

Background

- **Microbursts + other factors**
 - crash aircraft taking off or landing
 - close runways
 - cause delays
 - force alternative airport landings.
- **Microburst detection, location and measurement**
 - will enhance airport usage and safety.

MITRE

Microbursts, streams of rapidly moving, downwardly directed air, are a principal cause of wind shear hazards. The air within a microburst cools rapidly due to water drop evaporation and melting hail, both of which maintain negative buoyancy in the air and propel it to the ground. Microbursts are always associated with clouds and principally with severe convective storms, though microbursts have been observed beneath virga-like precipitation. Microbursts are typically elliptical in shape and initiate relatively high in the atmosphere where heavily water-laden air can have diameters of ten km or more. The negatively-buoyantly maintained rapid downward acceleration of this water-laden air causes a microburst to become narrower as it approaches the ground so that it may have a diameter of less than a kilometer near the ground. When the air in a microburst strikes the ground, it scoots out horizontally in a diverging pattern from a central point (or nadir).

Due to the strongly divergent air, a moving aircraft first experiences a headwind, which increases lift, rapidly followed by a tailwind, which reduces lift by reducing the relative speed of the aircraft. A significant loss of altitude can occur which, depending on the altitude of the aircraft, can cause a crash.

LONG TERM IMPACT

- HIGH CONFIDENCE OF DETECTING, LOCATING ALL MICROBURSTS
- ECONOMIC OBJECTIVE: AFFORDABLE LOW COST
- WORLDWIDE CONSCIOUSNESS OF MITRE'S COMMITMENT TO AIRPORT SAFETY
- POTENTIAL SPONSORS
 - GOVERNMENT AGENCIES RESPONSIBLE FOR AIRPORT SAFETY
 - FAA
 - MAJOR AIRPORTS
 - MINOR AIRPORTS
 - AIRPORT MANAGEMENT, WORLDWIDE

