Lockheed Quiet Aircraft:

QT-2 and its derivatives (also known as X-26B), Q-Star, and YO-3A.

Presented to Oklahoma State University
in Stillwater, OK on October 4th, 2010
Quiet Aircraft Association, Inc. A 501 C 3 Non-Profit-Organization
Dale Ross Stith, President

Background

Justification for Quiet Aircraft: A covert airborne reconnaissance platform needed to combat enemy forces in Southeast Asia

Basic Problems regarding the Vietnam War:

1. **An unconventional insurgency (guerilla) war, so unconventional systems and equipment needed to combat enemy.**

- **Our enemies moved and attacked at night, because we were mostly blind at that time. They hid in the daytime, or melded into the civilian non-combatant population.**
- **Searchlights and million candle-power flares were used to illuminate their area. But, approaching aircraft noise, which could be heard five miles, often caused them to disappear and avoid attack.**

2. **Essence of the Proble: The aural detection range of conventional aircraft exceeded detection/resolution range of available sensors. And our “Rules of Engagement” required positive identification and location of a target for approval to attack (even if “taking incoming”!).**

Typical Noise Sources of Conventional Propeller Driven Aircraft

Source	**Description**
Propeller	**Blade passage, wake shedding and tip vortex (pure tone and broadband) noise. (Note: Mini "Sonic Booms" at tip velocities above Mach 1).**
Engine:	**Combustion intake air and exhaust and cooling inlet and outlet air noises.** **Mechanical rotational and reciprocating vibration noises: Magneto(s), alternator(s), accessory drive, valve train, etc.**
Appendages	**Form Drag noise: Antenna(s), landing gear, struts, tie down(s), lights, etc**
Wing/Fuselage	**Friction Drag noise: Non-laminar turbulence and flow separation**
Skin Discontinuities	**Panel vibration noise.**
Cavities	**Resonance noise. Inspection and cable holes, mis-rigged hatches and landing gear doors, control surface hinges, oil cooling and air intake and outlet port(s), etc.**

Acoustics

Acoustic Terms used in this presentation:

Cause: Sound energy Intensity (I) in Watts/meter^2 from the source

Effect: Sound Pressure (P) in force/area. Usually, in Dynes/cm^2 to which our ears and microphones respond.

Decibels (dBs): A logarithmic ratio of acoustic levels (Intensity and Sound Pressure) referenced to an industry standard:

1. **Sound Intensity Levels (SIL). Usually, Watts/meter^2 referenced to 10^{-12} Watts/meter$^{2.}$**
2. **Sound Pressure Levels (SPL), Usually, in Dynes/cm^2 referenced to 2 10^{-4} Dynes/cm^2; bars referenced to 2 10^{-9} bars; lbs/ft^2 referenced to 4.17 10^{-7} lbs/ft^2, and Pascals, referenced to 2 10^{-5} Pa, etc.**

Weighting Scales:

dBA, dBB, and dBC ("weighting") Scales are used in acoustics.
In some applications the "A" Scale is used from 0 to 55 dB (It discriminates against low frequency sounds, so more closely approximates human hearing), B is used from 55 to 85 dB, and C is used above 85 dB.

Frequency in cycles/second: Hertz (Hz) or kHz (1000 Hz)

Notes:
1. Log to Base 10 (log10) is used throughout.
2. Sound and noise are used interchangeably.

Sound Attenuation and Masking

Attenuation:

Aircraft noise is modified as it travels from an aircraft to the ground:

Some aircraft noises are attenuated by our atmosphere more than others by:

- **Absorption**
- **Temperature and Humidity Effects**
- **Frequency Effects**
- **Scattering**

All aircraft noise is attenuated by Spherical Spreading.

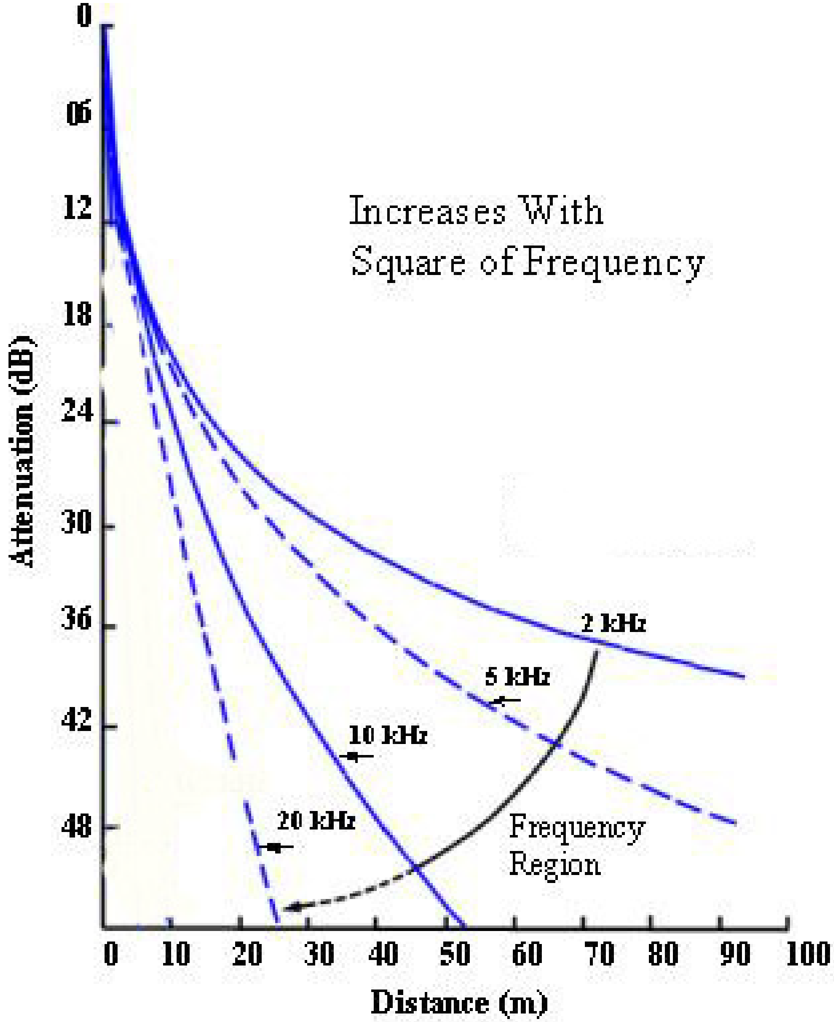
Environmental material, local to the observer, also attenuates aircraft noise by:

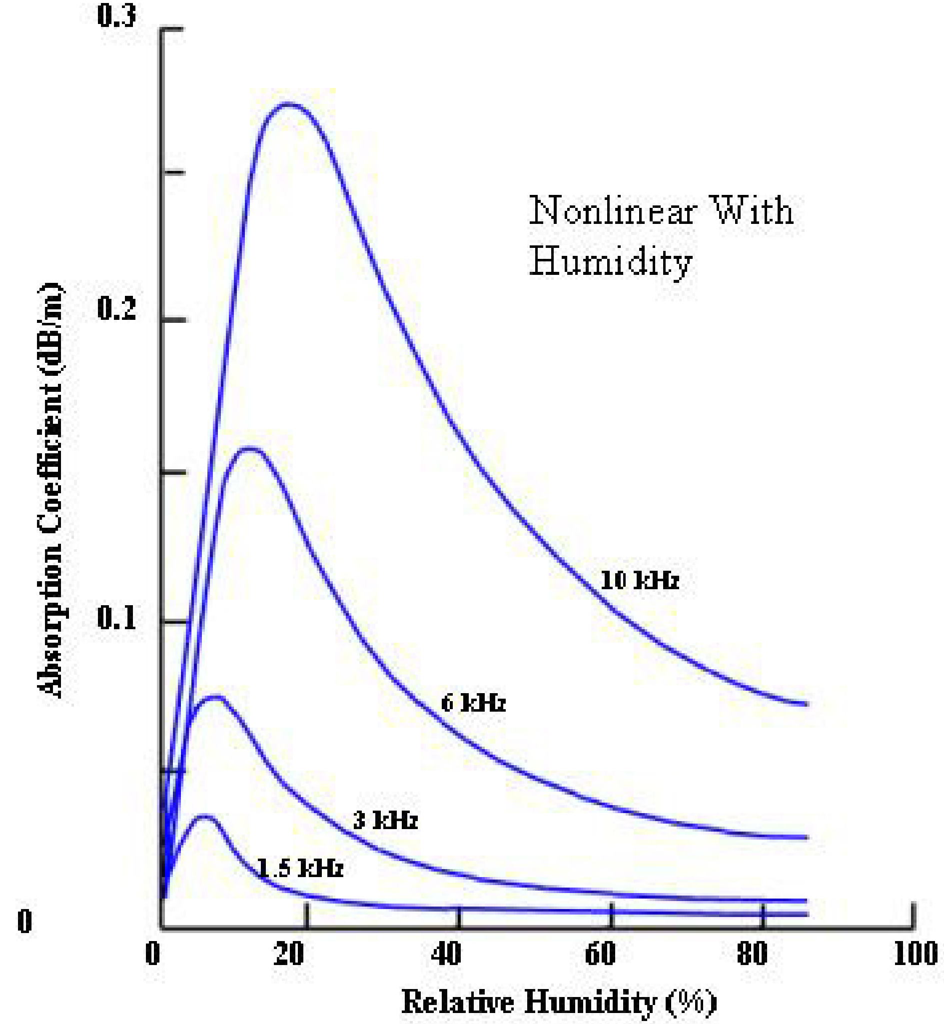
- **Reflection**
- **Refraction**
- **Diffraction**

Masking:

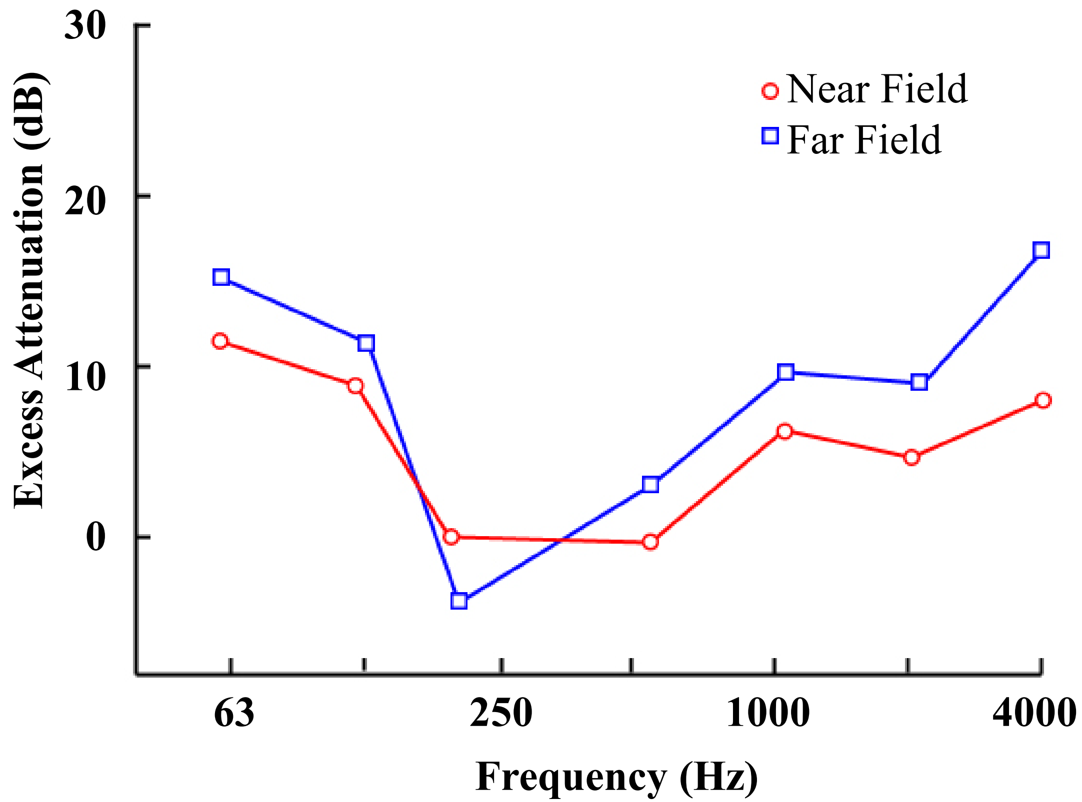
Environmental background noise (wind, equipment noise, music, conversation, etc) masks aircraft sounds. Aircraft noise masked if less than 3 dB above ambient noise.

