Summary

of the Mobile Temperature Sensor (MTS)

Business Opportunity

Dr. Rex J Fleming

- **Measuring temperature on moving platforms (e.g. commercial aircraft) is a lucrative business and vulnerable to a substantially improved product.**

- **Total temperature (T_T) and static (ambient) temperature (T_S)**

$$T_T = T_S\,(1 + 0.2M^2)$$

where M is Mach number.

Problems with TAT probes (Our fixes)

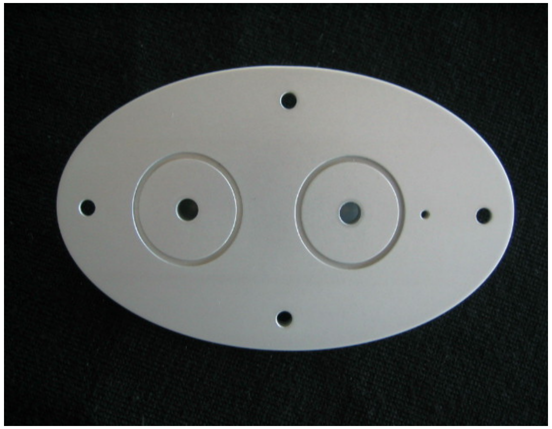
1) Accuracy (0.2 to 0.3 K is expected error: 2 to 3 times better than current Goodrich (Rosemount) TAT
   - at best, 0.6 to 0.8º accurate
   - large random errors and biases – birds, other
   - two identical sensors well protected

2) Probe heater (no heater required)
   - largest failure mode = delay time, repair costs
   - limits temperature accuracy

3) Probe drag (far less drag)
   - additional fuel costs = approximately $3 - 4M per year for 8000 aircraft in USA

4) Probe's radar cross section (far less cross section)

The flush Mounted Air Sampler for Mobile platforms



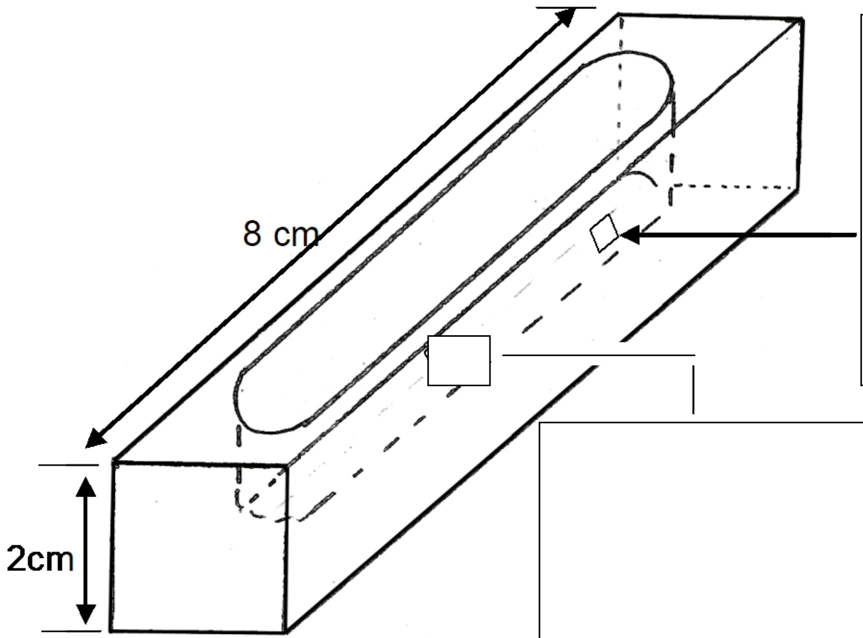
Scalable in size; current size of major ellipse = 5.39” (136.9 mm)

Proven successful in operations of the WVSS-II on UPS & Southwest

Temp measured is ambient air temp of atmosphere + friction effect of flow ~ 1. 0 to 2 cm from aircraft skin (not large but must be modeled)

Software to model friction as f (Mach #) exists & proven accurate!

Taper & inertial separator for WVSS not needed to accelerate heavy particles of liquid water, ice crystals, and aerosols out the back



T sensors here and on opposite side of tub – imbedded within walls 5/1000 of an inch

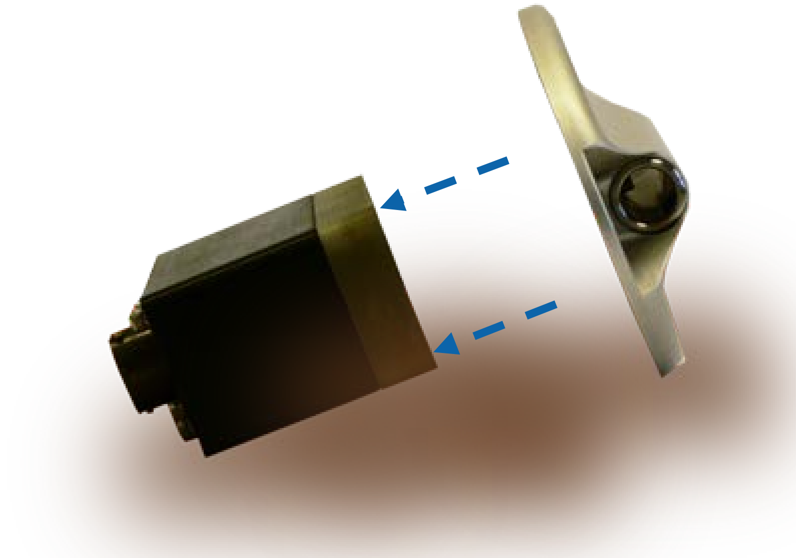
Cartoon of “tub - shaped” cell

SSI Mobile Temperature Sensor (MTS)