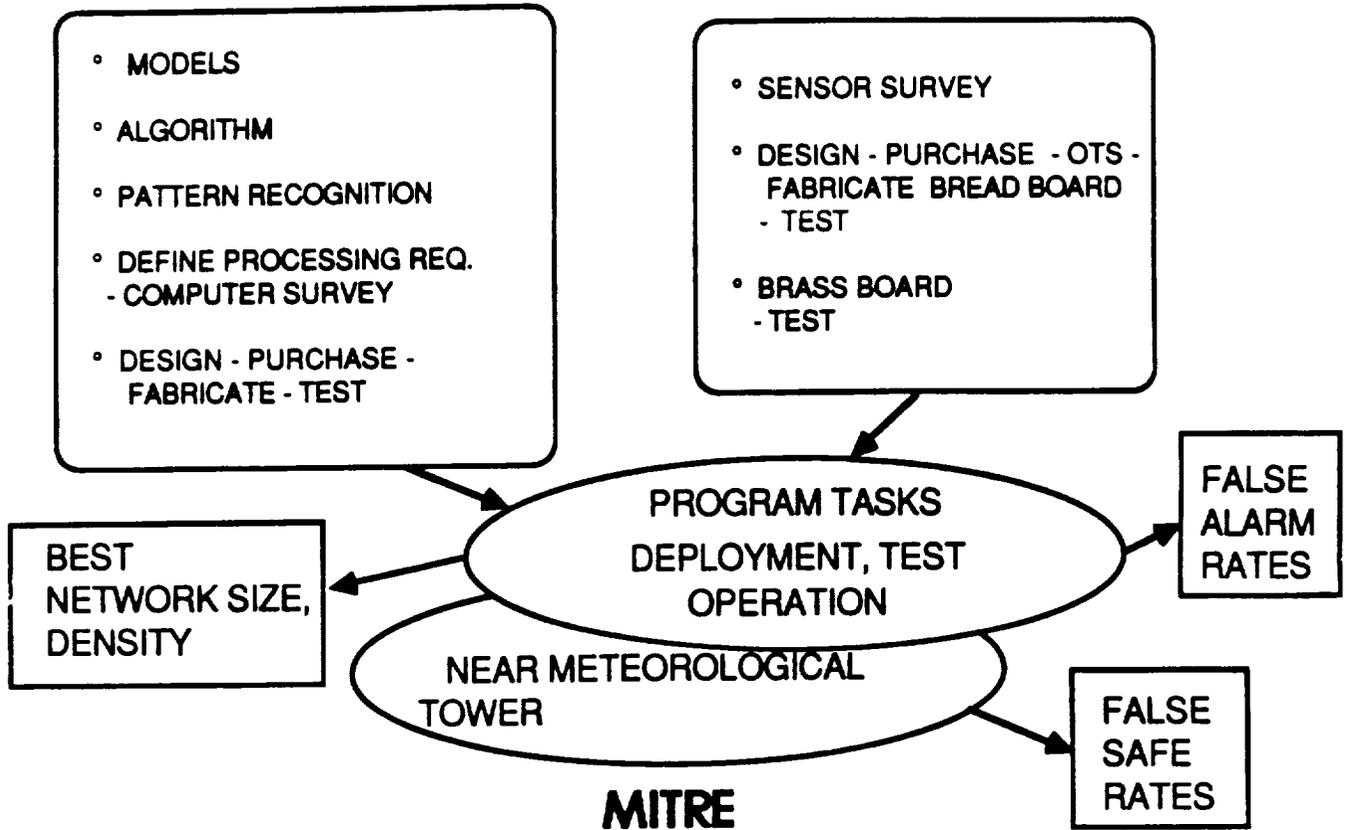
MITRE

Since its formation, the MITRE Corporation has been associated with Air Traffic Control (ATC). We are aware of the absolute requirement for high quality in the reliability, accuracy, precision and availability of equipment for ATC in that these provide confidence to the users: flight specialists including ATC specialists and air crew. Our objective was to show that both the equipment and the associated algorithms computing θ_E had these properties. The sensors and the equipment would be inexpensive, solid state, and solar powered. The equipment, displays and archiving would be based on standard IBM-compatible personal computers (PCs). The success of this very simplified wind shear detection system would affirm the company's interest in sensible, simplified but confidence-inspiring ATC equipment.

The experimental plan was to deploy a tight array of reliable solid-state meteorological sensors around an airport, to set up a digital data recording system and to operate this in a hands-off mode. In this first instance the data would be analyzed off-line, though it could be used for operational purposes, given the appropriate analysis and display capabilities.

