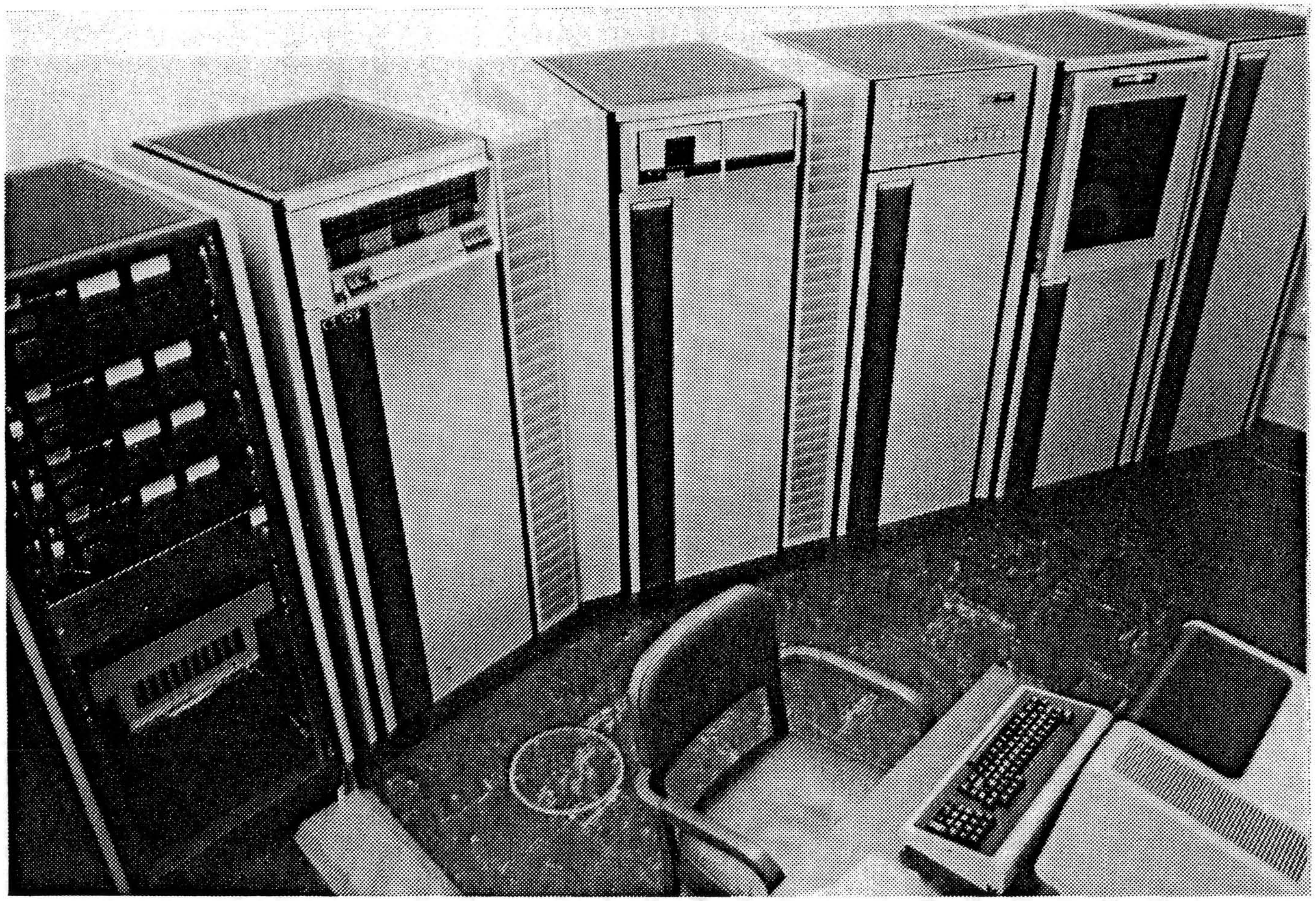


Figure 2. The SETS Control Electronics are contained in a Total of Six Cabinets, a Control Console and a Printer.

Table 1. SETS Characteristics

Sensed Volume (goal)	0.8-m by 1.4-m by 0.5-m
Target Sources, Number	Selectable from 2 to 63
, Type	Light-Emitting Diode
, Size	0.5-mm diameter
, Sequence	Selectable
Model Vibration Estimates	± 12.5-mm at 20-Hz ± 5-mm at 50-Hz ± 1.25-mm at 200-Hz
Trackers, Number	4 (Expandable to 6)
Optic Field	36° round (see Figures 5 and 6)
Distance from Model	122-cm below model
Center Pair	122-cm up- and down-stream on center
Side Pair (40 cm to side)	61-cm up- and down-stream
Capture Range at Model	
Center Pair	3.0-cm in a 120-cm diameter field
Side Pair	2.5-cm in a 100-cm diameter field
Target Location Resolution (Distance for Least Count)	0.02-mm
Target Sampling Rate	2270 targets per sec., maximum 1280 targets per sec., typical 555 targets per sec., minimum
Sensor Tube Type	ITT F4012, S20 photocathode
Environment	
Cold Operation	-193°C
Hot Operation	+65°C
Pressure	6-psia (380 Torr) to 130-psig (9 Atm)
Environment Control	Vortex Coolers and electrical heating for each tracker
Tracking Electronics	Digital, in Tracker unit
Distortion Calibration	Area map, prior to test
Pre-Test Reference	Pre-Test data run
Data Processor Type	MODCOMP Classic 7870
Data Storage	Magnetic Tape, 1600 BPI
Control/Display	Keyboard/CRT Display
Hard Copy	Line Printer, 300 LPM

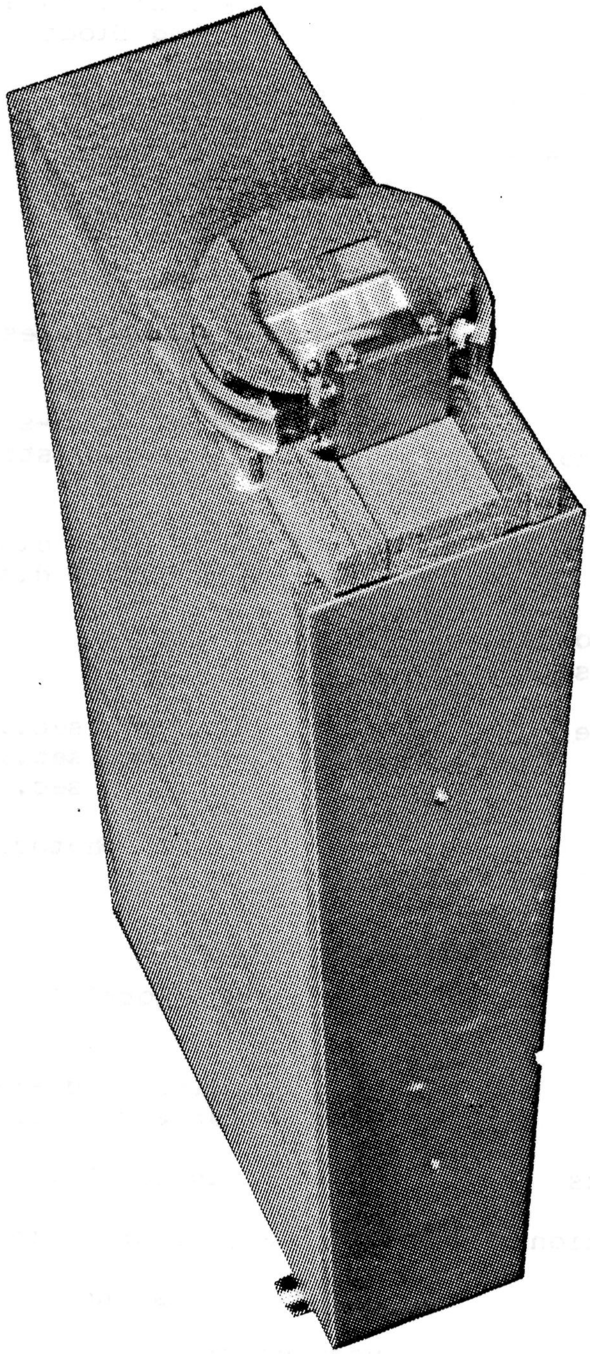


Figure 3. A SETS Tracker in a Stainless Steel Housing, with High Quality Insulation on all Outside Surfaces is Ready for the NTF Environment.

sical access only for maintenance. Each tracker has its own thermal control, power conditioning and pressure housing, providing independent operation. The electronics consist of two printed circuit board nests and a high voltage power supply assembly. Internal sub-assemblies are designed for thermal control with individual redundant controllers and heaters spaced on the nest surface and tube assembly to maintain the electronics in a range of 20°C to 40°C. A separate heater is provided to keep the lens warm at its location near the cold window.

Each Tracker consists of an image dissector tube assembly, optics, and associated electronics package inside a temperature and pressure controlled housing. The housing is insulated on the outside to protect the tracker from the wide range of temperature conditions in the NTF tunnel. The housing has a single optical quality window to prevent the tunnel pressure and temperature from entering the tracker. A second optical quality window in the tunnel test section floor isolates the tracker from the direct air flow. A drawing of this arrangement is shown in Figure 4.

Each tracker weighs approximately 32-kg (70-lb) mostly from the stainless steel pressure housing. Vibration isolators are provided to reduce vibrations which have the major effect on tracker performance (50-Hz and above). The housing design limits acoustic effects as well as mechanically coupled vibration.

Air Cooling

Mounting point temperatures can range from -193°C to 65°C. The tracker internal electronics present a 20-100 watt heat load. Because of the totally enclosed volume, this requries cooling at tunnel temperatures above 0°C. Internal heaters are thermostatically controlled to maintain a constant temperature when the tunnel is below that level.