Atmospheric Attenuation





Forests Attenuate Sound



Attenuation Depends on Frequency Due to Scattering and Absorption Effects

SOUND ATTENUATION by SPHERICAL SPREADING

CAUSE:

Acoustic Sound Intensity (I)

I = Acoustic Power/Area: Watts/4 pi R^2

PWL in dB = 10 log (I/W_{Ref})

Where $W_{Ref} = 10^{-3}$ Watts/m^2

$I = p^2$

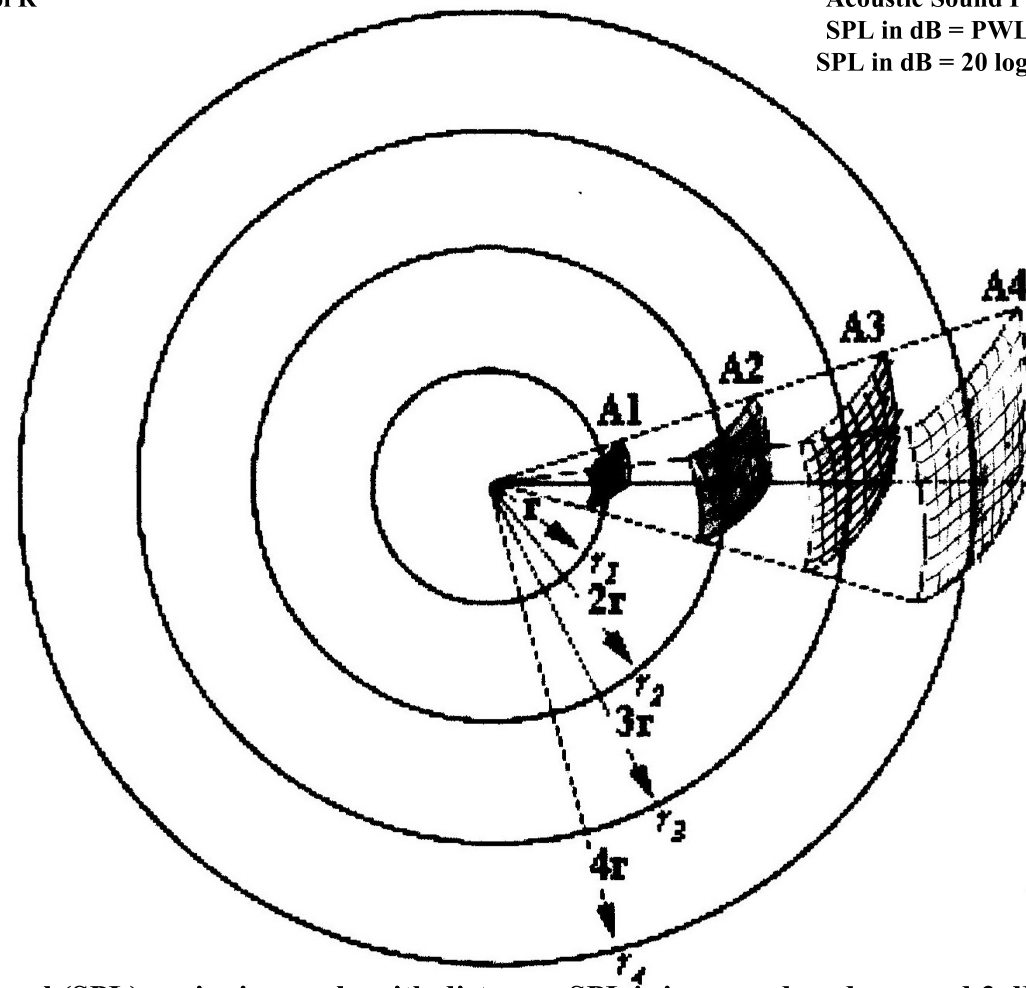
EFFECT:

Sound Pressure Level (SPL)

Acoustic Sound Pressure = Force/Area: Pascals/4 pi r^2

SPL in dB = PWL-10 log (4 pi r^2)

SPL in dB = 20 log (P/P_{Ref}) Where P_{Ref} is 2 10^{-5} Pa.



Acoustic Power at any radius:

$P_{rx} = (\text{Watts}/p\ a\ pi\ r_x^2)^{0.5}$

Where:

Watts = Acoustic Watts

p = Air Density

a = Speed of Sound

pi = 3.1414

r_x = radius

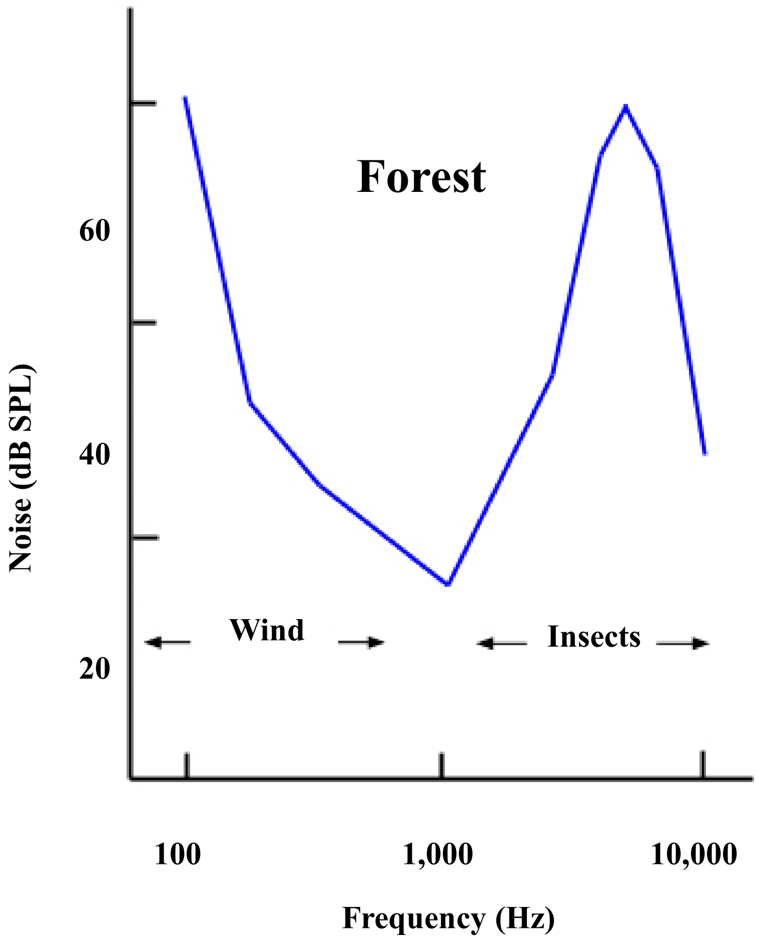
pa = air impedance

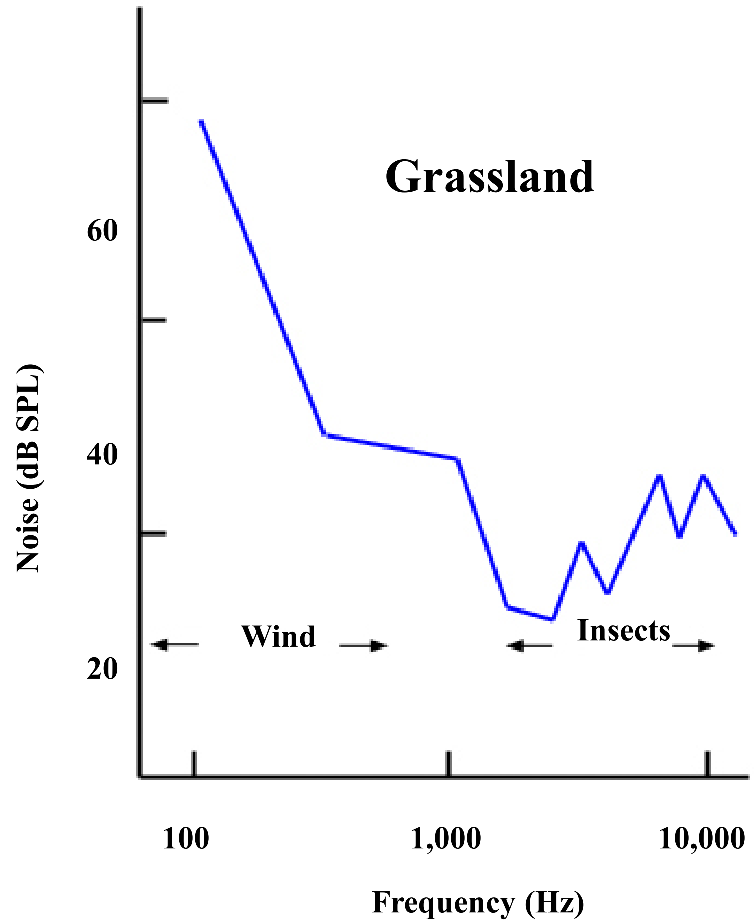
Notes: 1. Sound Pressure Level (SPL) varies inversely with distance: SPL is increased or decreased 3 dB with each halving or doubling of distance, respectively. If SPL at r_x is known, $SPL_y = SPL_x - 20 \log (r_y/r_x)$

1.Standard temperature and Pressure (STP)

2."log" is $\log_{10}$.

Background Noise Can Mask Sounds





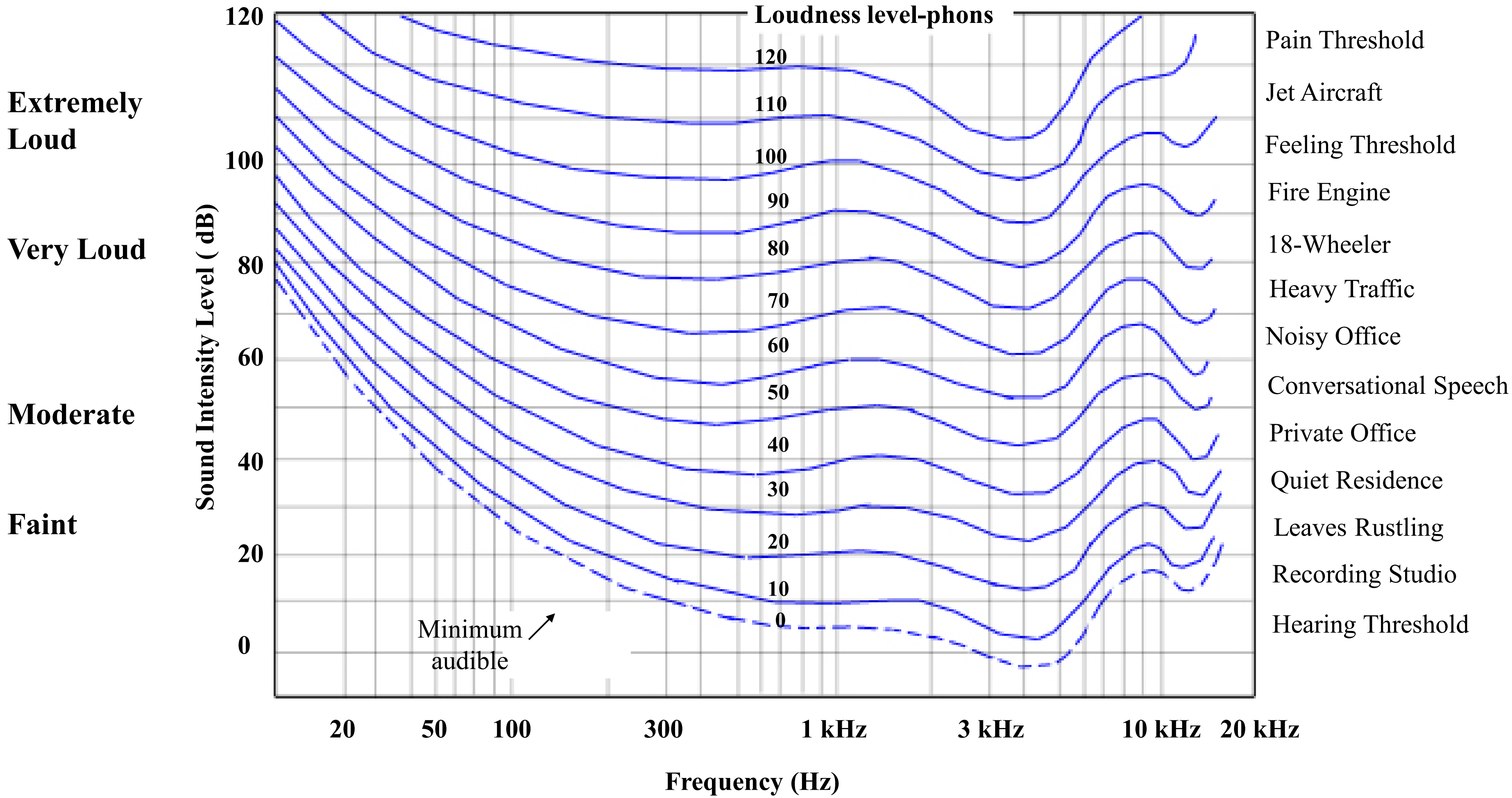
Notes:

1. **Animals, conversation, music, equipment noise, etc affect both graphs across the spectrum .**
2. **9 dB noises mask all others.**

Human Hearing:

- **Zero (0.0) db established as threshold of human hearing**
- **Useful Intensity range is 0 - 120 dB**
- **Sound frequency differences are perceptible at ~1 db (hearing threshold)**
- **Sound volume differences are perceptible with changes of ~3 db.**
  + 9 dB noises mask all others.
- **The loudness of short sounds will tend to fall off below a duration of half a second. That is, to sound equally loud as longer sounds, short ones must be more intense.**
- **Loudness only one factor but does not determine detectability alone, e.g. we hear objects (like aircraft) better when seen, than not.**
- **Our hearing is most sensitive to 4 khz, and less sensitive to frequencies lower than 0.700 kHz and above 6 kHz (see Fletcher-Munson loudness curves:)**