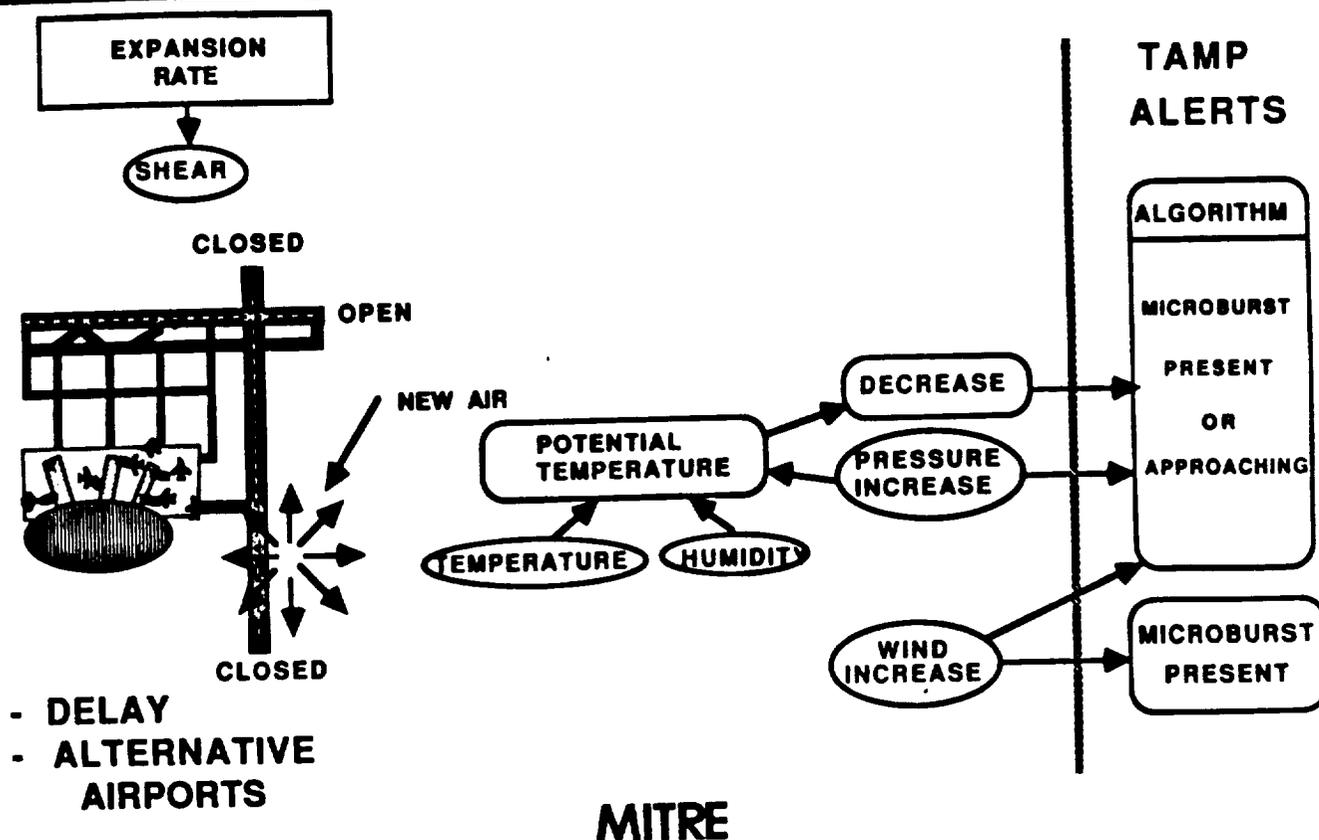
Other objectives of this MITRE-funded research were to have a high confidence of detecting and locating all microbursts, and to work to deploy operational θ_E -measuring arrays in places which there are no plans to detect microbursts at this time, such as secondary, General Aviation and third world airports.

APPROACH



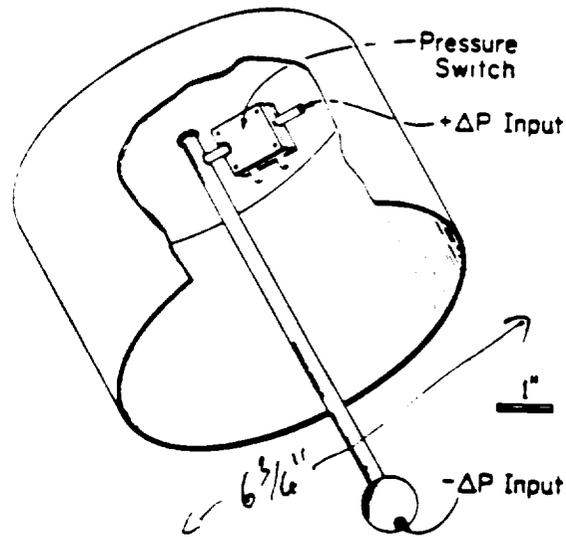
The MITRE approach to this problem was very standard. One of the first products was the development of a complete system specification. The slide is self-explanatory. It sets out the various major objectives including the detailed planning, purchasing and equipment refinement for the development and test of any large system including this thermodynamic alerter for microbursts.

Thermal Alerter for Microbursts Prototype (TAMP)



Since θ_E is conservative, new air from aloft will have a different θ_E from air at the ground. Therefore, a pool of different (almost invariably lower) θ_E will appear as a rapidly expanding pool within the currently present, nearly uniform, θ_E . Proctor has shown models of near-surface changes of this type due to temperature alone.