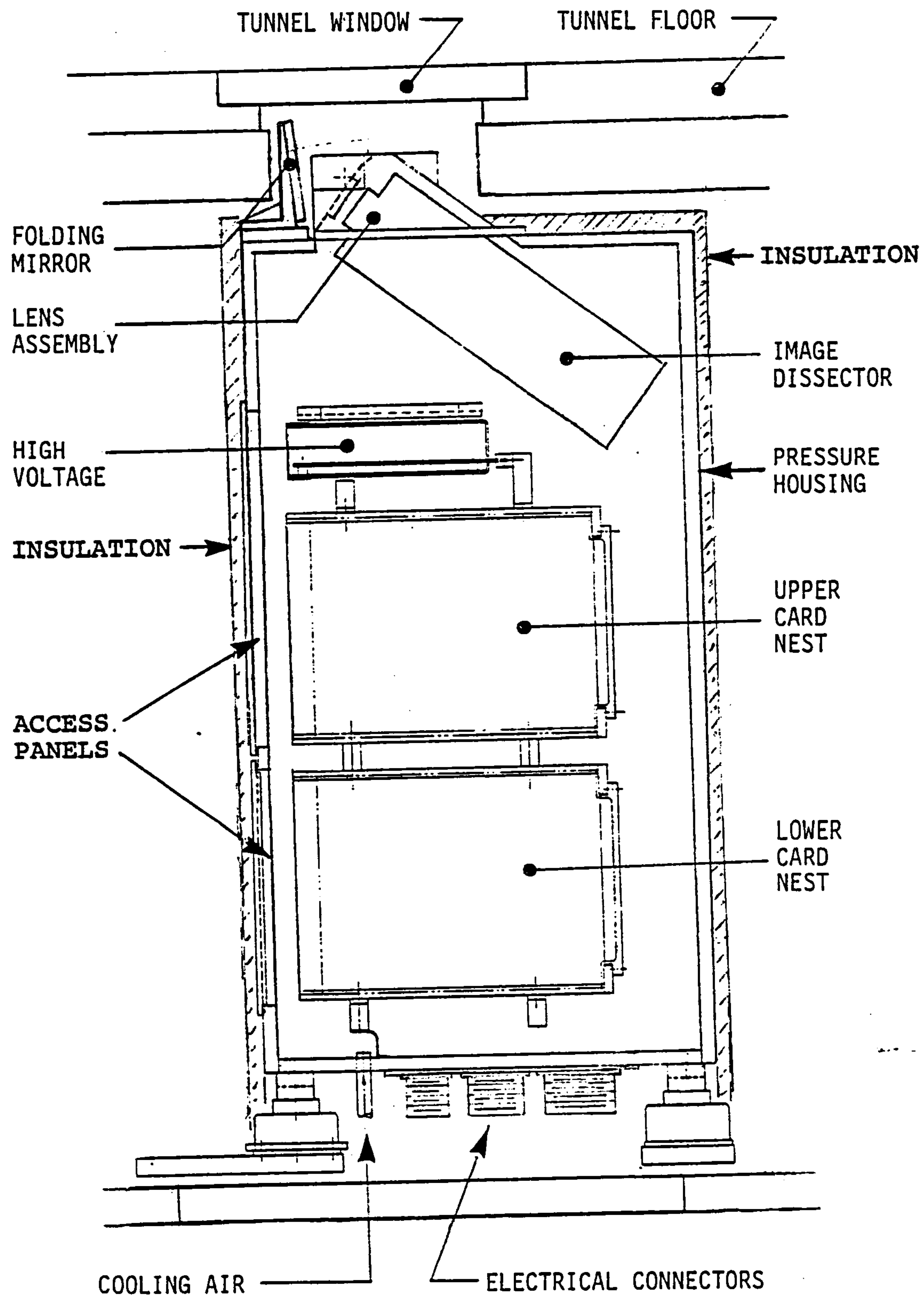


Figure 4. A SETS Tracker Layout Shows the Location of Key Parts

Cooling of the trackers is provided by dry air at 90-psi pressure through four 3/4-in. lines from a source outside the tunnel to a manifold below the floor beams. At that location, the air lines combine and then split again to four vortex coolers. These devices have an orifice shaped to cause vortex cooling of the air. Air cooler than -10°C is directed to the tracker, while hot air is vented to a large diameter return pipe. The cold air enters the tracker, circulates around the card nests and tube assembly, and exits back to the manifold for return to outside through a separate exhaust line.

The trackers interface electrically to the tunnel cabling at a junction box below the floor beams where connections to long cables are made. These long cables go to a tunnel penetration and from there to the TIU or to the Instrumentation room where the SETS computer and control cabinets are located.

Equipment Rack

An equipment rack, located outside the tunnel, contains the Target Interface Unit and Thermal Power supplies. Cables from the trackers interface here with a set of logic and control boards that provide the coordination of the trackers and control of the LED targets. All LEDs are wired into a matrix of 16 wires coming to the TIU. Power is applied to the two proper wires to turn on a given LED. In addition to providing control, the TIU can adjust the current level or brightness of the LED. This permits adjustment via an operator/computation routine during tunnel temperature changes to compensate for changes in LED brightness with temperature.

SYSTEM OPERATION

Optical Coverage

Figure 5 shows the location and optical coverage with respect to the model. There are two pairs of SETS trackers. Figure 6 shows the tracker field of view (FOV) identified with respect to the center of the model at the model height above the test section floor. Tracker locations have been selected based on the general requirements of models having a 122-mm (4-ft.) wingspan. Although any one or combination of the four trackers may be selected, the system is expected to be used in pairs. As seen in the figure, the available test volume has inexact boundaries, with the actual space extending to the limit of the tracker field of view. In the vertical direction, a region of at least 0.8-m by 0.5-m is sensed by each set of trackers, and at least 0.8-m in the combined view of the two trackers in the cross wind direction. The optic assembly for all trackers are the same and have a nominal full angle of 36° and an f number of 2.4 to assure detection of targets within the test volume. The field is set to view the target even when the model moves as much as 50-mm or is rotated ±19°.

Capture Range

The model is focussed on the face of the image dissector tube such that an area of 3.8-cm (1.5 in) at the model corresponds to the capture range of 435-μm (0.017-in) at the tube face. All light on the tube face is converted to electrons which are magnetically focussed at an aperture plate in the tube. The aperture plate has an opening 200-μm square. If the electron spot (approximately 20-μm diameter) goes through that opening, it will be detected as a signal.