Human Auditory Sensitivity to Noise

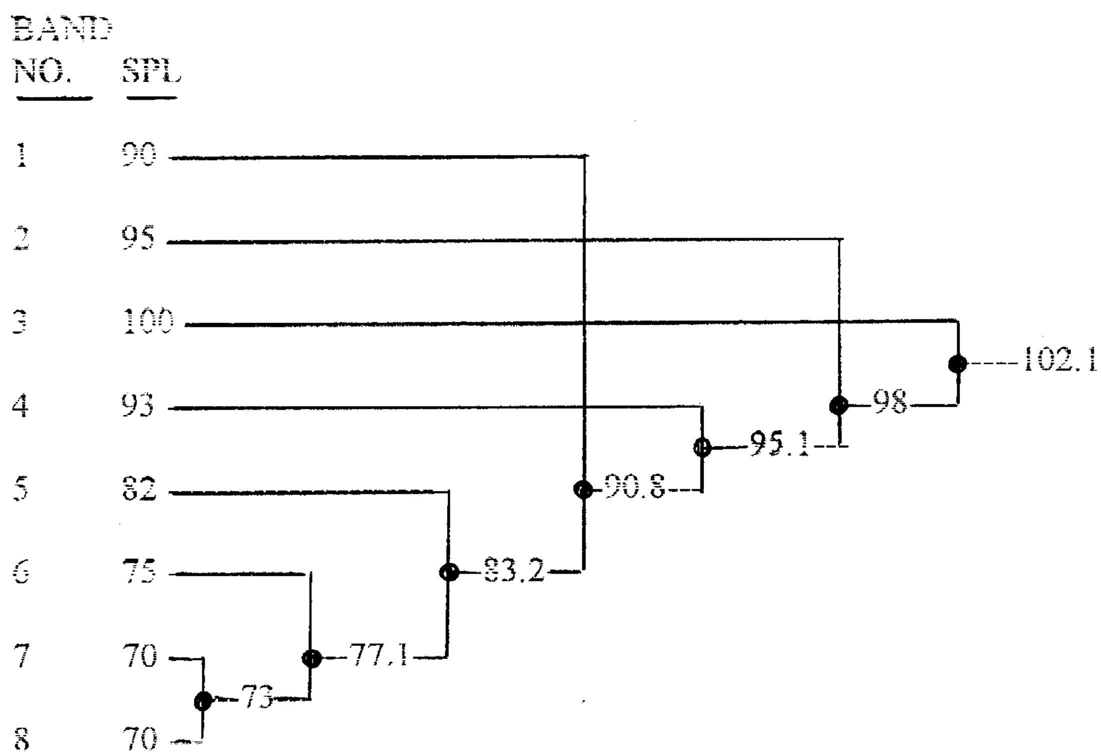


Fletcher – Munson Equal Loudness Curves

Sound Levels

						Range	
Situation and sound source	**Intensity (I) Sound Power PAC (Watts/m2)**	**Sound Pressure (SPL) Ratio**	**Energy (I) Ratio**	**Sound Pressure Level (Lp dB) re 20 µPa (SPL?) re 10−12**	**Sound Pressure (Effective Value) Pascals RMS (Pa)**	**Sound Pressure Level (Lp dB) Pascal re 20 µPa**	**Pressure (p) Range Pascals RMS (Pa)**
Theoretical limit for undistorted sound at 1 ATM				194	1.01E+05	194	1.01E+05
Rocket engine	1.00E+00	1.00E+06	1.00E+12	180			
Stun grenades				180	2.00E+04	170–180	6.00E+03 - 2.00E+04
.30-06 rifle being fired 1 m to shooter's side				171	7.27E+03	171	
M1 Garand rifle being fired at 1 m				168	5.02E+03	168	
Rocket launch equipment acoustic tests				165	4.00E+03	165	
Turbojet engine	1.00E-02			160			
Siren, Jet engine at 30 m	1.00E+03			150	2.00E+02	150	6.32E+01 – 2.00E+02
Jet engine at 100 m				140	6.32E+02	110 – 140	6.32E+02
Heavy truck engine or concert loudspeaker	1.00E+02			140			
Threshold of pain				130	6.32E+01	120 -140	2.00E+01 - ?
Machine gun, Jackhammer	1.00E+01			130			
(Hearing damage possible)	1.00E+00	1.00E+06	1.00E+12	120	2.00E+01		
Excavator, trumpet	3.00E-01			115			
Chain saw	1.00E-01			110			
Helicopter, Jack hammer at 1 m	1.00E-02	1.00E+05	1.00E+10	100	2.00E+00		
Traffic on a busy roadway at 10 m	1.00E-03			90	6.32E-01	80 – 90	2.00E−01 – 6.32E−01
Hearing damage possible with long-term exposure				85	3.56E-01		
Passenger car at 10 m	1.00E-04	1.00E+04	1.00E+08	80	2.00E-01	60 – 80	2.00E-02 – 2.00E−01
Usual talking, Typewriter	1.00E-05			70			
Handheld electric mixer,				65			
TV, Normal conversation at 1 m	1.00E-06	1.00E+03	1.00E+06	60	2.00E-02	40 – 60	2.00E-03 – 2.00E−02
Washing machine, dish washer				53		50-53	
Refrigerator	1.00E-07			50			
Reference Level	1.00E-08	1.00E+02	1.00E+04	40	2.00E-03		
Very calm room				30		20 – 30	2.00E−04 – 6.32E−04
Reference Level	1.00E-10	1.00E+01	1.00E+02	20	2.00E-04		
Light leaf rustling, calm breathing				10	6.32E-04		6.32E−05
Auditory threshold at 1 kHz	1.00E-12	1.00E+00	1.00E+00	0	2.00E-05		2.00E−05

Numerical Sound Relationships



Total SPL due to Multiple Non-Coherent Sources

Note: Combine dBs on a case-by-case basis.

Source: **BAT 171- 49**

Quiet Aircraft Research

Initiation: **DoD DDR&E appealed to Military Industrial Complex for technical solutions to winning the Vietnam War.**

Response: **Resulting coincident, but independent research and proposals:**

- **DARPA RACIC BAT-171-49 Feasibility Study**
- **USN Technical Statement Of Requirement (TSOR) (1)**
- **Lockheed's R&D effort and Quiet Thruster (QT-1 and QT-2) Proposals (2)**

The proposals converged at DARPA Counter Insurgency Warfare (COIN) and agreed:

- **A covert airborne reconnaissance platform was justified**
- **Noise is related to energy expended. Energy expended (in Engine Horsepower (HP) is related to Lift, Drag (L/D). Wing Loading (W/S), Air Speed, and Altitude above Ground Level (AGL).**
- **A high Aspect Ratio (AR) glider airframe with a quiet efficient propulsion system was the solution. The critical frequencies for covert aircraft are 130 to 600 Hz.**

Conclusion: **DoD rejected the QT-1 design. But, awarded LMSC a contract to build and demonstrate two Experimental Quiet Thruster (QT-2) Aircraft**

Notes:
1. USN Horn, patrolling the RVN waters, submitted his TSOR to prevent ambushes to Navy vessels and crews.
2. Lockheed commenced studying tactical systems for the Vietnam War in 1965: Intelligence sensors, aircraft, balloons, satellites, etc.

LMSC Quiet Aircraft
Quick Reaction
Development and Production Programs

1967: LMSC covertly established a development shop at the San Jose (CA) Municipal Airport. Using Kelly Johnson's "Skunk Works Rules", two Experimental QT-2s and Q-Star were produced:

- **Most rigorous DoD and Lockheed requirements (documentation and inspection) were waived to save time and budget.**
- **Commercial (even non aero) parts and local vendors were allowed.**

1969: LMSC established a DoD SECRET Full-Scale-Development (FSD) production factory in Menlo Park, CA . Eleven YO-3As were produced in two years. Final Assembly and initial tests occurred at Naval Air Station (NAS) Moffett Field (CA).

Notes:

1. **The QT-1, a single-seat conceptual design, powered by a 36 HP Volkswagen Auto Engine; was rejected in favor of a two-seat configuration, powered by an "aero qualified" engine.**
2. **The QT-2s were produced (in 6 months) and later modified (in 90 days) to military tactical QT-2PCs. Returned to the Navy in 1969, the were designated as X-26Bs.**
3. **A specification that would guarantee "no aural detection" in normal operating conditions was not available So, our plan was to develop and demonstrate and experimental aircraft that would fly as quietly as possible at 1000' AGL (70 dB Overall SNL was used as a goal).**
4. **Emphasis was on practical engineering and testing. "Analysis Paralysis" was to be avoided.**

Quiet Aircraft Propellers

Propellers can be major contributors to overall aircraft noise:
• Conventional aircraft propellers accelerate small amounts of air to high velocities.
• Quiet Aircraft Propellers are less noisy, because they accelerate large amounts of air to lower velocities. Propeller tip speeds were 0.2 to 0.3 Mach in Quiet Cruise Mode to eliminate "mini sonic booms".

Propeller Efficiency: $n_p = TV/P = V/nD(C_t/C_p)$ and anti-proportional to Blade Angle

Where:

TV: Propulsive Power

P: Power supplied to prop

n: Prop rotational speed

D: Prop diameter

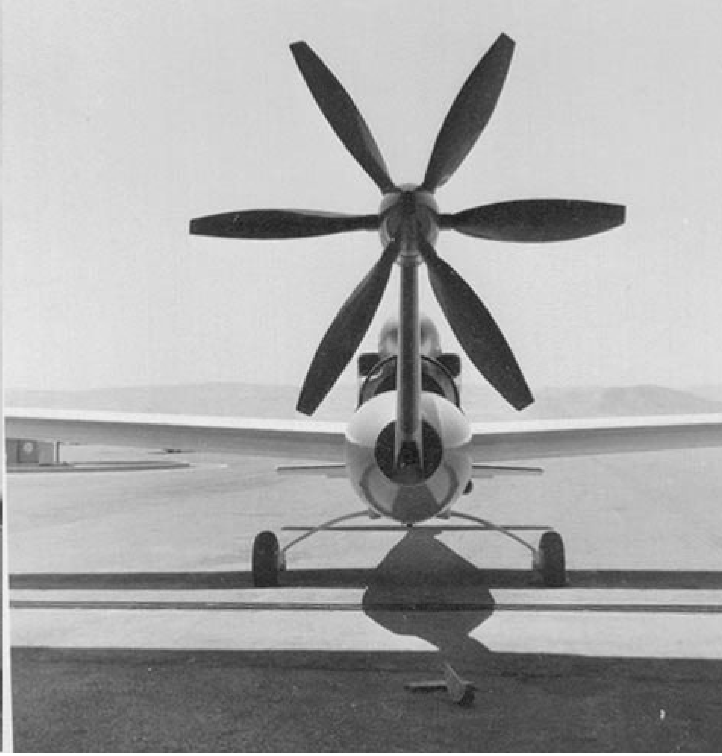
C_t: Thrust Coefficient

C_t: Power Coefficient

Notes:

1. **More than 18 different engine/reduction systems were evaluated: Fixed and variable pitch wood propellers with 88 to 100 In. diameters, 2 to 6 blades, and chord-widths up to 13 In.**
2. **Final designs included large multi-blade wood propellers, with the large chord-to-length ratios and the blades positioned at shallow angles. The propellers were then turned only as fast as was necessary (in RPM) to produce the required thrust.**
3. **The initial YO-3A Propellers were Fixed – Pitch 6 - Blade. They were modified to 3 -Blade Variable – Pitch configuration in March 1971.**