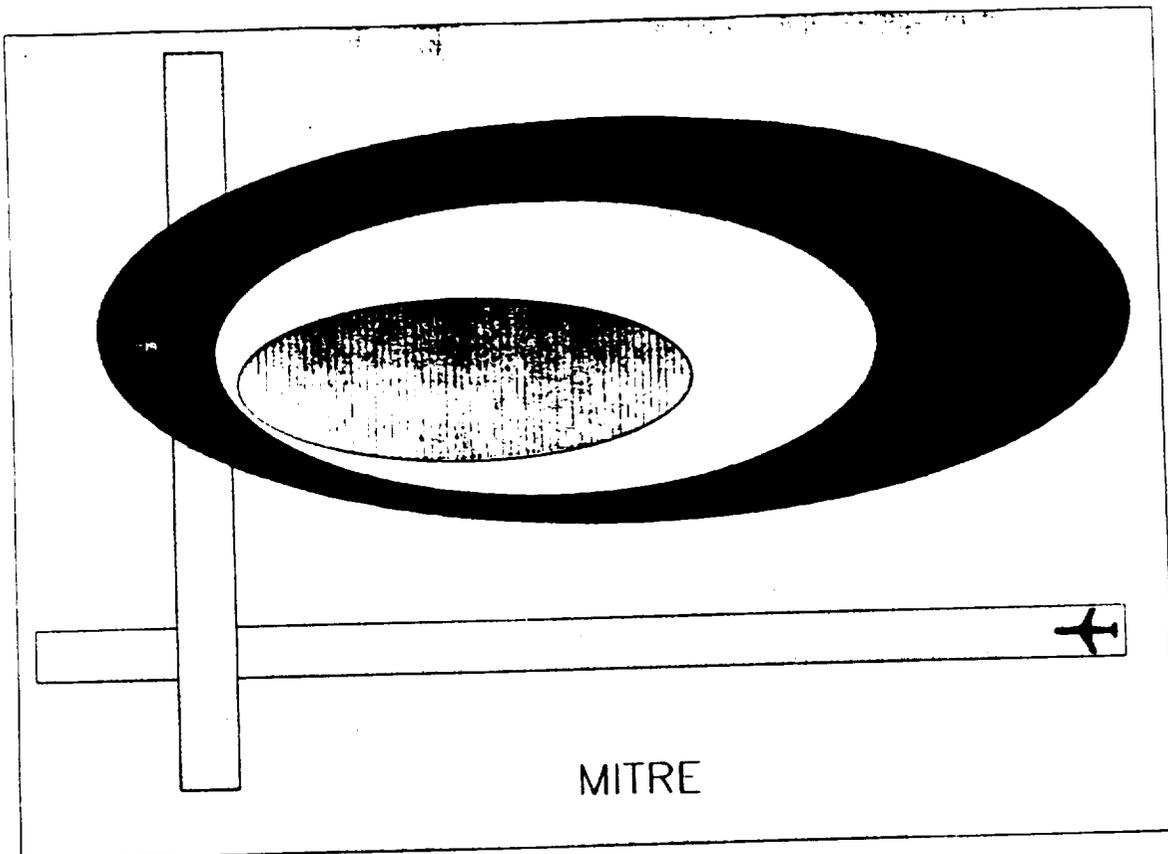
In addition, the movement of the boundaries of the pool yield a measure of shear, microburst strength, or the so-called maximum expected loss across the microburst. The depth of the change will also give a measure of the change, much like the relation given by Proctor of δv (m/s) = $2.5 \delta T^\circ\text{C}$.



Cross-sectional view of wind speed threshold sensor.

The sensor-transmitters (Senstrans) in the array have wind speed sensors similar to the Bedard-Fujita design shown, but modified by MITRE to include direction sensors, which are strain gauges mounted directly on the rod which holds the Bernoulli sphere. When the ball moves, the direction is measured by resistance changes in the strain gauges. In the MITRE design, the pressure switch is replaced by a solid state pressure transducer soldered to the printed circuit board (PCB). The wind shear is then potentially obtainable in three ways, direct measurement, inference from the temperature depression, and geometrically, from the rate of expansion of the pool of new air.

Further, total pressure change, defined as the sum of the scalar pressure change and the dynamic pressure computed from the kinetic energy of the moving air, gives yet a third potential indicator of the presence of a microburst (Fujita). Changes in the static pressure over short periods of time (infrasound) have been postulated by Bedard as indicators of the presence of microbursts, but are not a possible output from the Senstrans array.