Accurate over a wide operating range (90 C to 50 C)

Lower cost of ownership

- Longer maintenance interval
- Accuracy upheld without re-calibration
- Fuel savings: less drag, less weight



MTS

Fast measurement response

- Data sent every second to avionics

Two PRTs are 1000 Ohm, 2 mm square, 1 mm thick, (thin film encased in ceramic) recessed into measurement cell walls 5/1000”

New circuit design tested with 100ppm/C resistors; resistors now exist with 2ppm /C capability should lead to temperature drift of 0.01C

Measurement area protected from all heat sources except the ambient atmospheric temperature and the additional heating due to friction

Two T_S sensors imbedded 5 x 10^{-3} inches just inside measurement cell walls (one on each side of cell --both function all the time providing additional stability (redundancy) and this meets backup requirement for the FAA if one fails.

The thermal resistance of the insulated measurement cell (G10 material) must be very high (shown to be 11,759 ºC / Watt)

The thermal resistance of the aluminum (or copper) tub wall must be very low to measure temperature (shown to be 0.155ºC / Watt)

Ratio of difference is ~ 76,000 or nearly 5 orders of magnitude!

Total Available market (TAM) for MTS

Larger air frame market		Smaller air frame market	
Commercial aircraft	30,000	General aviation	360,000
Military a/c (major)	10,000	Military aircraft (minor)	40,000
		UAVs	10,000
Total	40,000		410,000
Boeing estimated increase valid for our 10 yr profile	9,000		60,000
TOTAL	49,000		470,000
Target market share after 10 years: 40% of large frame; 5 % of smaller frame	19,600		23,500

Business Opportunity for SSI: Mobile temperature sensor (MTS)

Current Year (CY) (Already completed) Patents in place!

CY + 0.5: Invest capital for flight test on Boeing or research aircraft.

CY + 1: Invest capital for FAA STC and optimize manufacturing

First sales in first quarter of 20xx; assume same total cost for large or smaller version = $7524 (total cost details on next slide)

Sale price per unit equals:	**$9,800 large**	**$9,700 small**
Profit per unit	**$ 2,276**	**$2,176**
Number of units :sold	**19,600 large**	**23,500 small**
Profit by year 10 (before tax)	**$ 44.61 M**	**$ 51.14 M**

Cost of Goods Sold (COGS) for Mobile Temperature Sensor (MTS)

	300 / year	3000 / year
Air sampler (with royalty fee)	800	780
PRTs	300	280
SEB, enclosure, misc.	800	640
Labor	300	300
TOTAL	$2200	$2000

Above numbers from Randy May in 2008

Increase these by 20% for current COGS = $2640 (hold at same level)

Business Opportunity for SSI: Mobile temperature sensor (MTS)

Assume costs same for MTS whether for large scale aircraft or for smaller scale a/c and other mobile platforms:

COGS:	**$ 2,640 per unit**	
Overhead:	**$ 3,960 " "**	**{1.5 x COGS}**
G & A:	**$ 660 " "**	**{ 25% of COGS}**
Marketing:	**$ 264 " "**	**{ 10 % of COGS}**
Total cost:	**$ 7,524 " "**	

Sales price:	**$9,800 for large a/c**	**$9,700 for smaller MTS**
Profit:	**$ 2,276 " " 19,600 units**	**$2,176 / unit; 23,500**
Profit by year 10 (Before tax)	**$ 44.61 M**	**$ 51.14**

$ 95.75 M total

$$\Delta T_{(friction)} = Y(x) = a_1 + a_2 x + a_3 x^2 + a_4 x^3$$

Determine model parameters (a_k) based on data (x_i, i=1,N)

Minimize:

$$\chi^2 = \sum_{i-1}^{N} \left[\frac{Y_i - \sum_{k=1}^{M} a_k x_k(x_i)}{\sigma_i} \right]^2$$

Where each data point has its own standard deviation σ_i

Most powerful algorithm to do this is the use of Singular Value Decomposition “SVDFIT” in Press, et al, Numerical Recipes, 1986.

Various Models Used in Simulations and Outlier Analysis

e.g. $Y=A_1+A_2M+A_3M^2+A_4M^3$

$Y=0.1+5.0M+5.0M^2+5.0M^3$ [=9.86 for M=0.8]

Y=0.1+6.77M+6.7M2+0.0M3 [=9.86 for M=0.8]

Assume one of the above as “Truth”

$Y_{Truth}(I)=A_1+A_2\ X(I)+A_3\ X(1)^2+A_4\ X(I)^3$ * * *

X(i) = i (0.8/1000) for i = 1, 1000 [0.8x10-3 to 0.8]

Then add some uncertainty to each Y(I)