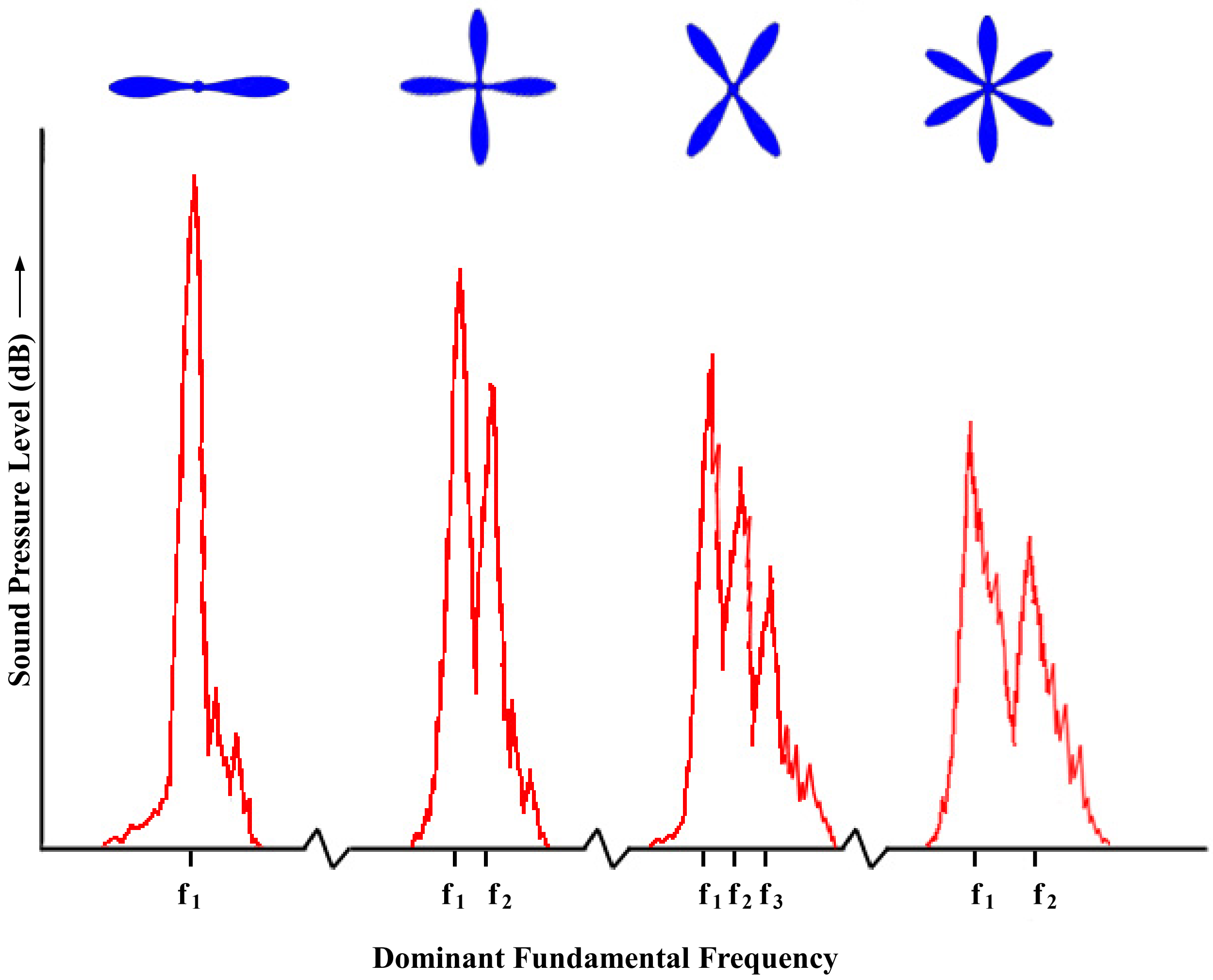




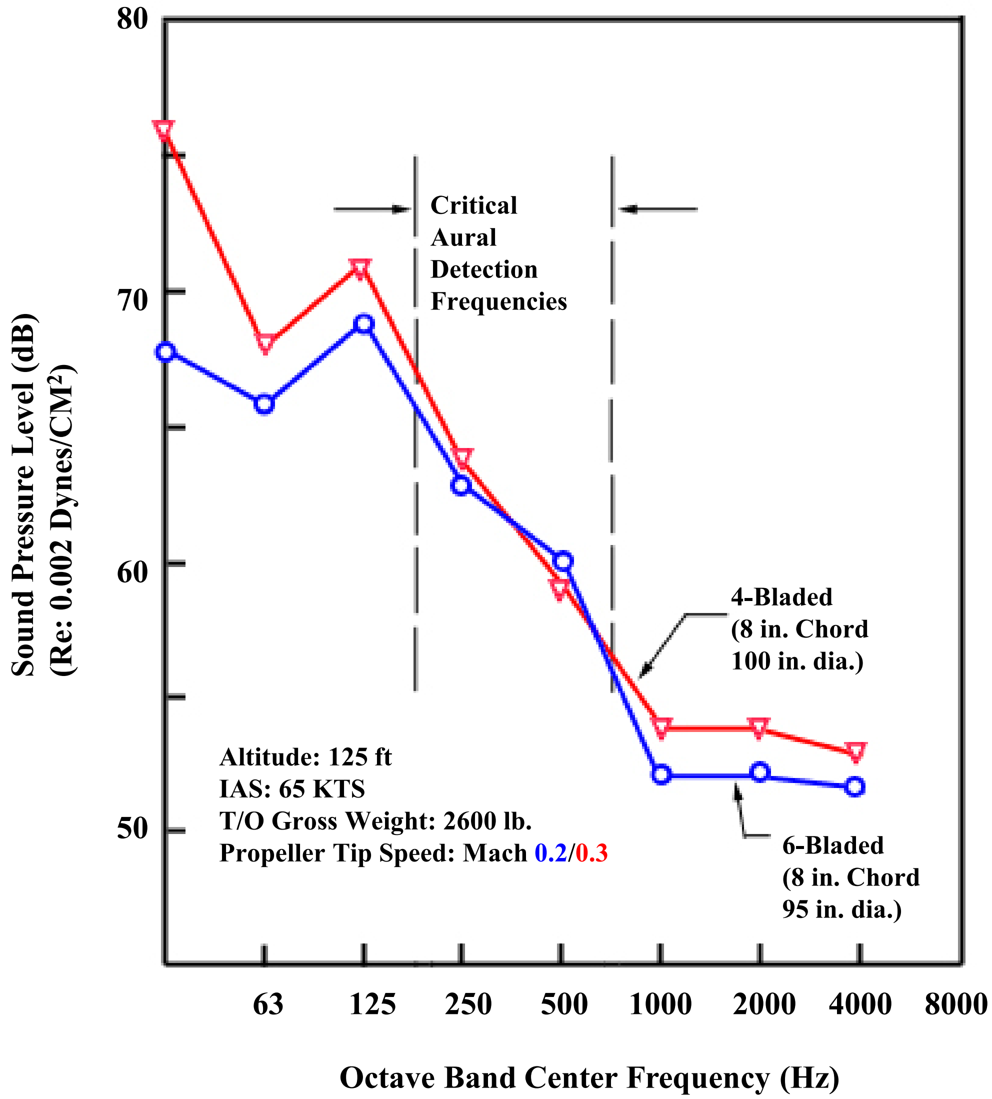
Above:
Continental Engined Q-Star Aircraft
with 3, 4, and 6 Blade Propellers

Right:
Special acoustic propeller on YO-3A Engine in Test Stand:
100 In. Dia,
13” Chord.

Sound Pressure Level Distribution for Various Propeller Blade Configurations



Noise Generated by 4 and 6 Bladed Propellers



V-Belt Propeller Speed Reduction System: Common to all LMSC Quiet Aircraft

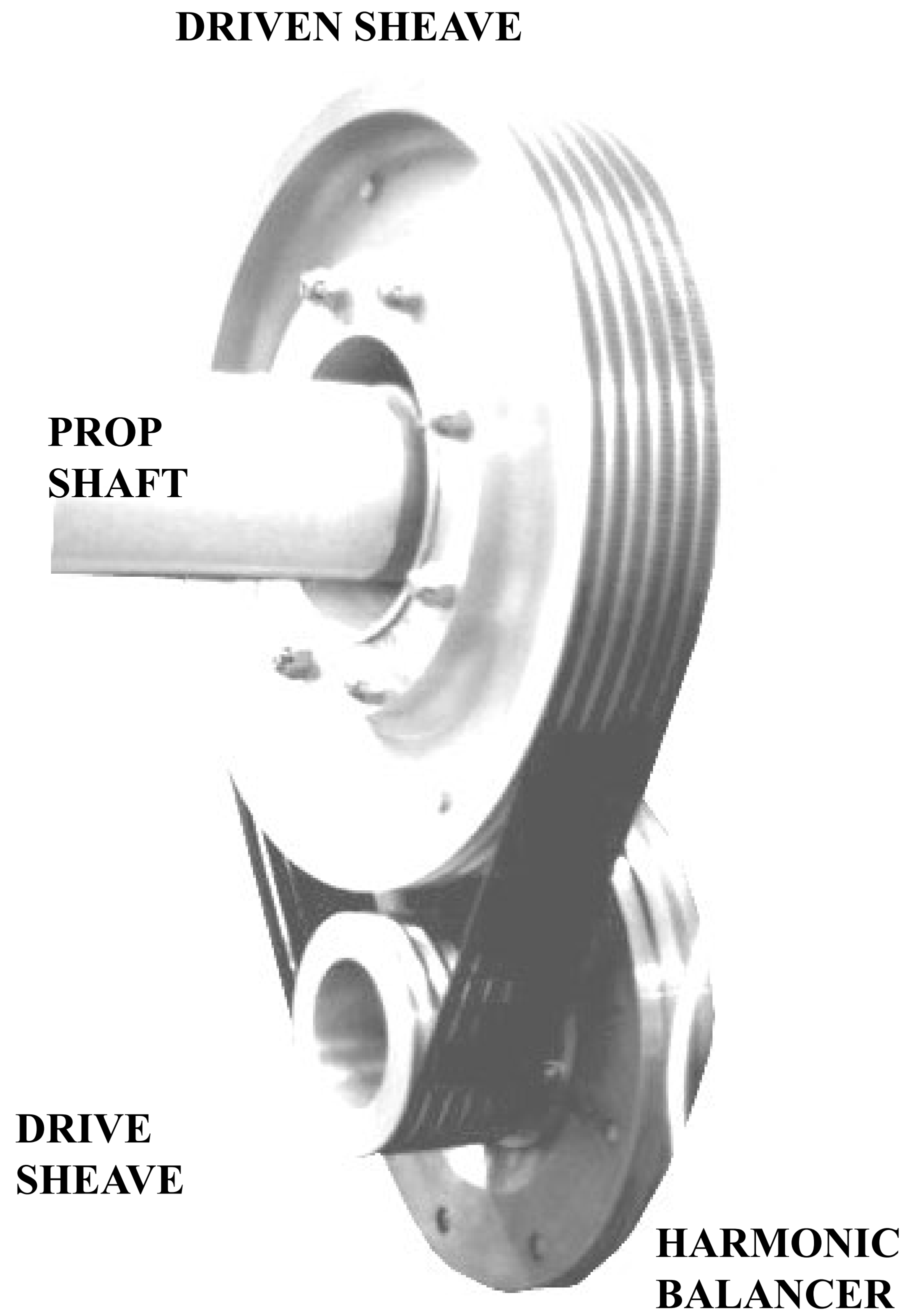
Heavy harmonic balancer on engine crankshaft, multi-sheave pulleys, and V-Belts.

Reduction System reduced:

- Propeller tip speed to approximately 0.3 Mach

- Engine combustion "pulses" to driveshaft and propeller.

	Engine Type	
	Continental (Opposed Reciprocating)	Curtiss-Wright (Wankel Rotary)
Drive Ratios:	3.33:1	5.34:1
Number of V-Belts:		
- 100 HP O-200	6	---
- 210 HP IO-360D	12	---
- 185 HP RC2-60	---	12



Quiet Aircraft Engines

Engines can also be major contributors to overall aircraft noise [(1)] So, small efficient engines with mufflers were used (at the expense of aero performance [(2)]).

HP_{REQ} = 4/3C(1/eV)(W/S)(W/AR)

Where:
Altitude Constant (C): 1000' AGL (Nominal)
Efficiency Factor (e).
Velocity (V): Quiet Cruise: 50 to 75 Kts (Nominal, 115% V_{Stall})
Weight (W): 1600 to 3700 (Kept to a minimum, no weapons or armor)
Wing Surface Area (S): G.T.E. 180 ft^2
Wing Aspect Ratio (AR): L.T.E. 18:1
Wing Loading (W/S): QT-2 (1600 lbs/ 180 ft^2) to YO-3A (3700 lbs/ 200 ft^2)

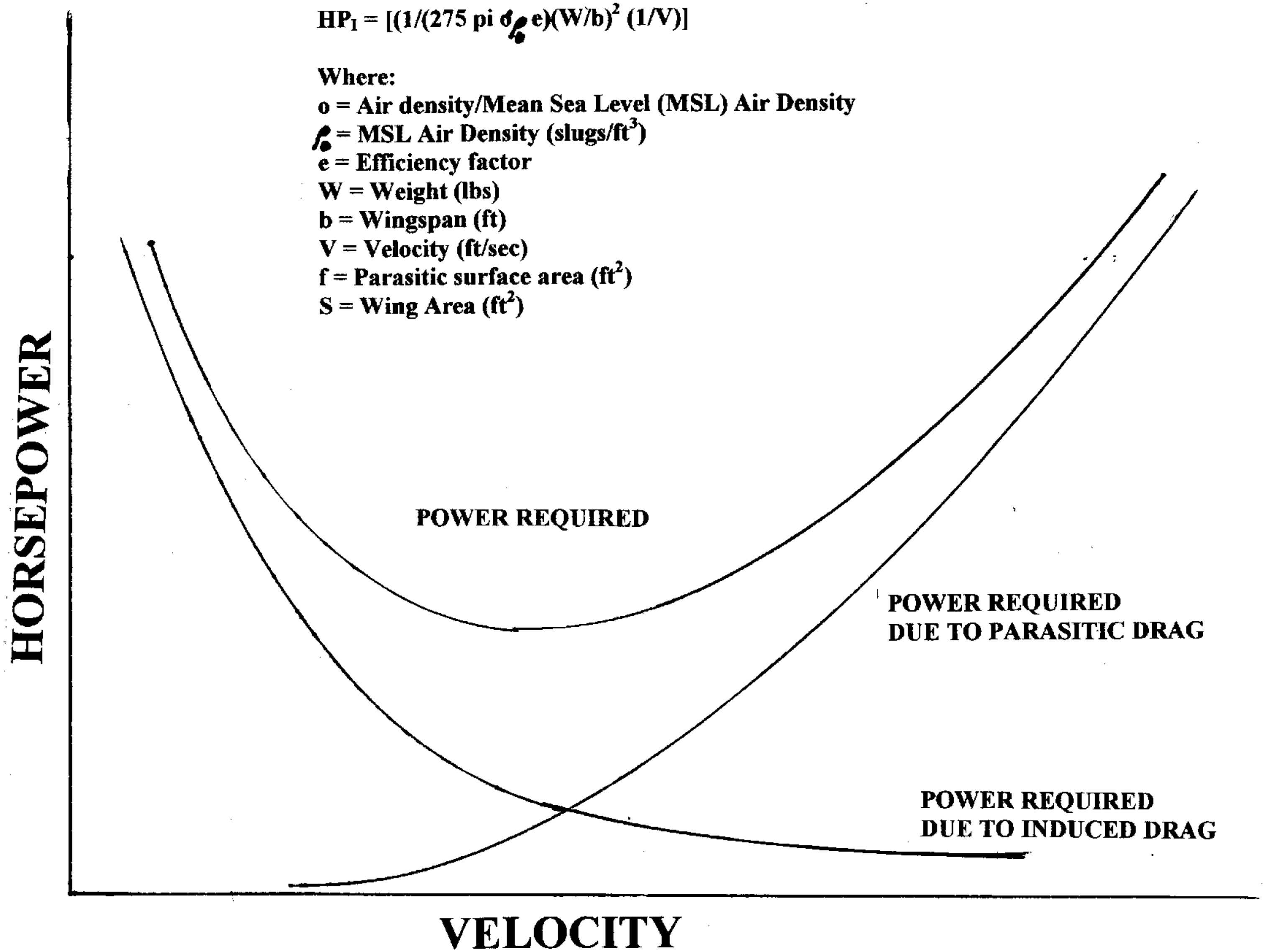
- **Continental Motors Corp. Air-cooled, (opposed) cylinder, push-rod, overhead-valve:**
  - **4 Cylinder 100 HP O-200: QT-2 and (Initial) Q-Star**
  - **6 Cylinder 210 HP I/O 360D: YO-3A**
- **Curtiss-Wright liquid cooled rotary combustion chamber (Wankel Type)**
  - **2 Cylinder 185 HP RC2-60: Q-Star (Final Version)**

Notes:
1. Per RACIC 171-49: PWL = 125 + 10 log HP, Where HP = (Drag x Velocity)/550.
2. Having only sufficient power required to do the missions, the Quiet Aircraft were operated "Low and Slow" during their 4 to 5 hour missions.

$HP_P = (\sigma\rho/1000)\ f\ V^3$

$HP_I = [(1/(275\ pi\ \sigma\rho\ e)(W/b)^2\ (1/V)]$

Where:
o = Air density/Mean Sea Level (MSL) Air Density
ρ = MSL Air Density (slugs/ft^3)
e = Efficiency factor
W = Weight (lbs)
b = Wingspan (ft)
V = Velocity (ft/sec)
f = Parasitic surface area (ft^2)
S = Wing Area (ft^2)



Horsepower versus Parasitic and Induced Drag

NOT TO SCALE

Note: Coincidentally, Aspect Ratio (AR), as a function of HP_{Reqd} and Velocity is similar to POWER REQUIRED.