The plan for the operational air traffic controller (ATC) display is for a simple nested family of non-overlapping threat-indicating ellipses. Ellipses are very simply defined: five bytes completely describe the location and size of an ellipse. Therefore sixteen bytes completely describe three ellipses, since only one byte is needed for color. Given this economy of information to be transferred, the inner ellipse would be filled with red, indicating the highest threat, probably impenetrable by any aircraft on landing or departure. The area between that and the next ellipse, which totally surrounds the former, would be amber, indicating considerable threat, but possibly successfully penetrable by a microburst-experienced pilot. The finally enclosed area would be green indicating a moderate threat, but penetrable by all pilots except those who have no wind shear training. There would be no confusing overlapping of ellipses. However, there might be a small number of red ellipses within one amber ellipse, and there might similarly be multiple amber ellipses within one green ellipse. However, for transmission to flight decks, a simpler, three nested ellipse family for any one airport would be generated from the available data.

The advantage of ellipses is that they simplify the overly-complex shape of meteorological iso-lines or contours (such as radar echoes) which describe random noise phenomena and are not meaningful in detail. Where threats are defined, however, the selected ellipse is guaranteed to be the smallest ellipse which contains the defined threat, and does not overlap any inner ellipse.

Sixteen bytes of data can be transmitted in one information packet of Mode S data. In addition, at the low transmission rate of 1200 baud, 16 bytes of data can be transmitted anywhere in the world in a tenth of a second. Thus, the functional information of the location and size of a microburst on an airport can be transmitted in graphical form more economically than the ASCII format of the current controller verbal transmissions.

On the flight deck a color display of threats should facilitate pilot intentions, and an appropriate choice. In addition, a smart flight-deck computer could generate a probability of survival number between zero and 1 (1 being survival, 0 being impact) since it contains the aircraft configuration information.

Senstrans - Field Equipment

- Sensors and their sensitivities
 - Temperature sensor: 0.1deg C in 7 s; shelter air limits rate.
 - Pressure sensor: 0.1 mb, no time limit.
 - Will sense pressure changes ahead of descending air.
 - Allows estimate of temperature change due to pressure.
 - Wind speed sensor (Bedard-Fujita design, modified): 1 m/s above 5 m/s, no time limits.
 - Uses the same sensor as the pressure sensor.
 - Relative humidity sensor: 3% RH in 5 minutes.
 - Water content change will cause temperature change.
 - Sensor slow, but look-ahead and nowcasting possible.
 - Solar insolation
 - "Free": From output voltage of solar power supply.