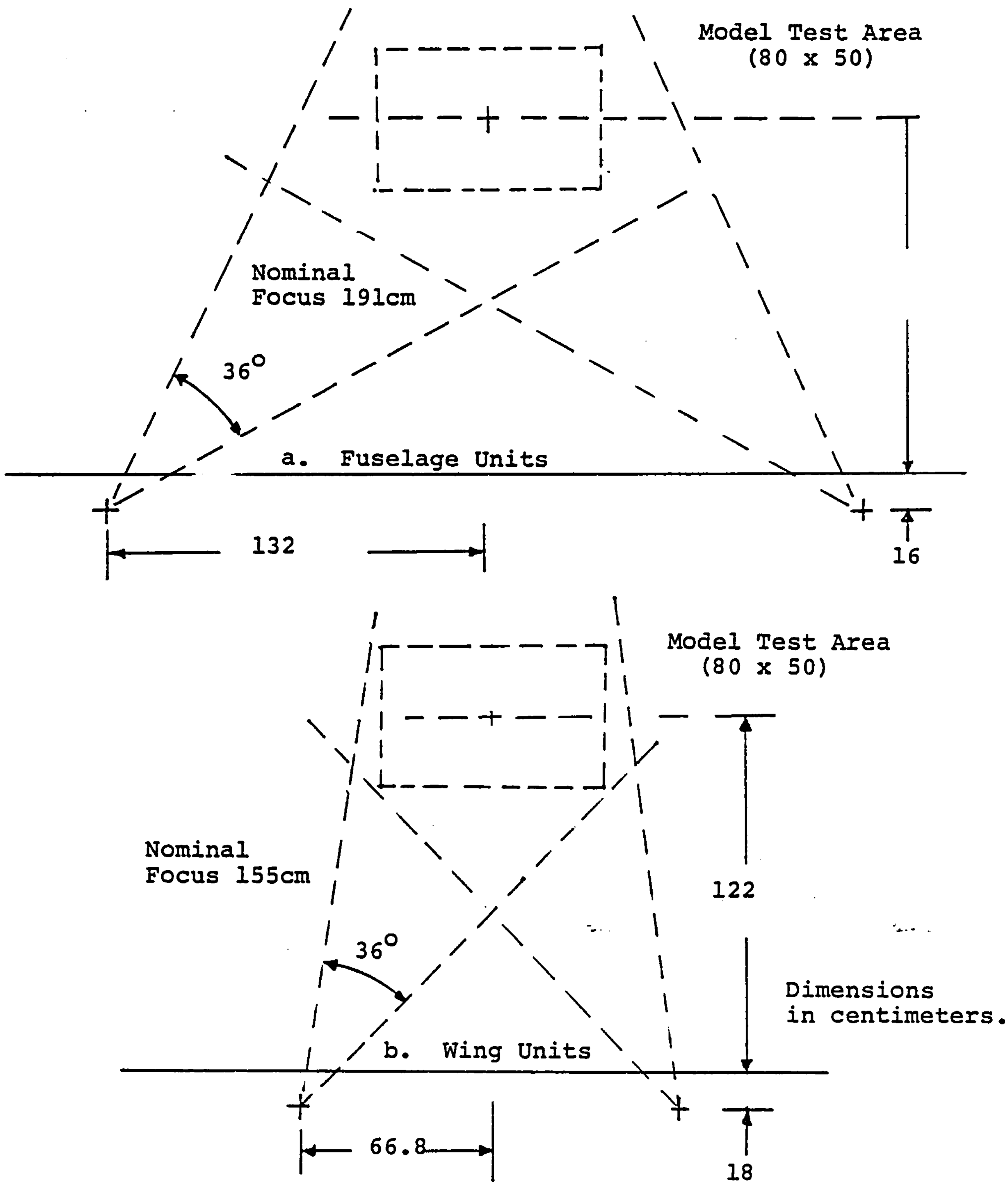
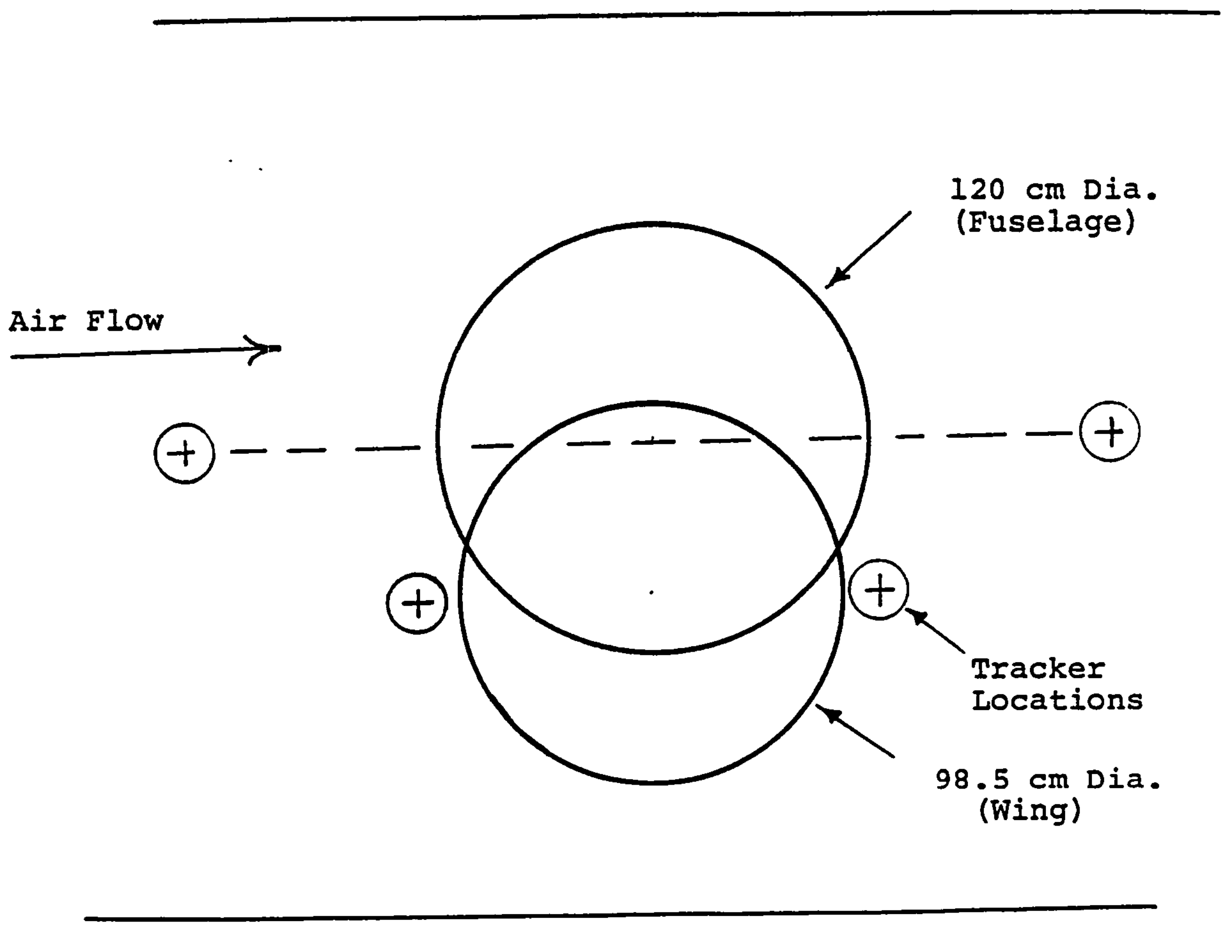


Figure 5. Tracker Location and Optic Patterns Set and Field for Model Viewing



Note. Fields are in a plane parallel to the tunnel floor and passing through the model center of rotation.

Figure 6. Tracking Fields at the Model Location Cover Large Areas.

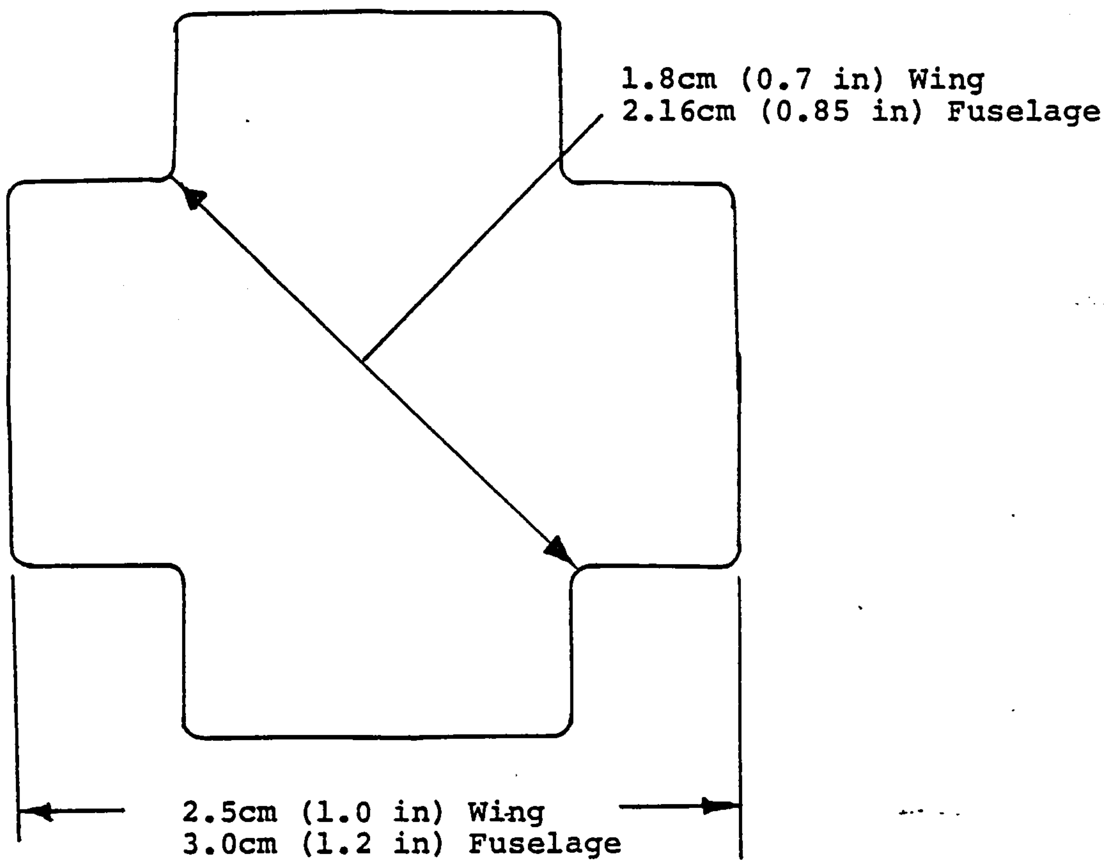
Deflection of the electron field permits capture of spots from any location in the scene. Once detected, the location can be accurately determined by moving it slightly in each axis and measuring the relative output signals. When equal output is detected from two near locations, the center of the spot can be inferred to a very high precision. An instantaneous capture range is established by the aperture size, outside of which the system must use a raster scan acquisition to locate a target. In Figure 7, the projection of the 200-μm by 200-μm capture area is shown enlarged. The center of the spot may be beyond that edge and still be detected since a typical light spot has a radius of at least 20-μm.

In terms of the model and capture of an LED target, the projection of the aperture area to the center of the model may be determined. From the two trackers as shown earlier, this area projects at a magnification of 69.4 for the side tracker and 85.6 for the center tracker. A light source can therefore be captured if it is within a roughly square area of 3.0-cm (1.2-in) or 3.7-cm (1.46-in) perpendicular to the optic axis for the side and center trackers, respectively.

Tracking Sequence

The central processor controls the entire system by sending commands directly to the TIU and each tracker. They echo back a reply that is checked to ensure the correct command was received and executed. Once the computer has transmitted all the necessary instructions, the hardware is capable of taking over and performing the tracking of targets itself. At this point, the computer monitors the hardware and records the data. A computer command stops the data recording and again puts the computer in control.

Figure 8, System Block Diagram, shows the main components and data flow. The control cabinet block includes the computer and the



Note: All values are approximate. Actual values depend on individual tracker calibration, target size, and target location.