RACIC BAT 171-49 B2

Quiet Aircraft Exhaust Silencers (Mufflers)

Common to all LMSC Quiet Aircraft:

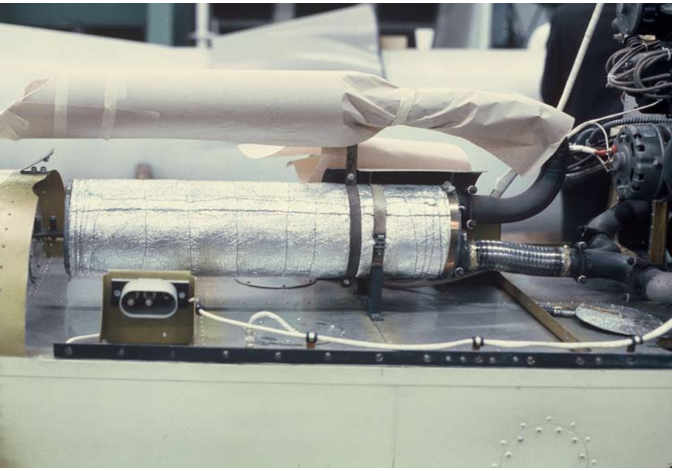
- **Exhaust gas outlets obscured from ground observers.**
- **Exhaust outlets sized to match exhaust gas velocity to aircraft airspeed, so relative velocity was nil:**

Peculiar to specific Quiet Aircraft:

- – **QT-2 and Initial Q-Star with Continental 4-Stroke Engines: An off-the-shelf 1958 General Motors Buick Automobile Muffler**
- – **Q-Star Final Version with Curtiss-Wright 2-Cylinder (Wankel) Rotary Combustion Chamber Engine: Probably two expansion chambers plus a muffler. (No data currently available).**
- – **YO-3A: A custom engineered for the Continental 6-Cylinder 4-Stroke Engine. Asymmetrical as regards the airframe, it ran the length of the fuselage. Exhaust gasses exited though a diffuser.**

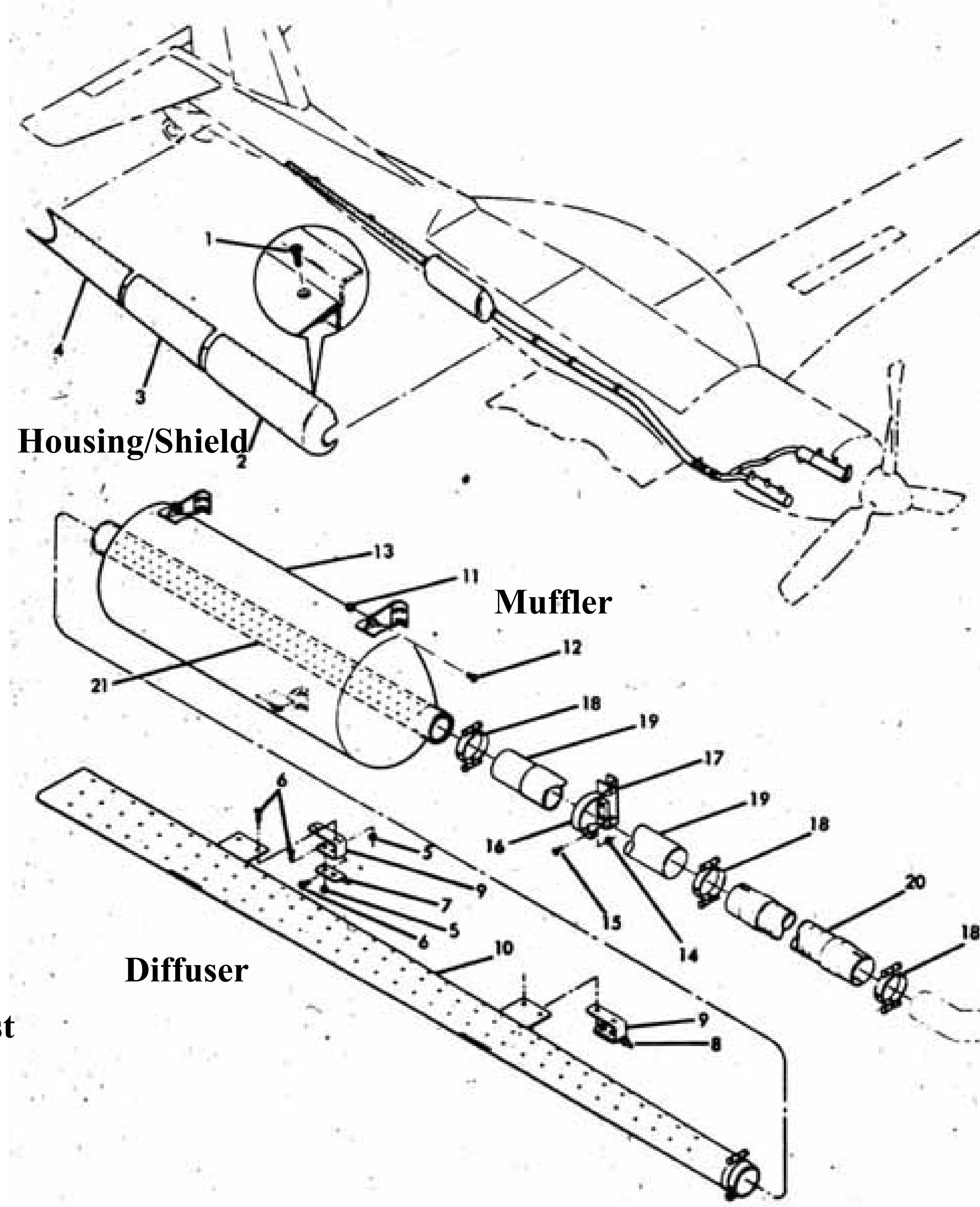
Notes from references:

1. **Resonance (f_o): Lamda = (1120/Hz)[(Deg F+460)/530], f_o anti-proportional size.**
2. **Weight and Back Pressure minimized (+ 4 PSI reduces Engine Power 10%).**
3. **Attenuation, also know as Transmission Loss (TL):**
   - **Mufflers, General: $\leq$ to 20 dB**
   - **Resonant and expansion chambers: $\leq$ 19dB.**
   - **90^o Bends: $\leq$ 5-7 dB,**
   - **“Ys”: $\leq$ 4dB.**



ABOVE:
Typical
Buick Muffler Installation in work:

- **QTs and Initial Q-Star**
- **180° Turns**
- **Exhaust Outlet (wrapped in paper) Pointed Aft (to left)**



RIGHT:
YO-3A Exhaust System

Airframes, Wings, and Aerodynamic Noise

All LMSC Quiet Aircraft are based on Schweizer SGS2-32 Glider Airframes: Aerodynamically efficient light weight, (all-aluminum) with generous high Aspect Ratio (AR) laminar flow wings with high Lift/Drag (L/D). Weight was minimized to reduce Wing Loading (W/L)

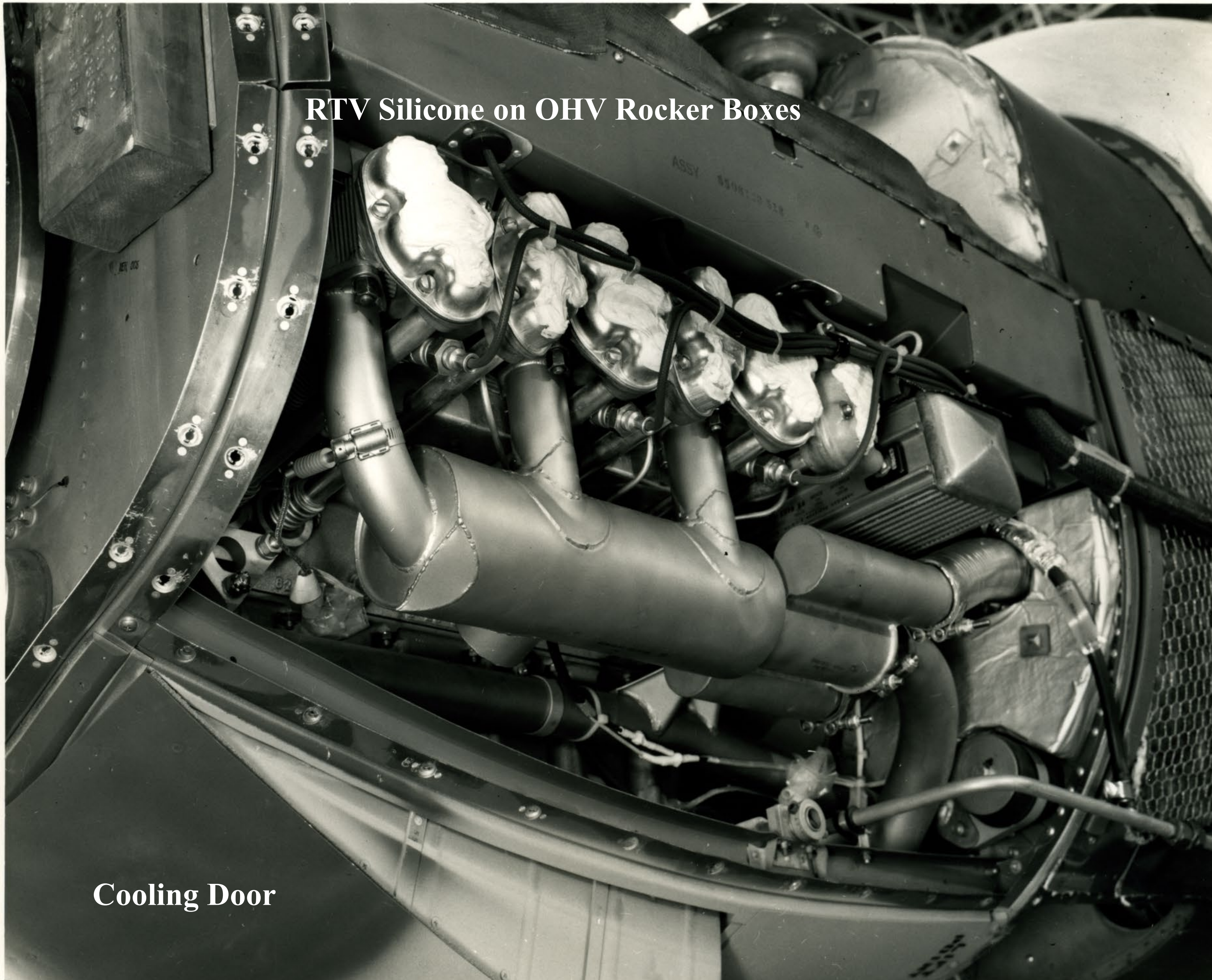
Remembering that noise is related to power and HP_{REQ} = 4/3C(1/eV)(W/S)(W/AR).
So, everything in the numerator was minimized and denominators maximized.

The airframes were fabricated using "all-flush" rivets and its wings were constructed with extra thick skins (two standard thicknesses) and spars for anticipated acceleration "G" loading and to reduce panel waviness, flexing, and panel vibration.
The modifications reduced aerodynamic drag and its associated noise.

Protuberances, cavities were minimized or eliminated. Grates added to engine air inlets and outlets Wake Noise, Vortex, and Cavity Noise negligible in Quiet Cruise Mode

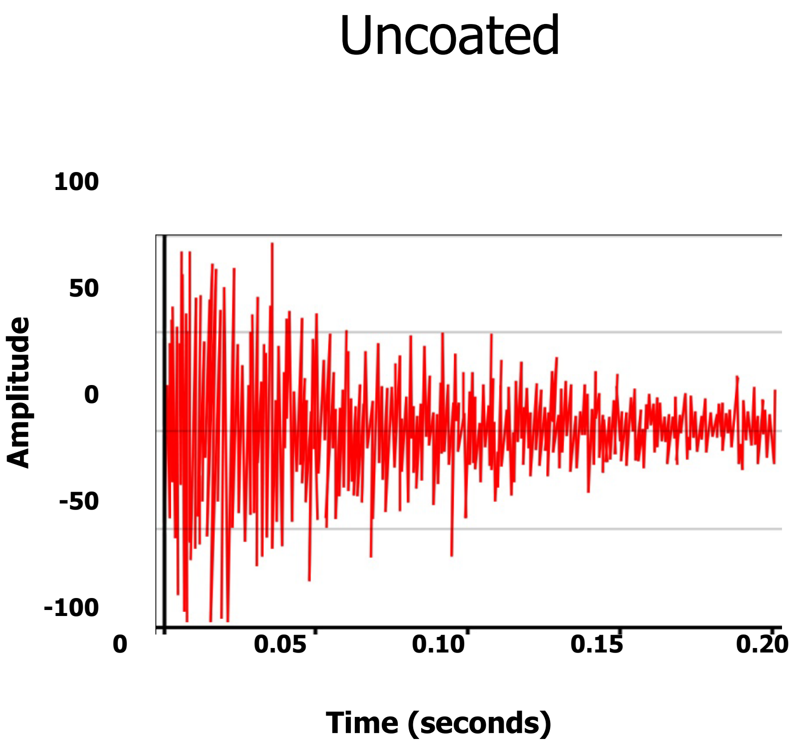
Johns-Manville insulation and vibration dampening foam added to some panel interiors

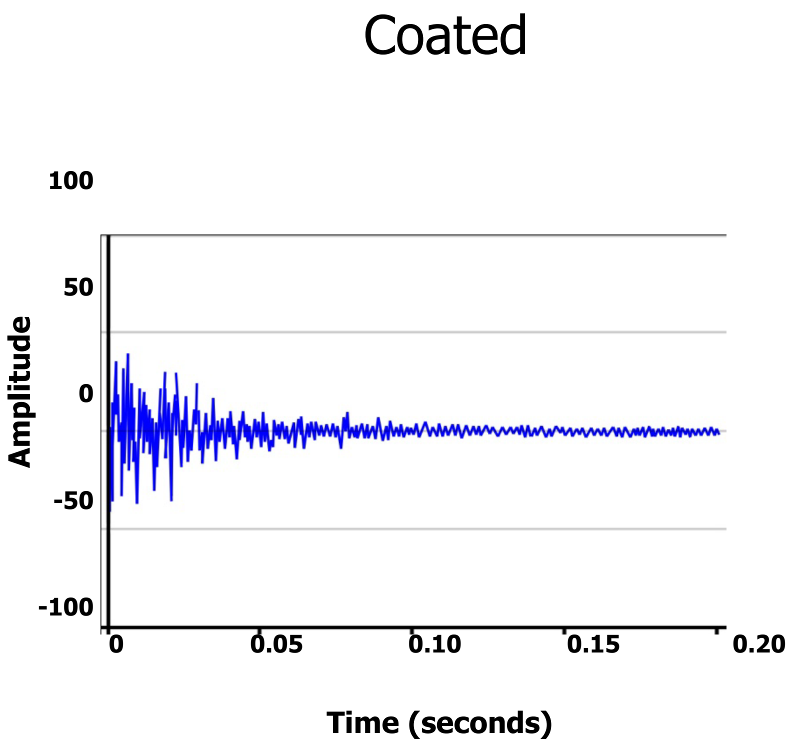
Notes:
1. Boundary Layer Noise:
- Laminar Flow: Very little noise
- Non Laminar Flow: Noise Producing: Transition and Turbulent Regions add Form Drag and noise
2. Only bottom half of fuselage and wings affect Boundary Layer noise to a ground observer: (fuselage + wing planform)/2).