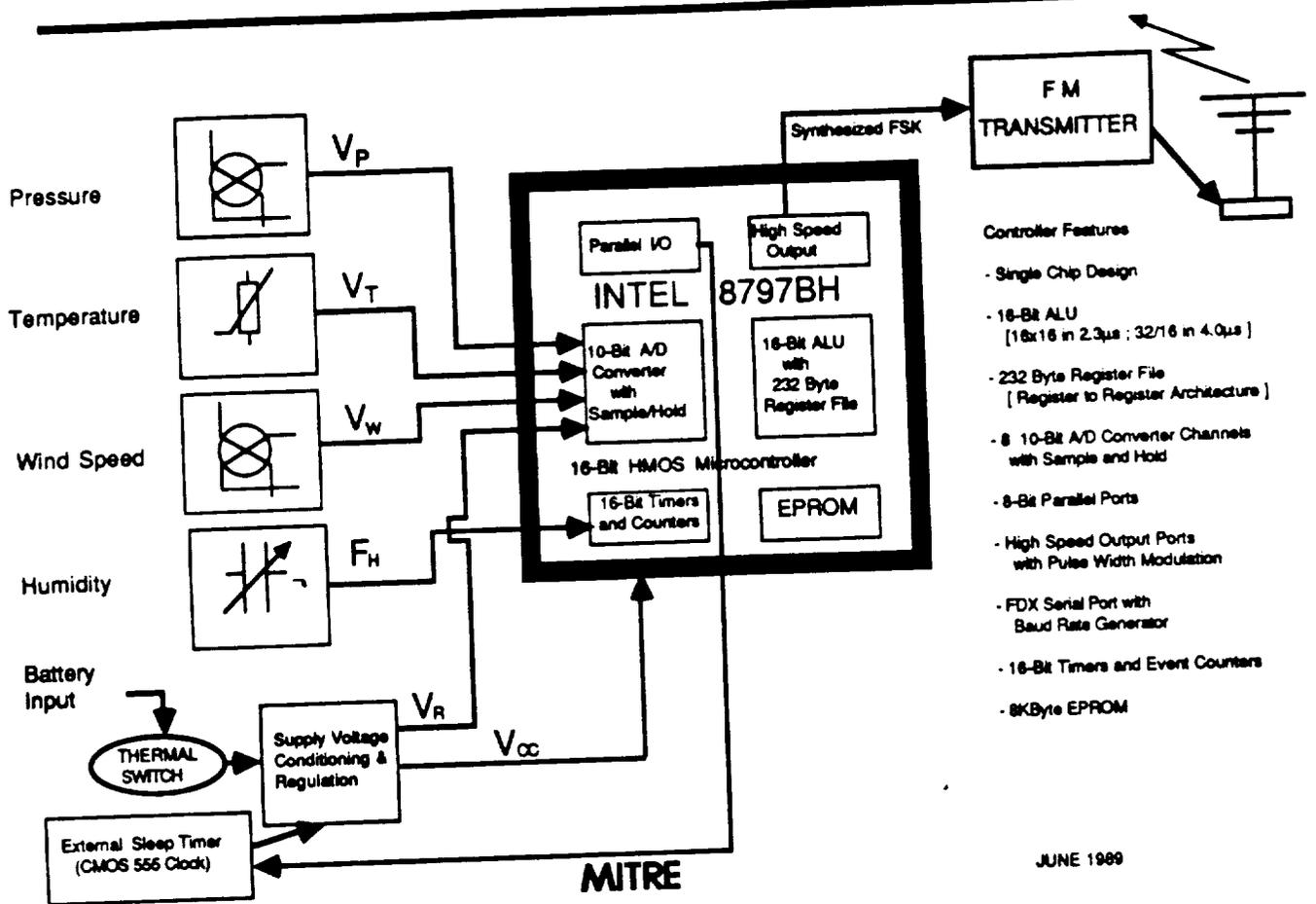
Adequate accuracy is achieved by accepting small lags in several parameters that are measured. Pressure and wind speed are available instantaneously, since they are measured on-chip by a sensor with a deflecting silicon membrane. Wind direction has similar qualities. Temperature has a slight lag because of the thermal mass of the sensor. Humidity, with a lag of the order of a minute, because of the need for water concentration change in a thin film, has the longest lag of the vital parameters.

Accuracies and lags are given in the following table:

Parameter	Sensor	Accuracy	Lag	Comment
Temperature	Thermistor	.1°C	7 seconds	
Differential	Silicon wafer	.1 millibar	zero	wrt Pressure
Wind Speed	Silicon wafer	1 m/s	zero	Above 5m/s
Relative Humidity	Thin film	3%	5 minutes	
Insolation	Solar array		zero	Accuracy N/A

Generally the sensors, the microcontroller, the transmitter are soldered on one two-sided PCB, thus eliminating many cables and connectors which are the most troublesome portion of complex equipment. This is mounted inside a standard instrument shelter which yields adequate exposure to the components within it. However, the solar panel, the battery, and the wind sensor must be elsewhere, so standard telephone cables with their gold-plated and sprung connectors are used where connectors are required.