Figure 7. Light from an LED Within this Area will be Captured by a Tracker Whose Scan is Centered on that Area

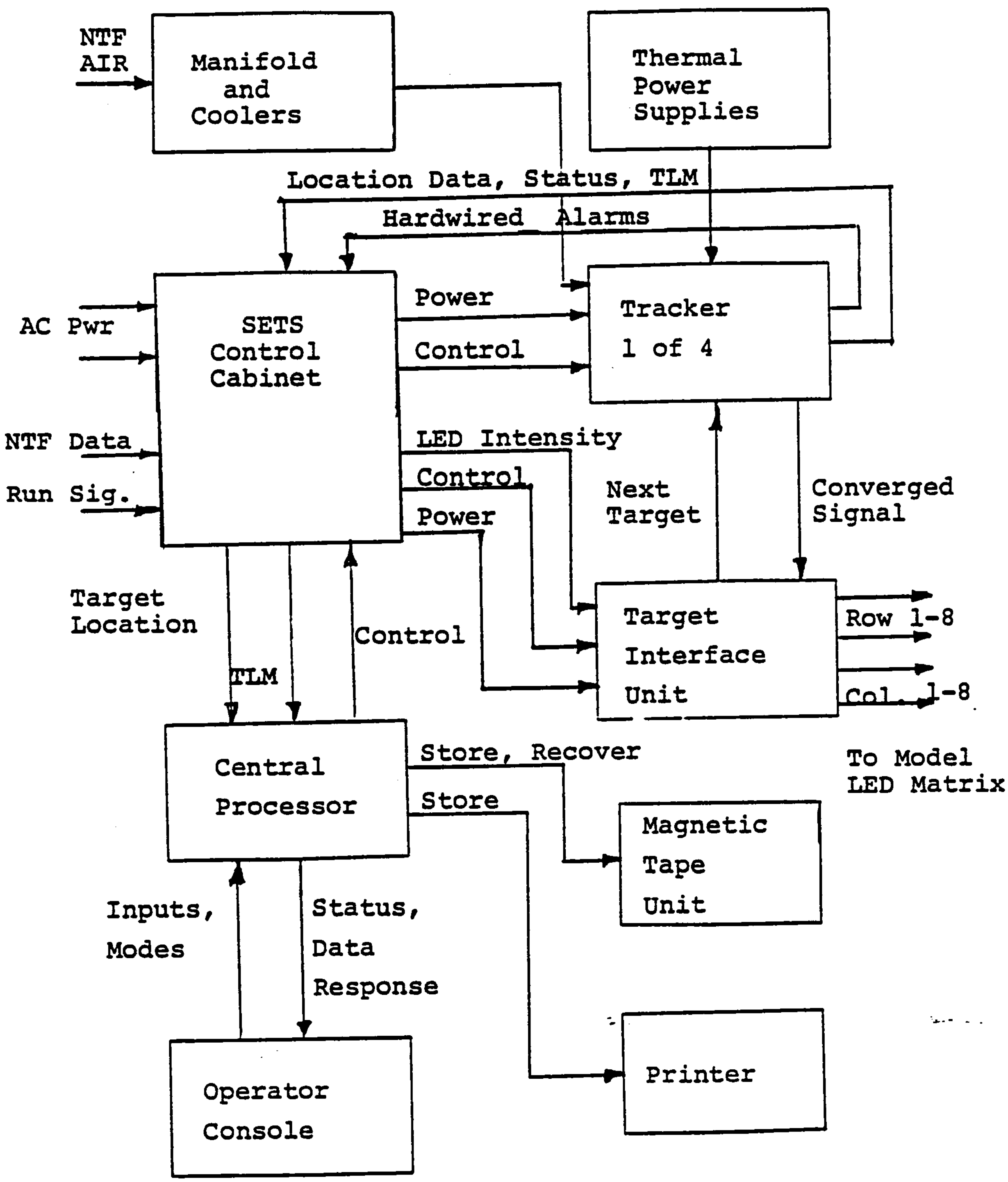


Figure 8. The System Block Diagram Shows Powers, Control and Data Interfaces.

SETS Control Cabinet. Only one tracker is shown to simplify the diagram. The sequence for SETS operation is to first locate the targets, then track them for some period of time, and finally, at the time of a test, record that data on magnetic tape. The first and last step of locating targets and recording data is under computer control. The middle step of tracking targets is under hardware control.

The computer locates the target position by using the Acquire software. This is a package of instructions that commands the trackers to scan the total field-of-view while a target is turned on and off. Once this target is located, its position is put into the memory of the tracker. The location is a 16-bit word for X and 16-bit word for Y. It is loaded by the computer-to-tracker data link into the location in memory reserved for that target and the next target is activated. Space is reserved for 63 possible targets. If the software is unable to locate the target, it is assumed that it is outside the tracker's field of view and simply not visible from that tracker. This is expected to happen for targets on the opposite sides of the model or for targets blocked by the wing or fuselage. This inability to see the target is transmitted to the tracker and stored in memory. It is a single bit for each target and is referred to as the "out of field" bit.

When the SETS software is activated, all the target location information is stored in the trackers and the Target Interface Unit is loaded with the target sequence. A list of target numbers and sequence are shown in Figure 9. The operator has complete freedom in selecting the order the targets are to be viewed. Targets can be repeated as many times as required. Targets can be left out of the list entirely if their measurement is not wanted. The sequence of targets can be selected in any order and any length up to 128 before repeating. It is simply terminated by selecting target number zero (which does not exist).

With the TIU and tracker memory loaded with the appropriate information, the computer can command them to begin tracking. The

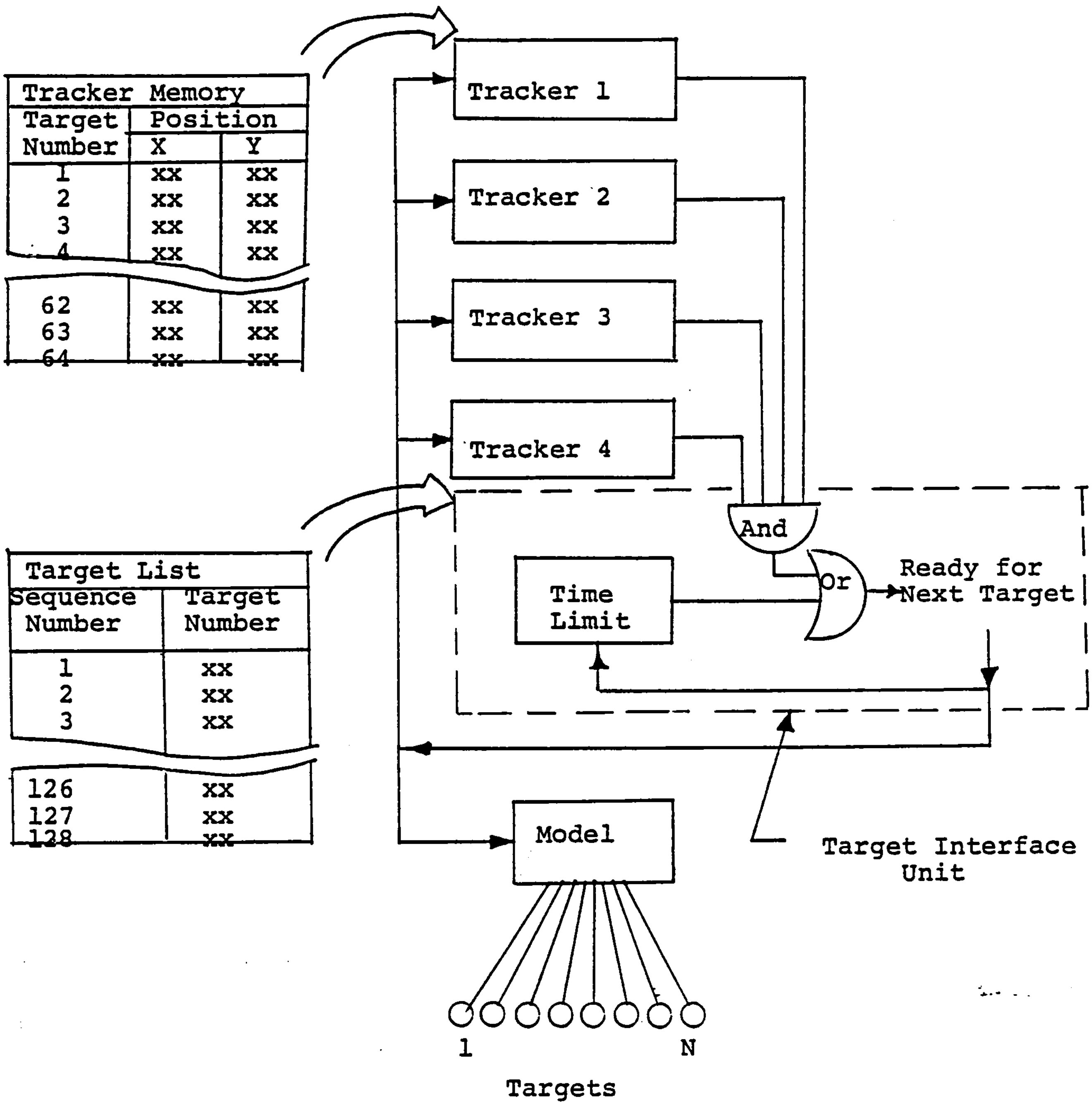


Figure 9. The Target Interface Units Controls the Target Selection and Advance Based on Operator Input and Tracker Convergence at Each Location.

trackers have two modes of tracking. In the Standby mode, the targets are tracked but their positions are not sent to the computer. This frees up the data lines and allows the operator to collect voltage and current (housekeeping) information. In the Record mode, the tracker will not only track but will send all the data to the computer. When in this mode, the data link is totally occupied with positional data preventing the monitoring or collection of housekeeping information for a short time.

The third step in the sequence is for the computer to collect and record the data. Each tracker has its own input to the computer. This input is buffered by the SETS interface board located in the control cabinet. The buffer temporarily stores the data, allowing the computer to record data in groups rather than at the continous rate that it is collected. The software collects data from up to four trackers and combines it in memory before dumping it to tape.

Automatic Tracking

The tracking sequence is hard-wired in each tracker and consists of calculating a new position based on four target signal samples as shown in Figure 10. These samples are centered on the last measured location of the target. The samples are taken one-half aperture width either side the initial location. The signals from the two locations are compared and a prediction of the new X location is based on the ratio of the sum and difference of the two signals. This new X value is then used during the Y measurement process. Measurements are taken one-half aperture distance above and below the initial Y value and the new Y location calculated. This sequence is repeated until the tracker has converged on the true center. The new locations are put into tracker memory. Typically, the system is converged in 4 cycles or less.