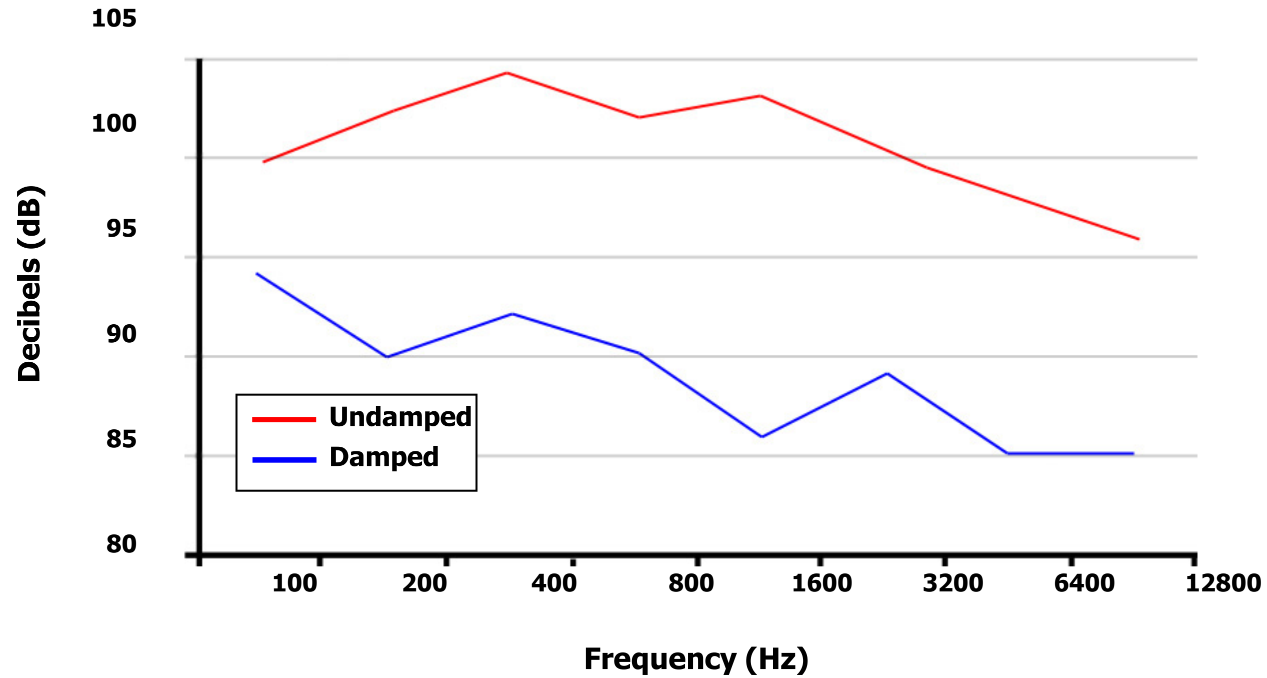
YO-3A IO-360D Continental Engine

Effect of Acoustic Coatings On Vibration Damping





Effect of Acoustic Coating on Noise Reduction (Typical Results)



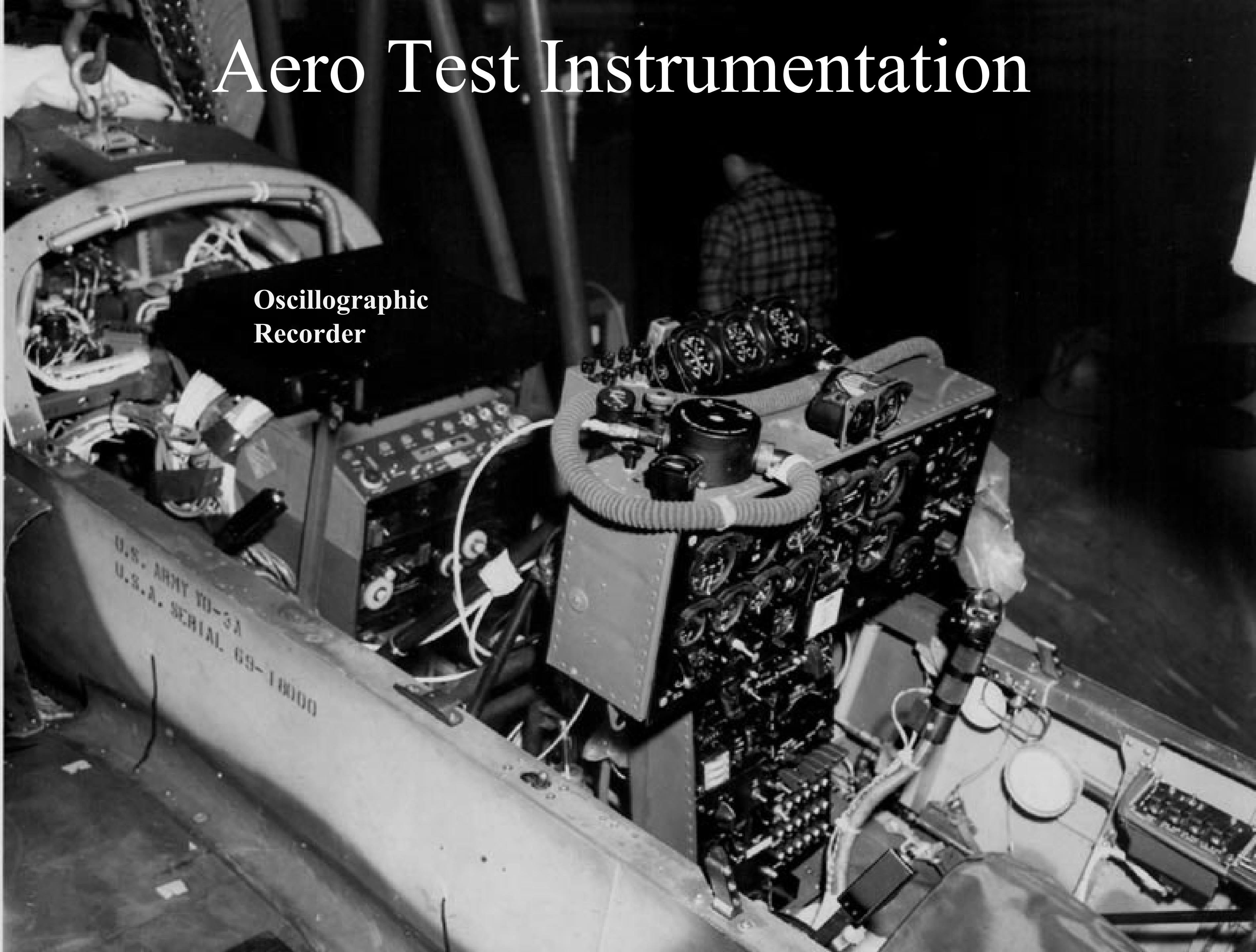
Note: Some coatings convert sound energy to heat energy

Acoustic Test Programs

In the early Quiet Aircraft experimental programs, the staff was very small (less than 15 full-timers) and only simple instrumentation was available (Octave Band Analyzers, sling Psychrometers, stopwatches, surveying instruments, etc).

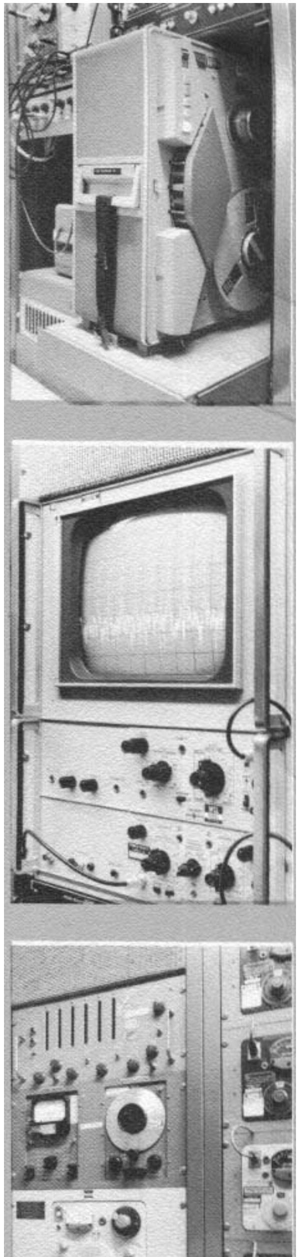
Later, for the Full-Scale-Development YO-3A Program; the staff included a large analysis team, the aircraft was fully instrumented, the Mobile Acoustic Test System (MATS) was available

Aero Test Instrumentation



- QT-2 Version

- YO-3A Version



Mobile Acoustic Test System (MATS).

A 15 ton 40' OTR all weather air-conditioned Trailer.

Equipment:

- •Silent 15KW power supply
- •Integrated commercial and military communications
- •Weather station
- •Crew quarters
- •Kitchen
- •Workshop Equipment:
    - •Machine Lathe
    - •Welding
    - •Shop air
    - •Tools
    - •External lights
- •Real Time PSD and data acquisition acoustic test equipment:
    - •14 track analog magnetic tape recorder
    - •Wide band analyzers
    - •Octave band analyzers
    - •Narrow band Spectrum Analyzer
    - •Ensemble averager
    - •Time code generator
    - •Graphic level recorder
    - •Visicorder
    - •High dynamic range microphones

“Fly-Bys” and Acoustic Signal Processing

Evaluation of noises in the human hearing range (20 to 20K Hz)

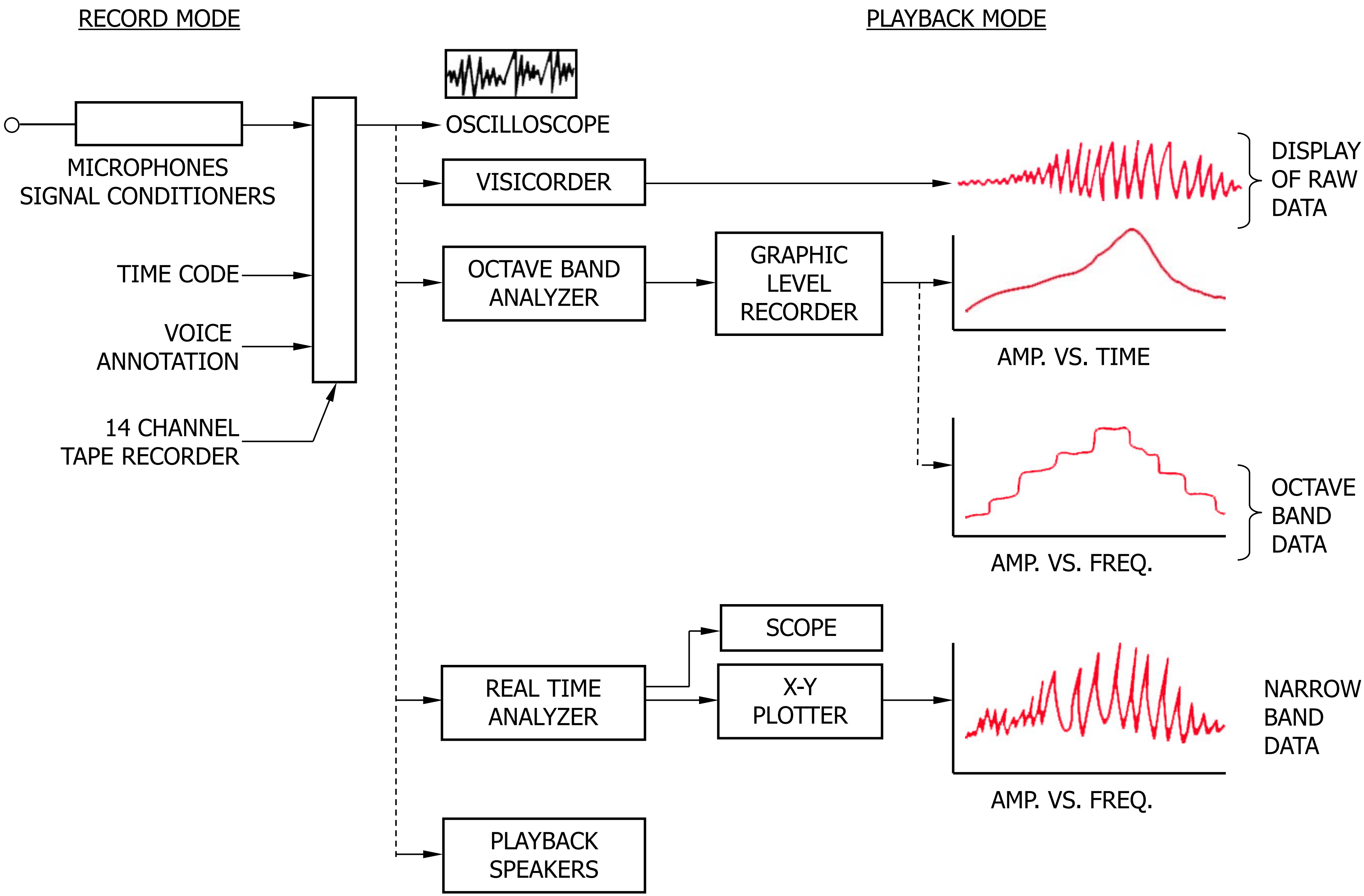
“Fly-bys” (at G.T.E. 50’ AGL) and ambient noises were recorded using a multi-channel analog recorder.