SENSTRAN DESIGN

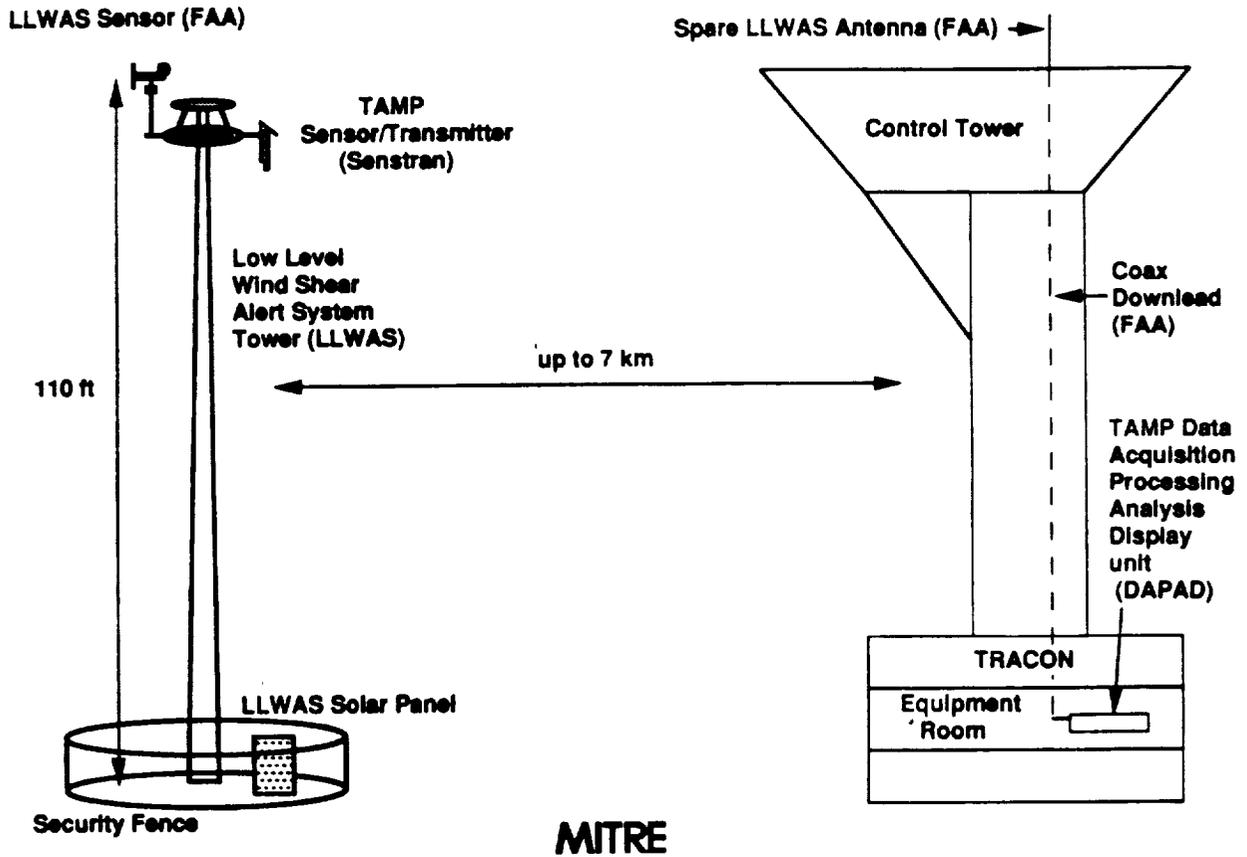


The microcontroller contains an A/D converter and has eight multiplexed analog inputs. These include one digital voltmeter which can be attached to any point on the PCB, and reads remotely. It feeds synthesized frequency shift keyed (FSK) tones to a 2.0 watt FM transmitter.

Unfortunately, the microcontroller also contains a fatal flaw which will not be addressed nor corrected by the manufacturer. Accordingly, many Senstrans exhibit "graceful failure", a tendency towards sparser transmission, and incorrect results. This could be detected and corrected by occasional visits to the various Senstrans. While this is not common to all microcontrollers, its unadvertised presence in the chosen chip was discovered too late to alter the design to accommodate some other chip.

Future Senstrans will be designed around permanently energized low-current microcontrollers to simplify design and to circumvent a similar fatal flaw should it be present in any of the low-current microcontrollers.