Dot • is last know position

Circle  is current target

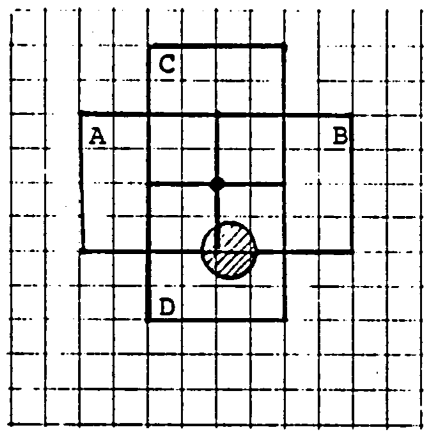
Gain (G) is 50

<u>First Cycle</u>

A = 3 B = 7 C = 0 D = 10

$$X' = X_o + G\left(\frac{9 - 1}{9 + 1}\right) = X_o + 20$$

$$Y' = Y_o + G\left(\frac{10 - 0}{10 + 0}\right) = Y_o + 50$$

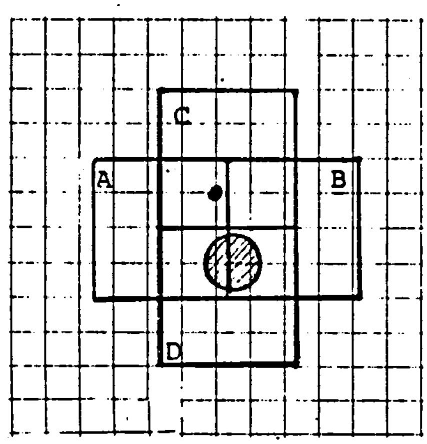


<u>Second Cycle</u>

A = 4 B = 6 C = 0 D = 10

$$X'' = X' + G\left(\frac{6 - 4}{6 + 4}\right) = X' + 10 = X_o + 30$$

$$Y'' = Y' + G\left(\frac{10-0}{10+0}\right) = Y' + 50 = Y_o + 100$$



<u>Third Cycle</u>

A = 4.5 B = 5.5 C = 4.5 D = 5.5

$$X = X'' + G\left(\frac{5.5-4.5}{5.5+4.5}\right) = X'' + 5 = X_o + 35$$

$$Y = Y'' + G\left(\frac{5.5-4.5}{5.5-4.5}\right) = Y'' + 5 = Y_o + 105$$

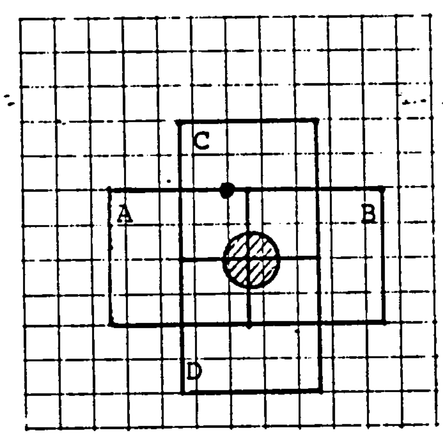


Figure 10. The Tracking Sequence is Simple Yet Effective

If the signal amplitude of the sum of the four samples is below a certain value, the target is assumed to be lost.

When the tracker has converged on the target, it generates a signal to the TIU. When all trackers have reported convergence, the TIU turns on the next target in its list and sends the next target number to the trackers. Each tracker then scans to its own location for that target, and the sequence is repeated. This can continue endlessly and is expected to maintain track during cooling and wind changes.

Time Relationships

Each action in the tracking cycle occurs in a timed sequence. As shown in Figure 11, the time spent at a given sample location is 20-μs. Each very small step on each axis (200-μm) is assigned 5-μs, movement to the other axis is given 40-μs, in a pattern which is repeated between X and Y until convergence. At convergence (or after 10 cycles if no acceptable target is found) the TIU command to go to the next target is given. A time of 140-μs is assigned to move to this new location and the cycles repeated.

The number of targets sampled in a second is variable, depending on the conditions which require more convergence cycles. As shown here, with 3 cycles as an example, a total of 610-μs is required to complete the sampling of one target and move to the next. At this rate, 1739 targets are sampled in one second. Four cycles require 780-μs, or 1280 per second. If one tracker does not find an acceptable sample on each target, and the limit of 10 is used, the total time per target is 130-μs x 10 + 40-μs x 9 + 104-μs = 1800-μs or 555 samples per second. This is the slowest rate of operation. Provision is made to delete a target in the list if it is not visible to a given tracker, and to change the number of limit cycles as experience dictates, to preserve the maximum useful samples rates.

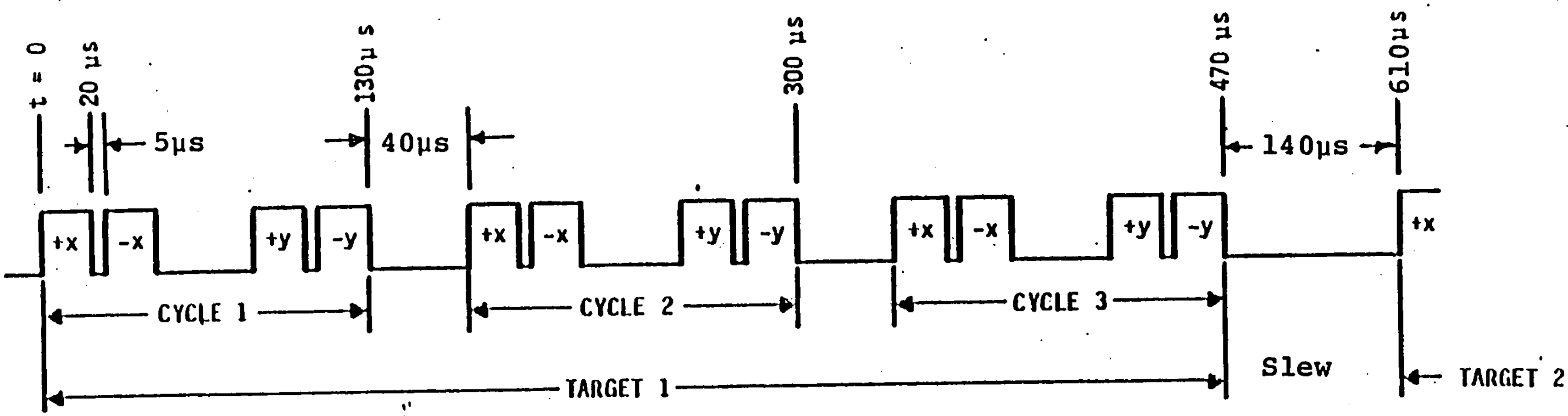


Figure 11. Tracker Function Timing Diagram Shows Specific Times for Each Operation.

Operating Modes

The SETS is designed for operator control from a CRT display and keyboard. Figure 12 shows the control of all operation originating from the Select Mode. The software is totally menu driven and always presents a list of functions that can be selected. The SELECT menu is shown in Figure 13. After selecting the appropriate function from the menu, the software may display a new menu for additional selections or it may request data or test information to perform the tasks assigned. The system is designed for flexibility of operation and will operate automatically once set in motion. The function of following the movement of a target (i.e., tracking) is performed totally within a tracker, thus permitting the operator and the computer to be doing other tasks while preparing for a run. When a data run is to be made, however, the computer is totally occupied collecting and storing the data. The SETS operating modes are summarized here.

<u>Initialize</u>. - The Initialize Mode is automatically activated when the SETS software is first run. This mode places the central processor in the configuration required by the rest of the SETS software. It also checks the SETS hardware and places it in a safe power-down condition.

<u>Select</u>. - The Select Mode is the software state that allows access to the other modes. This mode is the normal SETS software used when the system has not been specifically commanded to do something else.

When the software is in the Select Mode, the trackers may or may not be tracking targets depending on previous commands. The Select Mode does not imply any particular condition or operation of the hardware.

<u>Acquire</u>. - The purpose of the Acquire Mode is to generate a set of X and Y coordinate data for each tracker and for each target. It is used the first time the system is turned on and after any disturbance that caused the system to stop tracking. The