The recordings were then “played back” into various analyzers numerous times to characterized them in:

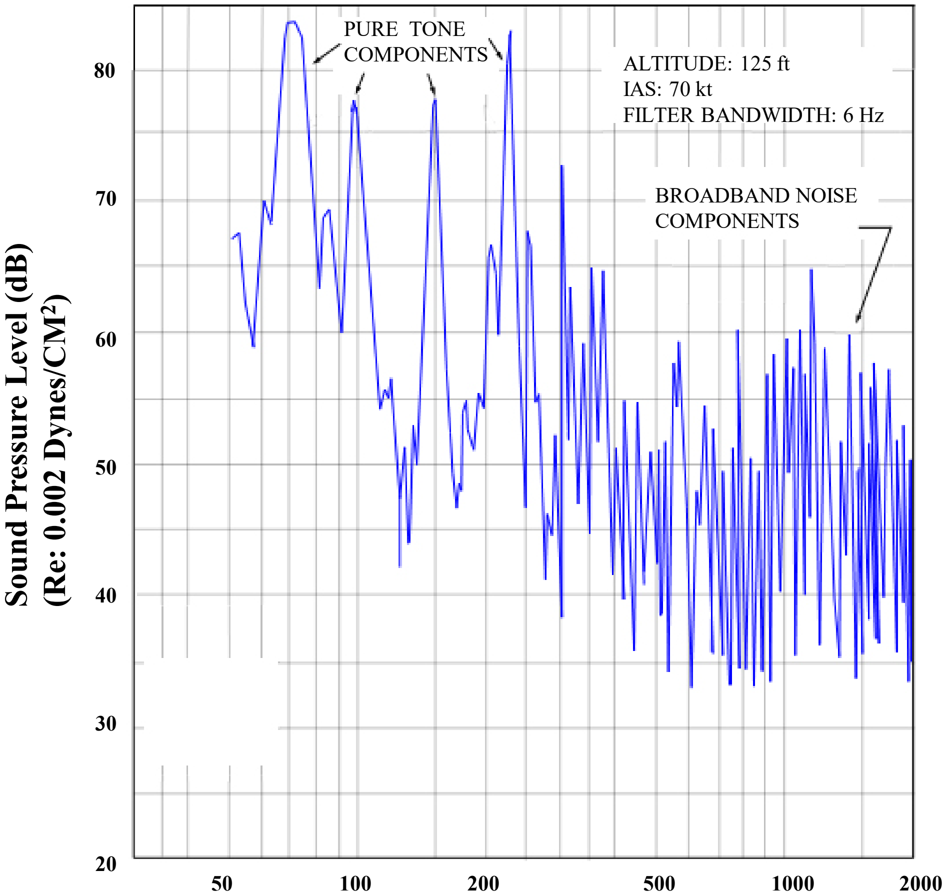
- Overall Sound Power Level (SPL)
- Octave Band Sound Power Level (SPL)
- Very narrow band Power Spectral Density (PSD, the most important measure).

A digital Spectrum Analyzer, using Fourier Transforms, converted the Time Domain noise signals into Frequency Domain measurements: dBs at discrete frequencies (Hz).

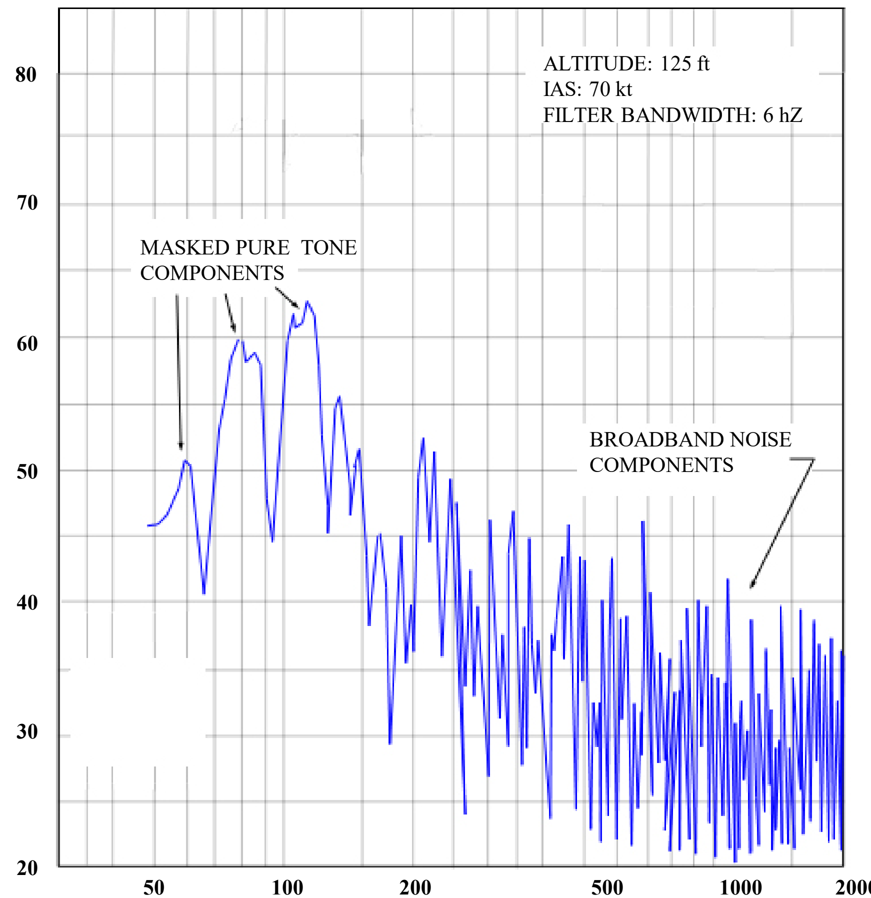
Acoustic Signature Data Processing Flow Chart



Noise Comparison of "Quieted O-1" and Quiet Aircraft



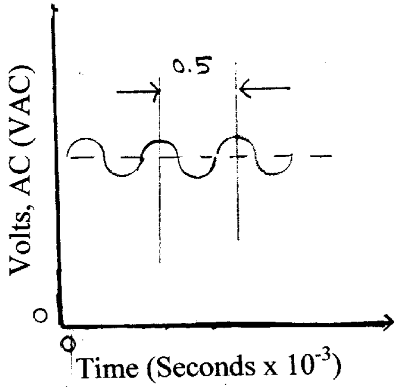
"Quieted O-1"



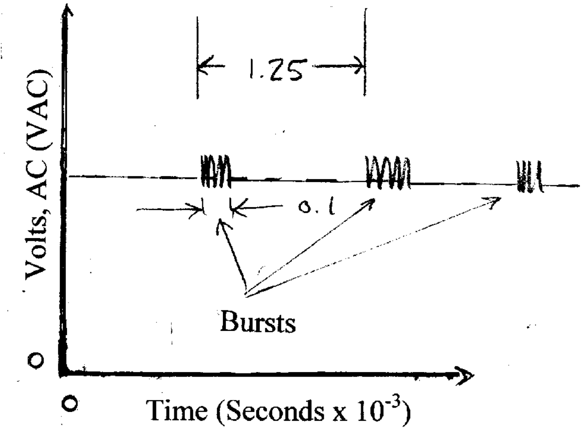
Quiet Aircraft

Frequency (Hz)

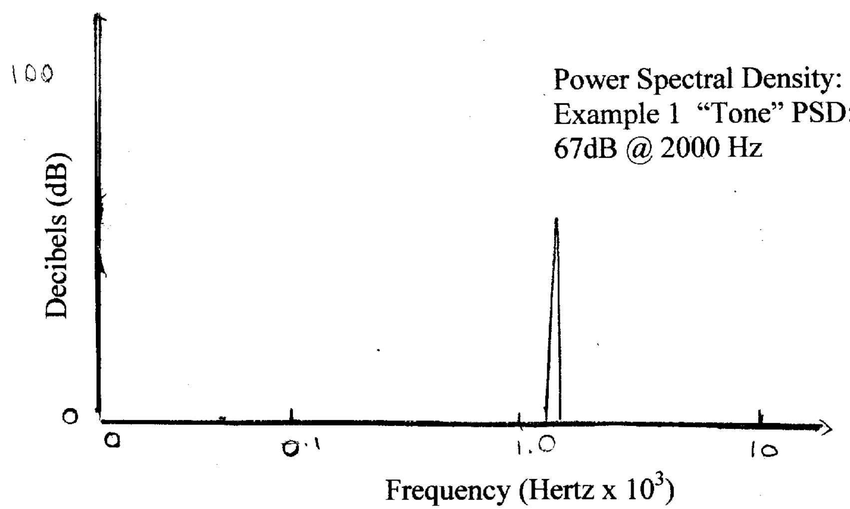
EXAMPLE 1:
A 2000 Hz
Sine Wave "Tone"
(Cavity whistle,
howl, bearing
"whine", etc.)



EXAMPLE 2:
Periodic bursts
of complex noise
(Prop blade passage,
engine exhaust pulses,
panel vibration, etc)



TIME DOMAIN (Oscilloscope, etc.)

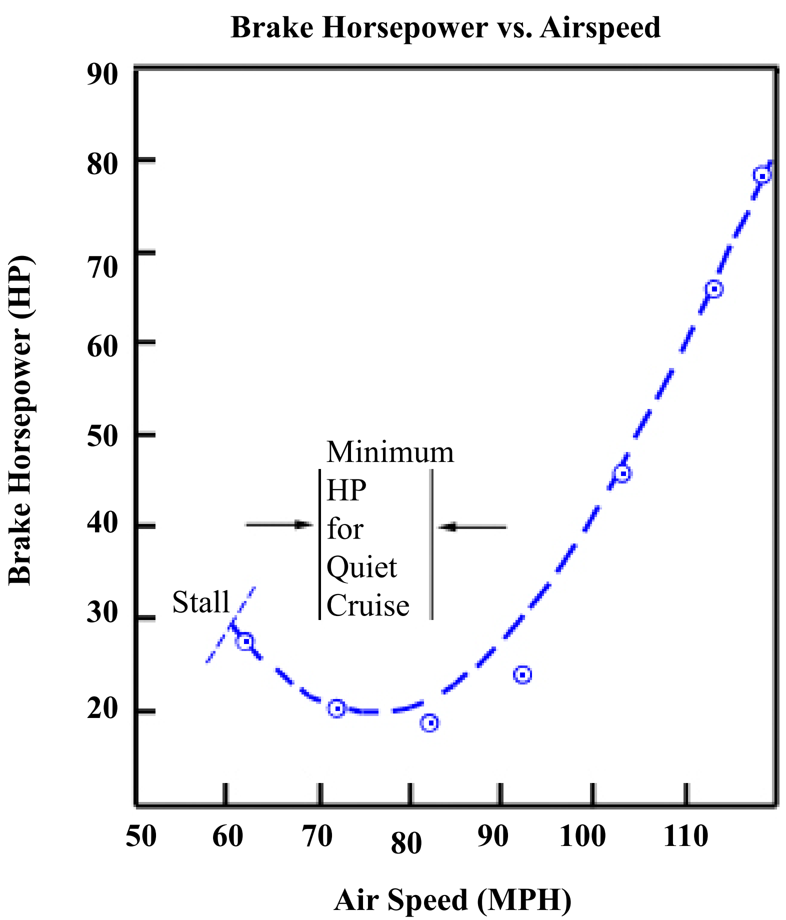


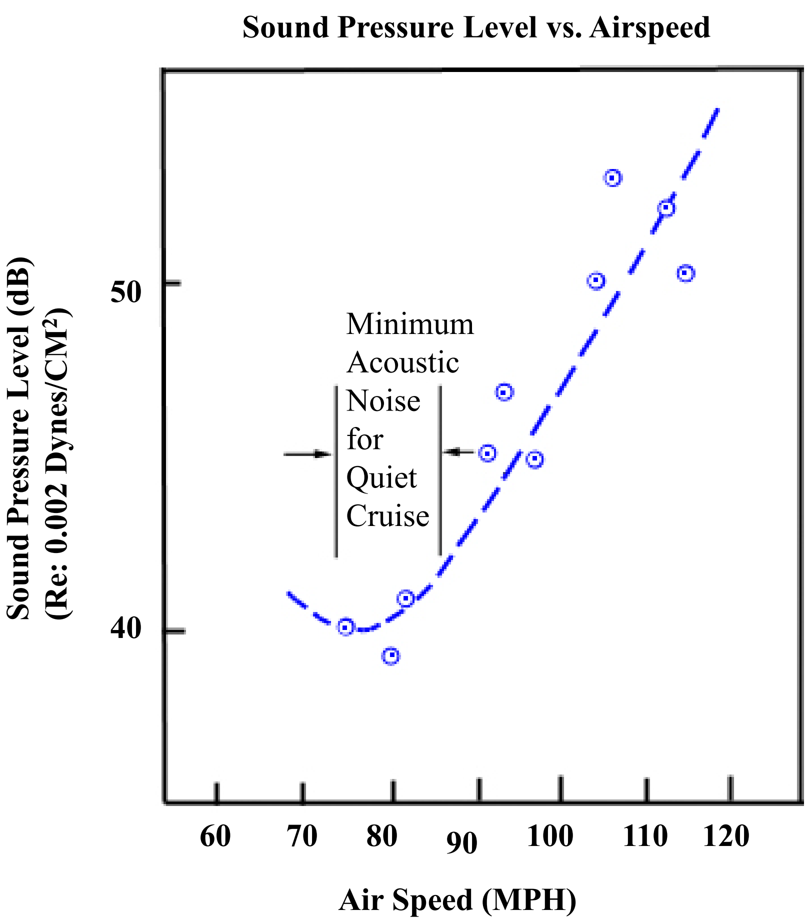
FREQUENCY DOMAIN (Spectrum Analyzer)

Note: Until the 1960s (LSI)
Microchips were available,
Spectrum Analyzers were
almost unaffordable.

Not to scale

Typical Comparison of Power Required and Quiet Cruise Airspeed





Acoustic Qualification Test Program

Numerous tests were done in reasonably quiet environments. However, an environment 10 db quieter than the greatest anticipated quiet aircraft noises was desired: one with low winds, no vehicle traffic, and few animals.