TAMP Installation at Stapleton



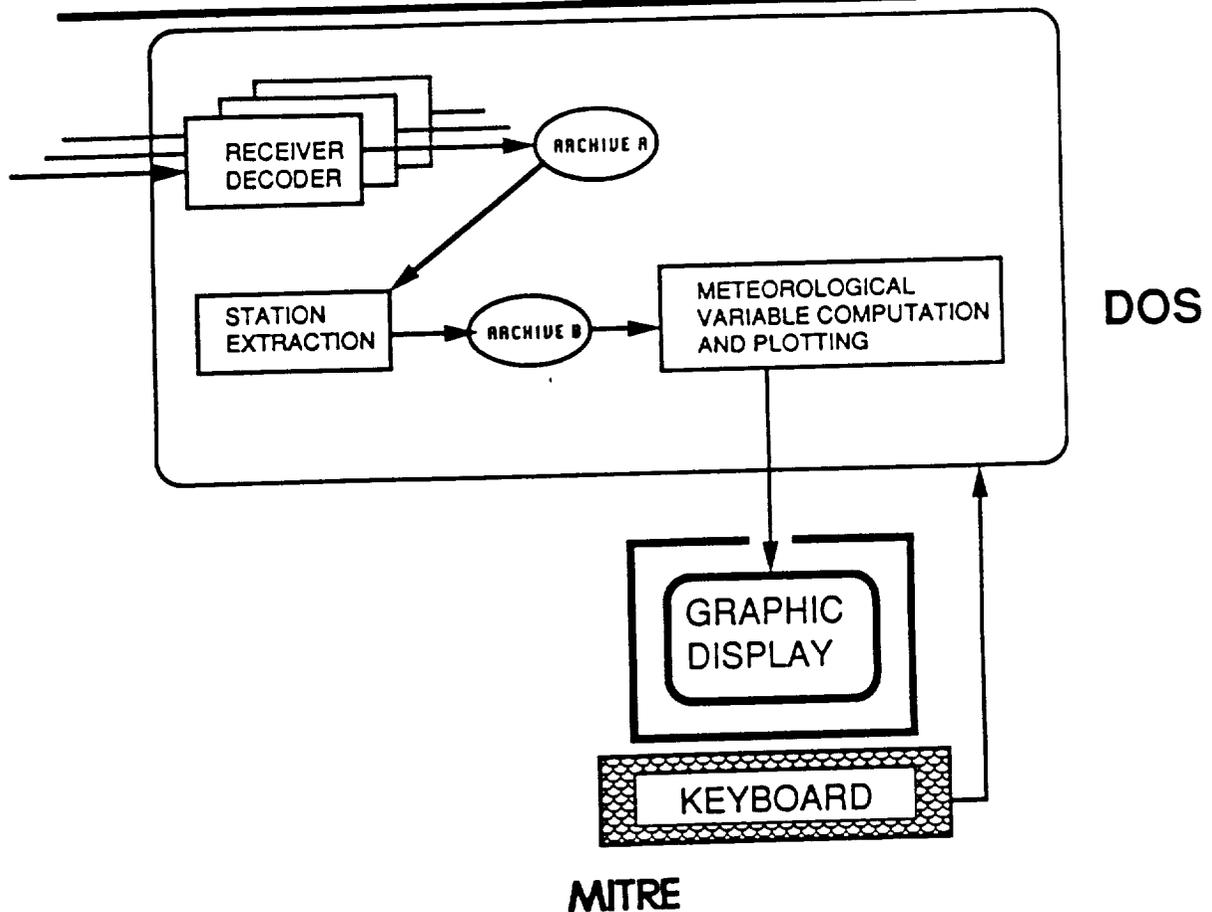
The receiving antenna is a spare LLWAS antenna on the roof of the ATC Tower, which feeds a receiver in the FAA equipment room. This is connected to a standard communications port on a PC via a 1200 baud demodulator. The decoding and archiving software is a Basic program.

With permission of the Stapleton Facilities Section, each of thirteen Senstrans is mounted on an LLWAS tower within a few feet of the operational LLWAS unit, and is up to 7 km from the receiver in the ATCT. It has no impact on the operation of LLWAS.

Operation was achieved on June 26, 1990 and continues.

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DAPAD Software



The software within the data acquisition processing analysis and display unit (a PC) is a simple Basic language program. The archive is initially the hard-drive in the PC. Files are occasionally written to 3.5" floppy disks and are then sent to MITRE.

Results

One comparison has been made with the 11 August 1990 microburst. At this time there were only three remaining operational Senstrans, but its presence was detected by all of them.

Acknowledgments

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Session VI. Heavy Rain Aerodynamics

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