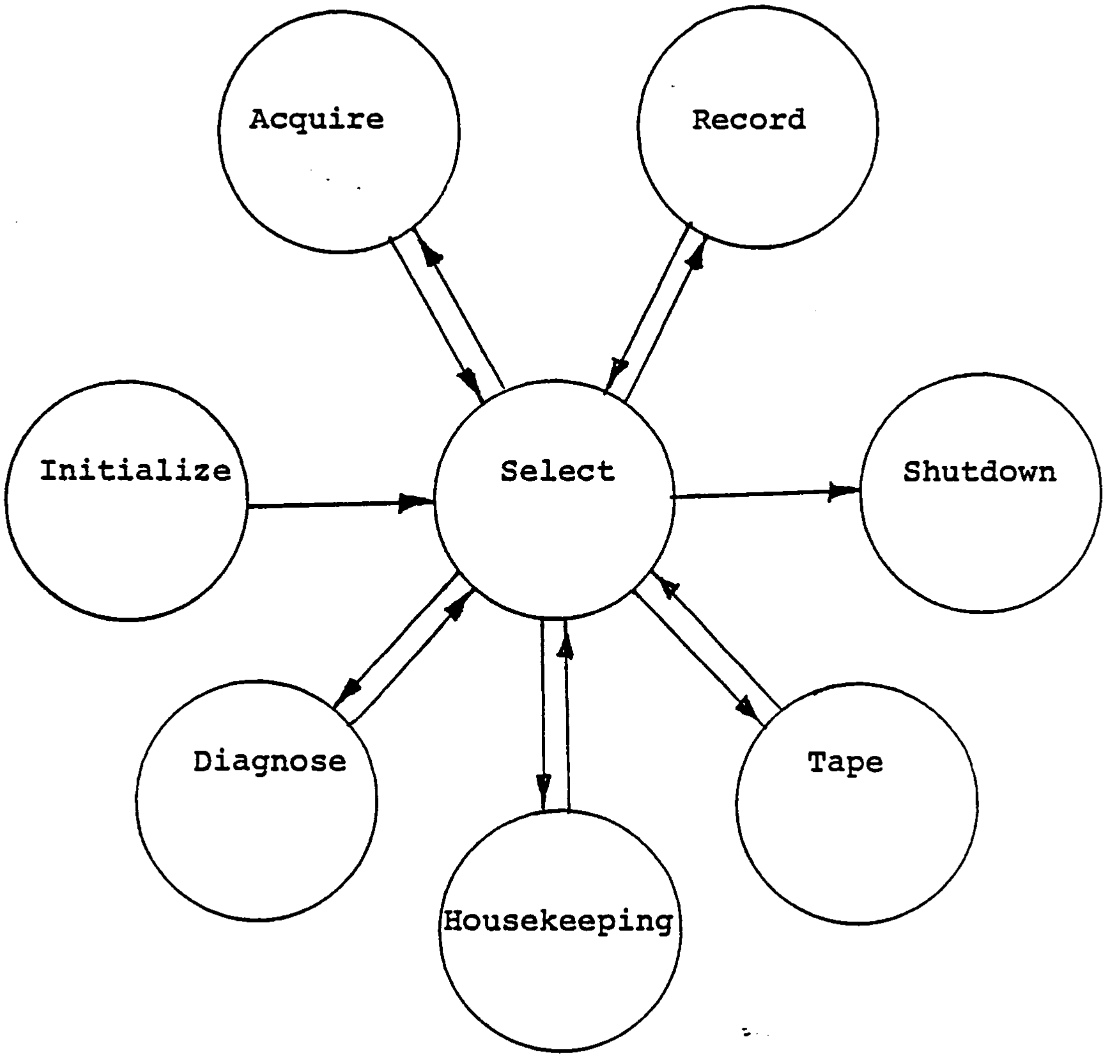


Figure 12. SETS Functional Modes are Initiated from a Select Mode where Menus Simplify System Operation.

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System Mode:   Select                                  Tracker 1:  ON
                                                       Tracker 2:  ON
Active Procedure:   Menu                               Tracker 3:  ON
Tape:               Unloaded                           Tracker 4:  ON
-----------------------------------------------------------------------

Possible Activities are:

 1)  Record Data          - Measure Target Position and Record Them
                            on Tape with the 'RUN' Label.
 2)  Record Data          - Measure Target Position and Record Them
                            on Tape with the 'TARE' Label.
 3)  Housekeeping         - Collect Current Housekeeping Data and
                            Add to Data File
 4)  Acquire all Targets  - Can Require considerable time if Targets
                            are not Presently being Tracked.
 5)  Diagnose Mode        - Continue Tracker Operations but Switch
                            to Computer Program for Self Testing.
 6)  Tape Change          - Continue Tracker Operations but Switch
                            to Computer Program for Tape Handling.
                            This will Prevent Data Recording.
 7)  Shutdown System      - Stop Tracking Targets.  Put Trailer on
                            the Tape, and turn Off Entire SETS System.
-----------------------------------------------------------------------

Enter Option Number.
```

Figure 13. The Select Menu Provides Easy Access to Every Operating Mode.

SETS operator may manually activate the Acquire Mode from the SELECT menu. At that time, the trackers stop any automatic tracking of targets and are put under computer control. (The only restriction is that Record Run Data Mode takes priority and cannot be interrupted).

In preparation for acquisition, the operator may estimate the location of each target to speed the process. He may load a separate file with the probable location of each target for each tracker. An alternative is to have this file recorded from a previous run (such as before system shut-down using the same model).

The computer directs each tracker to look for the targets at the location found in the target list. A measurement is made with the target turned off and again with it turned on. If the "on-level" is above the "target-off level" by a set value, the target is considered found. If it is not, the computer starts a scan of the nine areas centered on the initial area, moving 200-μm for each area. Again, the measurement of light-off and light-on are compared and the location which had the highest brightness is identified.

In the event that the light source is still not located, the computer enlarges the search area to a nine by nine element raster, and again to an 85 element by 85 element raster. This largest size raster covers the total field of the tracker.

The Acquisition sequence is repeated for every target in the target list. At completion, the computer will have a set of stored coordinates for each target that should be within the capture range of each tracker. If a target is not visible to a given tracker, that condition is given as out-of-field and will be recognized to prevent lost time searching for a non-existent target.

Record Mode. - In this mode, the computer records the X and Y coordinates received from each tracker. The data is buffered to take the data from all four trackers and reorganize it into a format for the magnetic tape. During a recording, the data system is fully occupied while the high data rate information is being collected, preventing any other command or diagnostic activity. The trackers continue their sequence of measuring a targets location and advancing to the next target with the Target Interface Unit in control. A typical Record Mode lasts for only a few seconds.

Diagnose Mode. - An operator has a variety of options and test routines available within the SETS programs. These include exercising the system for analysis, listing of electrical and temperature values, check housekeeping values, collect data from one target, test the memory, verify commands, check electronic gain, adjust LED intensity, perform raster scans, and add comments or information into the file. These functions are for the purpose of routine monitoring of the system health and for detection of problems in the hardware and software.

Housekeeping. - Analog values of temperature, pressure, voltage and current are read from many parts of the instruments and control systems. This data is converted to digital form in a special analog-to-digital conversion unit. At timed intervals, or when requested, this information, along with date, time and other header inputs, are collected for display, recording on the printer or on the magnetic tape.

Tape Change. - As its name indicates, this mode helps the operator through a checklist of tape related activities. Proper identification and headers are used in a NASA approved file system for accurate recording of all information.

Shutdown. - Functional conditions of all parts of the system are monitored in a shutdown sequence. Care must be exercised to control latent heat in the trackers and to be certain that all data is fully complete and the system stable before shutdown. The operator is guided through a series of steps and decisions in the closing down of the system.

PROGRAM STATUS

The SETS program (contract NAS1-16883) was initiated in December 1981 for the fabrication, test and installation of a complete system. The technical requirements grew from the preliminary study given in Reference 1 and the supporting study of Reference 2. Requirements for the measurement of model deformation were well defined, but the physical interfaces to the incomplete wind tunnel and model control systems were much less defined.

Development of the system was based on a definition of the tracker design and a complete software program design. As these progressed, numerous interface discussions modified and eventually solidified the physical, environmental, electrical and operational interfaces. Experience of the NASA Langley Instrumentation Branch and NTF engineering team was incorporated in the design to attain optimum performance under the extremes of pressure and temperature requried of an NTF instrument. This led to such decisions as the type of stainless steel for the housing, connector specifications, mounting location limitations, air cooling definition, tunnel penetrations, cable definition, parts location and others. The present configuration satisfies all of the known requirements and appears capable of coping with all combinations of environment and operation.

Software programs were developed for equipment control, data processing, operator interfaces, data recording and interfaces to the various instruments, processors, recording and control components. This effort was more complex and extensive than originally conceived, and was hampered significantly by the incomplete status of the Modcomp FORTRAN'77 diagnostics, and unfamiliarity of the ITT software developers with this particular equipment. Effort on fine tuning and correcting the operating, test and calibration routines continued up to the time of delivery and will probably be a continuing activity as the system is exercised in the laboratory environment preparatory for installation in the NTF.

Test programs for the validation of instrument performance required in-depth analyses and consideration of new test methods. The high resolution capability of each tracker (one part in 65,000 of the optic field) required both design and test to provide control and stability of optical, magnetic deflection and electronics to this level of quality.

Testing was accomplished at the circuit level where accuracy and stability of such circuits as the high voltage supply and focus current regulators were verified. Signal sensitivity tests on the tubes using representative diodes verified the ability to locate and track targets with sufficient signal-to-noise margin. Scan capability was tested using diodes mounted to a metal bar with known dimensions located at the model position. Speed, capture range and convergence were tested using pairs of diodes on micrometer controlled spacings where sequential gating provided the necessary inputs for evaluation.

Ambient, warm and cold tests required major test setups for controlling the temperature and monitoring performance. An enclosed aluminum box acted as the test chamber, where one tracker could be held in a still air environment while the box was heated or cooled. Electrical and air line interfaces provided simulated tunnel conditions. The warm tests led to several changes to improve air circulation and heat dissipation within the tracker. These and other improvements were needed as the system was subjected to a cold environment since both inherent dissipation and thermal control heaters provided non-uniform heat distribution within the instrument. Even in cold conditions, it was found desirable to maintain a low level of dry nitrogen gas to purge the unit and distribute the heat loads.

Operation at -193°C (-315°F) was obtained by inserting the aluminum test box containing a tracker in an insulated enclosure and filling the interspace with liquid nitrogen. Even after many hours of exposure, the system operated at very realistic temperatures and in full functional performance. It was difficult to perform a quantitative test of performance under those conditions but the indications are that the system would operate at full capacity.

Tests of the housings with optical windows in place were performed at NASA, subjecting one housing to repeated cold temperatures and all housings to pressures from 6 psi to 160 psi. No fatigue or failures were noted in any housing. The windows were found to be severely stressed, with some broken and others crazed at the mounting locations. A redesign of the windows was initiated and all new windows procured. These have not yet been tested in a similar environment.

Measurement of operation over a wide field of view to high accuracies was obtained by the fabrication of a precision test plate 122 cm (4 ft.) square containing 576 light emitting diodes. These diodes were wired to provide arrays that individually and collectively could define the distortion patterns of each tracker. The diodes were connected and operated as if they were part of an aircraft model, producing a full system simulation with one to four trackers operating.

At the completion of the development program, a test and demonstration was given at the contractor's facility. This occurred on May 23-25, 1984, with all functional and performance features demonstrated.

The total system, including all special test equipment was disassembled and shipped to NASA Langley, leaving ITT on June 6, 1984 arriving at NASA on June 13. The material was installed in a laboratory environment where a section of NTF test section flooring was simulated for accurate system testing. Engineering and training assistance was provided to NASA from June 25 to July 20, 1984, constituting final acceptance from the contractor and the end of this reporting period.

Effort is to continue by NASA in operation, test and interface with models and the NTF computer complex. Support services will be provided by the contractor as required to assist in understanding, maintaining or modifying the equipment or software as requested by NASA. Installation in the NTF will occur after completion of these interim activities and at a time chosen by the operating and test managers.

PROJECT TEST DATA REVIEW

The test plan for final system functional and operational testing is given in Figure 14. These tests were completed over a period of weeks preceding the final acceptance at the contractor's facility. Selected tests were repeated at the time of review in May.

A synopsis of the tests performed and final data from the major tests are given below.

- Field of View
- Tracking Convergence
- Capture Range
- Intensity
- Distortion
- Hot Test
- Cold Test

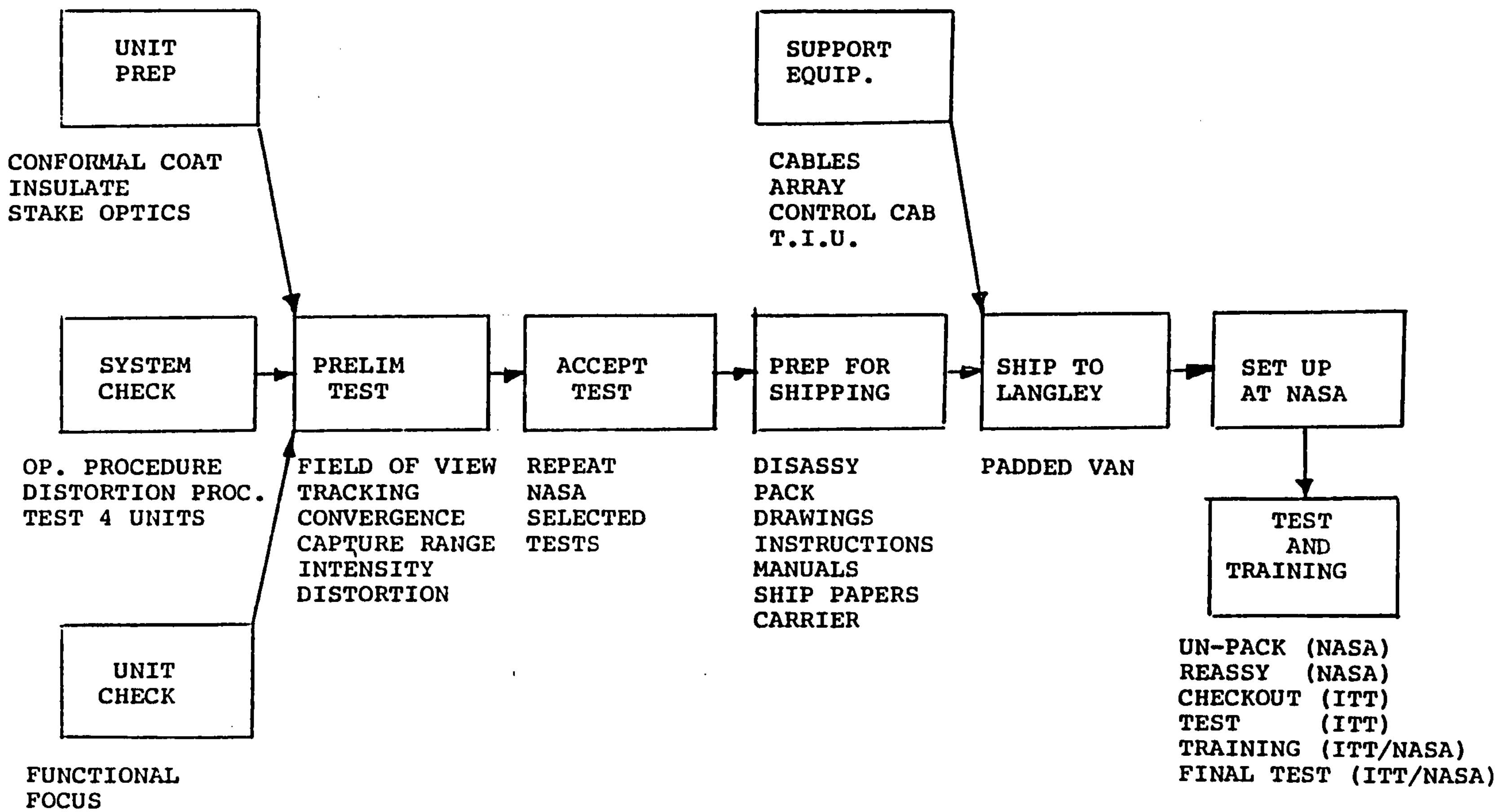

Figure 14. SETS Final Test Flow Diagram

TRACKER DATA SUMMARY

STEREO ELECTRO-OPTICAL TRACKER SYSTEM

TRACKER NUMBER: 1

TRACKER TYPE: WING

CALIBRATION			
DIRECTION (AXIS):	X	Y	
SCALE FACTORS	1547	1529	Counts per Inch
OFFSET	0	0	Counts
FIELD OF VIEW			
FULL FIELD DEGREES		36.0	Degrees
WIDTH AT MODEL CENTER		38.8	Inches
IMAGE DISSECTOR APERTURE			
50% WIDTH IN TRACKER		782	Counts
50% WIDTH ON MODEL		.505	Inches
CAPTURE RANGE			
WIDTH IN TRACKER		1564	Counts
WIDTH ON MODEL		1.011	Inches

TRACKER PERFORMANCE

(STANDARD DEVIATION - X AXIS)		
DARK ROOM	1.22 Counts	0.0008 Inches
	1.35 Counts	0.0009 Inches
NORMAL ROOM LIGHTING	1.12 Counts	0.0007 Inches
	1.20 Counts	0.0008 Inches
(STANDARD DEVIATION - Y AXIS)		
DARK ROOM	1.41 Counts	0.0009 Inches
	1.43 Counts	0.0009 Inches
NORMAL ROOM LIGHTING	1.35 Counts	0.0009 Inches
	1.27 Counts	0.0008 Inches

CONVERGENCE

ERROR at 10 count position:	0	Counts
MAX SLEW RATE:	96	Counts

TRACKER DATA SUMMARY

STEREO ELECTRO-OPTICAL TRACKER SYSTEM

TRACKER NUMBER: 1

TRACKER TYPE: WING

NOMINAL DISTANCE
TRACKER WINDOW TO MODEL CENTER 58.44 Inches

NOMINAL CONTROL CABINET READINGS

* PLUS 15 POWER SUPPLY (HI)	.93 Amps at 20.0 Volts
* PLUS 15 POWER SUPPLY (LOW)	.83 Amps at 20.0 Volts
MINUS 15 POWER SUPPLY	.45 Amps at 20.0 Volts
PLUS 5 POWER SUPPLY	.08 Amps at 12.0 Volts

* (The Plus 15 Current will change as the DAC heaters cycle) (Values are for THIS TRACKER and TIU ONLY and include approx. 0.15 A at -15V, and 0.3 A at +5V for the TIU)

NOMINAL INTERNAL VOLTAGES

PLUS 5 Vdc	4.89 Volts
PLUS 15 Vdc	14.89 Volts
MINUS 15 Vdc	-14.97 Volts
PLUS 45 Vdc	45.13 Volts
MINUS 45 Vdc	-45.46 Volts

NOMINAL INTERNAL CURRENTS

PLUS 5 Vdc	.72 Amps
PLUS 15 Vdc	.62 Amps
MINUS 15 Vdc	.31 Amps
PLUS 45 Vdc	--- Amps
MINUS 45 Vdc	--- Amps

IMAGE DISSECTOR VALUES

H.V. SETTING	H.V. REFERENCE	H.V. VALUE
0001 (HEX)	1.81	1427
0002	1.89	1490
0004	1.93	1524
0008	2.03	1599
0010	2.09	1638
0020	2.17	1701
0040	2.24	1759
0080 NOMINAL	2.36	1838
FOCUS CURRENT	0.08 Amps	

TRACKER DATA SUMMARY

STEREO ELECTRO-OPTICAL TRACKER SYSTEM

TRACKER NUMBER: 3

TRACKER TYPE: WING

CALIBRATION

DIRECTION (AXIS):	X	Y	
SCALE FACTORS	1598	1560	Counts per Inch
OFFSET	0	2000	Counts

FIELD OF VIEW

FULL FIELD DEGREES	36.6	Degrees
WIDTH AT MODEL CENTER	39.5	Inches

IMAGE DISSECTOR APERTURE

50% WIDTH IN TRACKER	768	Counts
50% WIDTH ON MODEL	.480	Inches

CAPTURE RANGE

WIDTH IN TRACKER	1536	Counts
WIDTH ON MODEL	0.960	Inches

TRACKER PERFORMANCE

(STANDARD DEVIATION - X AXIS)				
DARK ROOM	1.36	Counts	0.0008	Inches
	1.24	Counts	0.0008	Inches
NORMAL ROOM LIGHTING	1.27	Counts	0.0008	Inches
	1.47	Counts	0.0009	Inches
(STANDARD DEVIATION - Y AXIS)				
DARK ROOM	1.64	Counts	0.0011	Inches
	1.64	Counts	0.0011	Inches
NORMAL ROOM LIGHTING	1.44	Counts	0.0009	Inches
	1.32	Counts	0.0008	Inches

CONVERGENCE

ERROR at 10 count position:	0	Counts
MAX SLEW RATE:	96	Counts

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TRACKER DATA SUMMARY

STEREO ELECTRO-OPTICAL TRACKER SYSTEM

TRACKER NUMBER: 3

TRACKER TYPE: WING

NOMINAL DISTANCE
TRACKER WINDOW TO MODEL CENTER 58.44 Inches

NOMINAL CONTROL CABINET READINGS

* PLUS 15 POWER SUPPLY (HI)	.94 Amps	at 20.0 Volts
* PLUS 15 POWER SUPPLY (LOW)	.84 Amps	at 20.0 Volts
MINUS 15 POWER SUPPLY	.46 Amps	at 20.0 Volts
PLUS 5 POWER SUPPLY	.08 Amps	at 12.0 Volts

* (The Plus 15 Current will change as the DAC heaters cycle) (Values are for THIS TRACKER and TIU ONLY and include approx. 0.15 A at -15V, and 0.3 A at +5V for the TIU)

NOMINAL INTERNAL VOLTAGES

PLUS 5 Vdc	4.96 Volts
PLUS 15 Vdc	14.77 Volts
MINUS 15 Vdc	-15.04 Volts
PLUS 45 Vdc	45.36 Volts
MINUS 45 Vdc	-45.35 Volts

NOMINAL INTERNAL CURRENTS

PLUS 5 Vdc	.64 Amps
PLUS 15 Vdc	.81 Amps
MINUS 15 Vdc	.31 Amps
PLUS 45 Vdc	--- Amps
MINUS 45 Vdc	--- Amps

IMAGE DISSECTOR VALUES

H.V. SETTING	H.V. REFERENCE	H.V. VALUE
0001 (HEX)	1.81	1466
0002	1.90	1529
0004	1.94	1564
0008	2.03	1634
0010	2.09	1677
0020	2.17	1736
0040	2.25	1795
0080 NOMINAL	2.36	1857
FOCUS CURRENT	0.08 Amps	

TRACKER DATA SUMMARY

STEREO ELECTRO-OPTICAL TRACKER SYSTEM

TRACKER NUMBER: 4

TRACKER TYPE: FUSELAGE

CALIBRATION			
DIRECTION (AXIS):	X	Y	
SCALE FACTORS	1261	1236	Counts per Inch
OFFSET	0	0	Counts

FIELD OF VIEW		
FULL FIELD DEGREES	37.0	Degrees
WIDTH AT MODEL CENTER	49.5	Inches
IMAGE DISSECTOR APERTURE		
50% WIDTH IN TRACKER	765	Counts
50% WIDTH ON MODEL	.600	Inches
CAPTURE RANGE		
WIDTH IN TRACKER	1530	Counts
WIDTH ON MODEL	1.200	Inches

TRACKER PERFORMANCE				
(STANDARD DEVIATION - X AXIS)				
DARK ROOM	1.62	Counts	0.0013	Inches
	1.49	Counts	0.0012	Inches
NORMAL ROOM LIGHTING	1.76	Counts	0.0014	Inches
	1.55	Counts	0.0012	Inches
(STANDARD DEVIATION - Y AXIS)				
DARK ROOM	1.83	Counts	0.0015	Inches
	1.88	Counts	0.0015	Inches
NORMAL ROOM LIGHTING	1.68	Counts	0.0014	Inches
	1.59	Counts	0.0013	Inches

CONVERGENCE		
ERROR at 10 count position:	0	Counts
MAX SLEW RATE:	96	Counts

TRACKER DATA SUMMARY

STEREO ELECTRO-OPTICAL TRACKER SYSTEM

TRACKER NUMBER: 4

TRACKER TYPE: FUSELAGE

NOMINAL DISTANCE
TRACKER WINDOW TO MODEL CENTER 73.21 Inches

NOMINAL CONTROL CABINET READINGS

* PLUS 15 POWER SUPPLY (HI)	.96 Amps at 20.0 Volts
* PLUS 15 POWER SUPPLY (LOW)	.85 Amps at 20.0 Volts
MINUS 15 POWER SUPPLY	.45 Amps at 20.0 Volts
PLUS 5 POWER SUPPLY	.08 Amps at 12.0 Volts

* (The Plus 15 Current will change as the DAC heaters cycle) (Values are for THIS TRACKER and TIU ONLY and include approx. 0.15 A at -15V, and 0.3 A at +5V for the TIU)

NOMINAL INTERNAL VOLTAGES

PLUS 5 Vdc	4.96 Volts
PLUS 15 Vdc	14.89 Volts
MINUS 15 Vdc	-14.85 Volts
PLUS 45 Vdc	45.36 Volts
MINUS 45 Vdc	-45.46 Volts

NOMINAL INTERNAL CURRENTS

PLUS 5 Vdc	.20 Amps
PLUS 15 Vdc	.72 Amps
MINUS 15 Vdc	.31 Amps
PLUS 45 Vdc	--- Amps
MINUS 45 Vdc	--- Amps

IMAGE DISSECTOR VALUES

H.V. SETTING	H.V. REFERENCE	H.V. VALUE
0001 (HEX)	1.81	1495
0002	1.90	1474
0004	1.94	1517
0008	2.04	1587
0010	2.10	1630
0020	2.17	1681
0040	2.25	1732
0080 NOMINAL	2.36	1798
FOCUS CURRENT	0.08 Amps	

TRACKER DATA SUMMARY

STEREO ELECTRO-OPTICAL TRACKER SYSTEM

TRACKER NUMBER: 2

TRACKER TYPE: FUSELAGE

CALIBRATION			
DIRECTION (AXIS):	X	Y	
SCALE FACTORS	1284	1252	Counts per Inch
OFFSET	0	+4400	Counts
FIELD OF VIEW			
FULL FIELD DEGREES		38.6	Degrees
WIDTH AT MODEL CENTER		52.3	Inches
IMAGE DISSECTOR APERTURE			
50% WIDTH IN TRACKER		782	Counts
50% WIDTH ON MODEL		.659	Inches
CAPTURE RANGE			
WIDTH IN TRACKER		1564	Counts
WIDTH ON MODEL		1.218	Inches

TRACKER PERFORMANCE		
(STANDARD DEVIATION - X AXIS)		
DARK ROOM	1.92 Counts	0.0015 Inches
	1.80 Counts	0.0014 Inches
NORMAL ROOM LIGHTING	2.01 Counts	0.0016 Inches
	1.83 Counts	0.0014 Inches
(STANDARD DEVIATION - Y AXIS)		
DARK ROOM	2.27 Counts	0.0018 Inches
	1.72 Counts	0.0013 Inches
NORMAL ROOM LIGHTING	1.86 Counts	0.0015 Inches
	1.85 Counts	0.0015 Inches

CONVERGENCE		
ERROR at 10 count position:	0	Counts
MAX SLEW RATE:	96	Counts

TRACKER DATA SUMMARY

STEREO ELECTRO-OPTICAL TRACKER SYSTEM

TRACKER NUMBER: 2

TRACKER TYPE: FUSELAGE

NOMINAL DISTANCE
TRACKER WINDOW TO MODEL CENTER 73.21 Inches

NOMINAL CONTROL CABINET READINGS

* PLUS 15 POWER SUPPLY (HI)	.92 Amps at 20.0 Volts
* PLUS 15 POWER SUPPLY (LOW)	.81 Amps at 20.0 Volts
MINUS 15 POWER SUPPLY	.45 Amps at 20.0 Volts
PLUS 5 POWER SUPPLY	.08 Amps at 12.0 Volts

* (The Plus 15 Current will change as the DAC heaters cycle) (Values are for THIS TRACKER and TIU ONLY and include approx. 0.15 A at -15V, and 0.3 A at +5V for the TIU)

NOMINAL INTERNAL VOLTAGES

PLUS 5 Vdc	4.91 Volts
PLUS 15 Vdc	14.81 Volts
MINUS 15 Vdc	-14.89 Volts
PLUS 45 Vdc	45.13 Volts
MINUS 45 Vdc	-45.57 Volts

NOMINAL INTERNAL CURRENTS

PLUS 5 Vdc	.67 Amps
PLUS 15 Vdc	.67 Amps
MINUS 15 Vdc	.31 Amps
PLUS 45 Vdc	--- Amps
MINUS 45 Vdc	--- Amps

IMAGE DISSECTOR VALUES

H.V. SETTING	H.V. REFERENCE	H.V. VALUE
0001 (HEX)	1.80	1431
0002	1.88	1497
0004	1.93	1529
0008	2.02	1603
0010	2.08	1646
0020	2.16	1709
0040	2.23	1767
0080 NOMINAL	2.35	1857
FOCUS CURRENT	0.08 Amps	

NASA Publications

1. Hertel, Richard: Study of a Stereo Electro-Optical Tracker System for the Measurement of Model Aeroelastic Deformations at the National Transonic Facility, NASA CR-159146, 1979.

2. Hertel, Richard; and Hoilman, Kent: Stereo Electro-Optical Tracker Study for the Measurement of Model Deformations at the National Transonic Facility, NASA CR-165821, 1982.

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Final Report, 1981-1984

16. Abstract
The SETS is a remote, non-contacting, high-accuracy tracking system for the measurement of deflection of models in the National Transonic Facility at Langley Research Center. The system consists of four (4) electronically scanned image dissector trackers which locate the position of Light Emitting Diodes embedded in the wing or body of aircraft models. Target location data is recorded on magnetic tape for later 3-D processing. Up to 63 targets per model may be tracked at typical rates of 1280 targets per second and to precision of 0.02mm at the target under the cold (-193°C) environment of the NTF tunnel.

17. Key Words (Suggested by Author(s))
Remote measurement
High-resolution motion detector
Electro-optical tracking
Wind tunnel instrument
Model deformation measurement

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