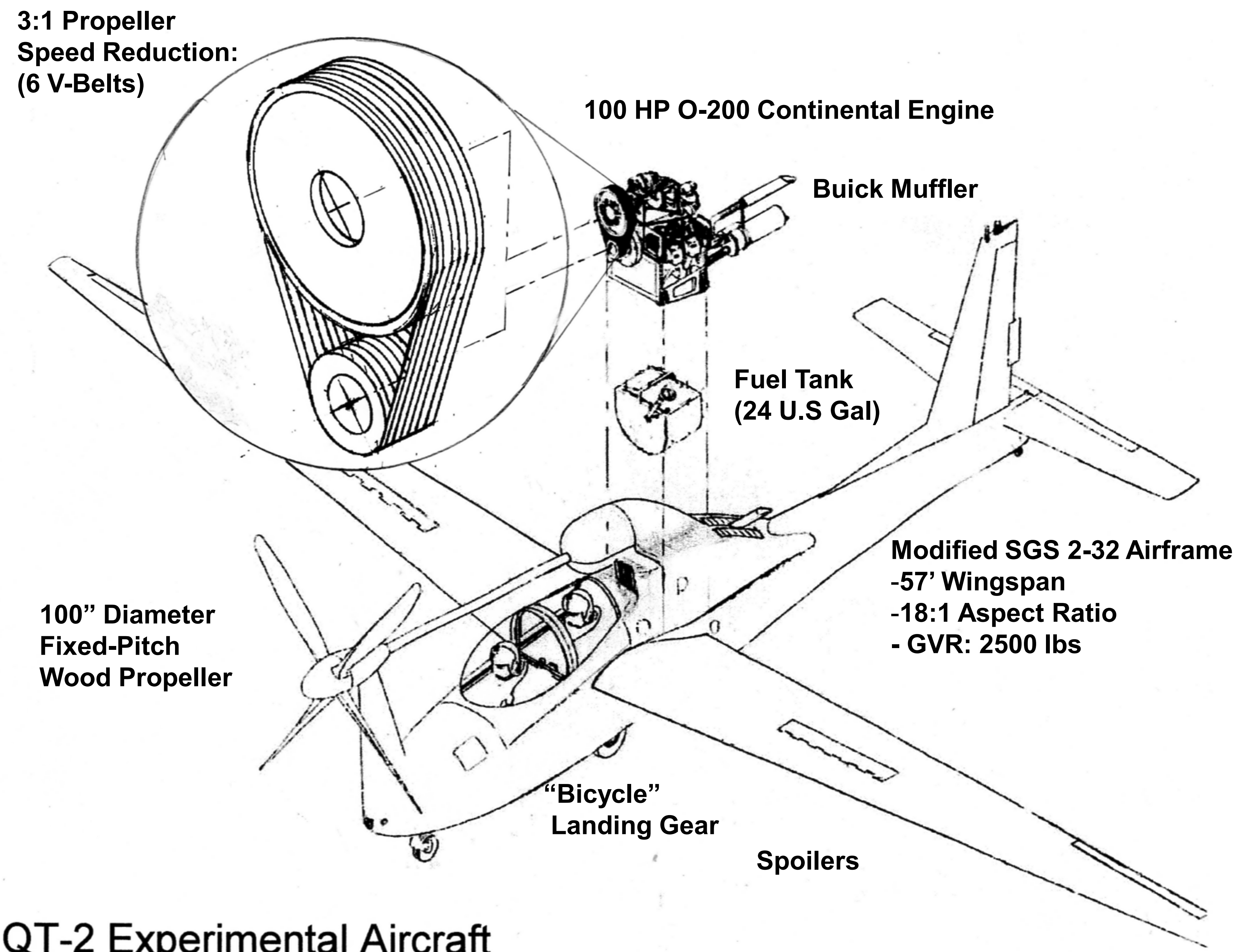
A site 25 miles East of Carson City, NV met all requirements:

- **Abandoned WWII desert airstrip on firm desert alkali base**
- **Remote/covert**
- **Secure (1)**

Using MATS and the quiet high desert environment, YO-3A noises were analyzed. The noise characteristics were matched to the characteristics of the aircraft component(s) and operating condition(s): Our "Which Hunt".
Once matched, the offending component(s) or condition(s) were addressed.
The loudest noises in the Critical Area (160 -600 Hz) were addressed first: Eliminated, Reduced, or characterized; e.g, adjust a control re-rig a Main Landing Gear Door, etc.

Follow-Up tests and demonstrations at Hunter-Liggett Military Reservation (H-LMR) Combat Development Experimentation Center (CDEC) confirmed the quiet character of the YO-3A: The YO-3A and competitive aircraft flew over USA Troops. The loudest aircraft were heard at the greatest distances.

Note: 1. Except for "red light" visitors



QT-2 Experimental Aircraft

QT-2, QT-2PC (I & II) and X-26B

A Modified Schweizer SGS2-32 Airframe (Pilot forward and Observer aft)

- **Bicycle Main Landing Gear (MLG)**
- **O-200 Continental Engine**
- **4-Blade Fixed Pitch Propeller**
- **Avionics:**
  - **QT-2: Portable AM-VHF**
  - **QT-2PC and X-26B: MIL-SPEC Communications-Navigation-Identification (CNI)**

QT-2
1967

QT-2PC
I & II
1968

X-26B
1969 to Current

Q-STAR

A LMSC owned test aircraft.
Capabilities: Evaluation of "quieting" techniques, propulsion systems, and payloads (sensors).

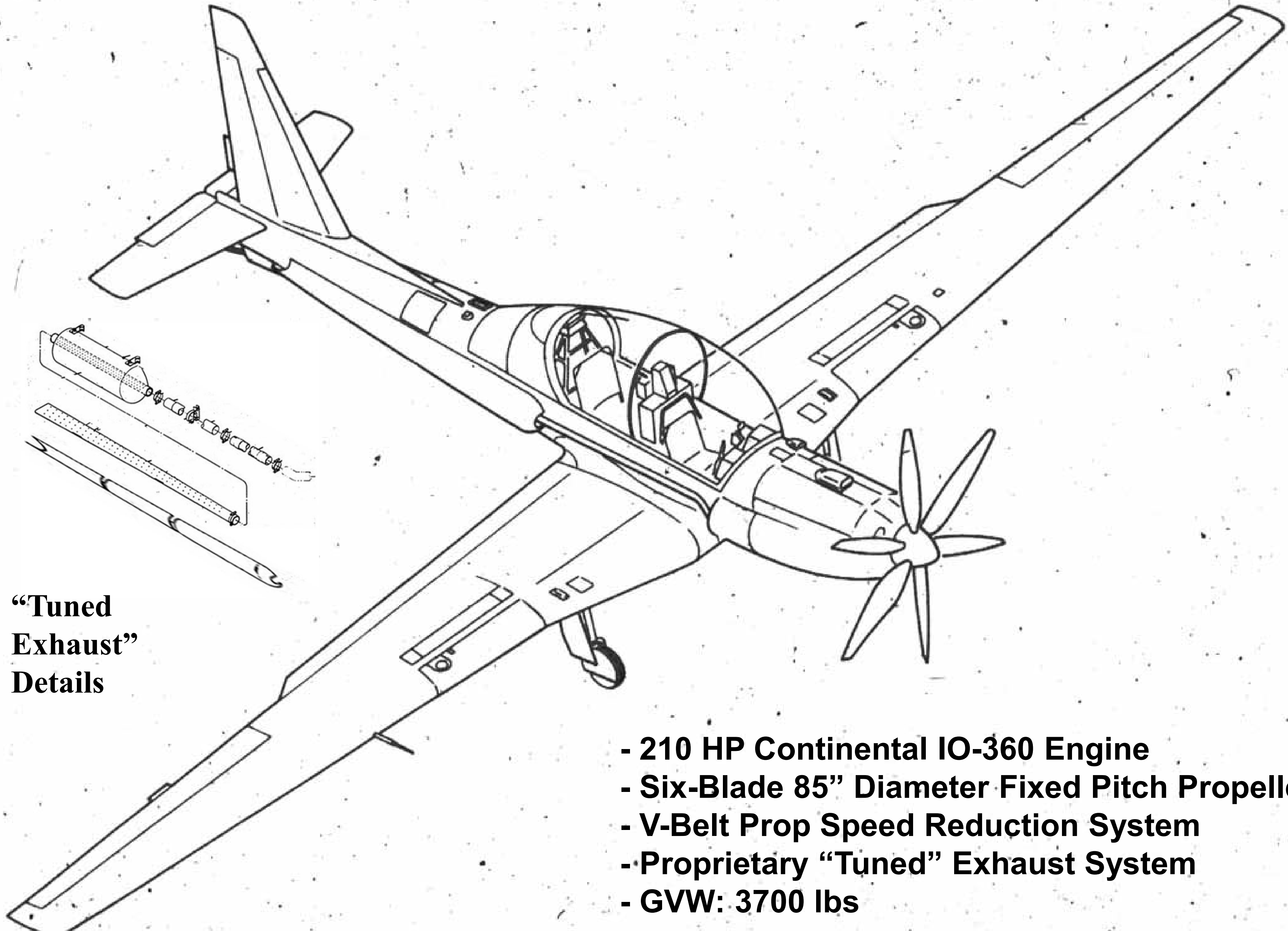
- **A Modified Schweizer SGS2-32 Airframe (Pilot forward and Observer aft)**
- **Tail Dragger with a fixed "Spring" MLG**
- **Engine:**
  - **Initial Configuration:100 HP Continental O-200 Engine with 3.33:1 Reduction System**
  - **Final Configuration: 185 HP Curtiss-Wright (Wankel) RC2-60 Rotary Combustion Chamber Engine with 5.34:1 Reduction System**
- **18 Different Pitch Propellers**
- **Sensors:**
  - **Black Crow**
  - **NVAP**

YO-3A

An all new single- purpose (covert) Full-Scale-Development Aircraft:

- **Clean low-drag airframe with all "BUMPS" on the inside (including five (5) Communication-Navigation-Identification (CNI) Antennas inside the empennage): High L/D, AR(18:1), low W/S (3700 lbs/200 ft^2) "Tail dragger" with folding main landing gear (MLG)**
- **Technical Observer forward and Pilot aft**
- **Cantilevered 210 HP IO-360D engine**
- **"Tuned" Exhaust System**
- **Large multi-blade slow turning propeller:**
    - **Initial configuration: 6 blade fix pitched**
    - **After march 1971: 3 blade variable pitch (constant speed)**
    - **Asymmetric "tuned muffler"**

- **State-Of-The-Art (SOTA) Night-Optics-Device/Night Vision Device (NOD/NVD) Sensor:**
    - **Night Vision Aerial Periscope (NVAP): 2nd Generation Stabilized 10 Degree Field-Of-View (FOV) NOD**
    - **100 W Infrared Illuminator (IRI)**
    - **75 mJoule NdYAG Laser Target Designator (LTD)**
- **SOTA Standard-Lightweight-Aviation-Electronics (SLAE) CNI Avionics plus Tactical-Communinications-And-Navigation (TACAN)**

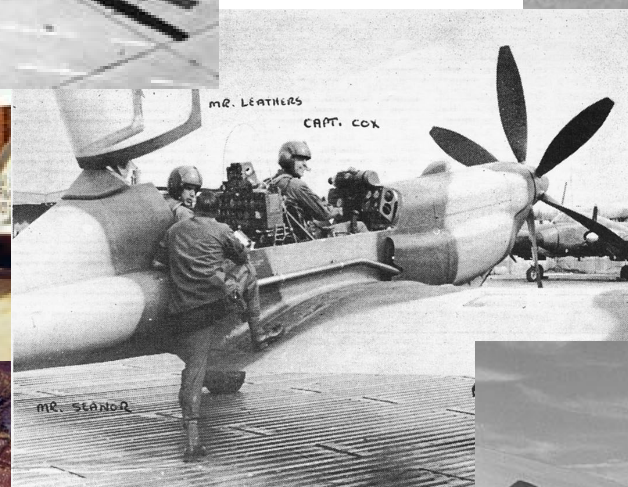


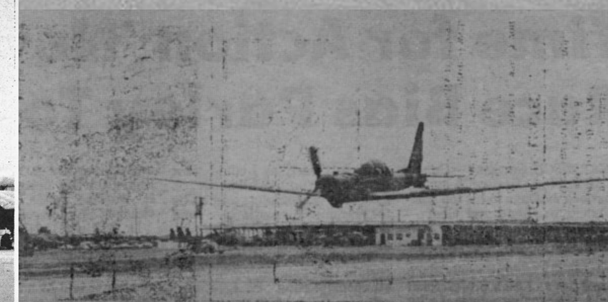
“Tuned Exhaust” Details

- **210 HP Continental IO-360 Engine**
- **Six-Blade 85” Diameter Fixed Pitch Propeller (1)**
- **V-Belt Prop Speed Reduction System**
- **Proprietary “Tuned” Exhaust System**
- **GVW: 3700 lbs**

YO-3A Aircraft

Note 1: Later changed to a Three-Blade variable pitch


MR. LEATHERS
CAPT. COX
MR. SEANOR



Post Military Applications

- **Law Enforcement (YO-3A 69-18006 & 7/N14425 & 6):**
  - **Louisiana Dept of Wildlife and Fisheries (LDWF)**
  - **Federal Bureau of Investigation (FBI)**
- **National Aeronautics and Space Agency (NASA N818NA):**
  - **Ames Research Center (ARC)**
  - **Dryden Flight Research Center (DFRC)**
- **Civilian:**
  - **Dick Osborne (YO-3A 69-18003)**
  - **Mile High Gliding (QT-2PC #2/N2472W)**
- **Museums:**
  - **USAAM QT-2PC #1 (X-26B[1] and 69-18000 [1])**
  - **Hiller Institute & Museum (69-18001)**
  - **Seattle Museum of Flight (69-18005)**
  - **Pima Air & Space Museum (69-18006)**
  - **Western Museum of Flight (69-18007)**

Note 1: Permanent Historical Document

Summary of LMSC Quiet Aircraft Programs

- **Inputs:**
  - **DoD requirement**
  - **USN TSOR**
  - **LMSC Proposals**
- **Output:**
  - **QT-2 demonstrated "Quiet" powered flight**
  - **QT-2PC Prize Crew OpEval validated: Covert Reconnaissance Concept.**
  - **Q-Star evaluated engines, propellers, propeller speed reduction systems, and sensors (including "BLACK CROW").**
  - **MATS: The Nevada acoustics tests characterized YO-3A acoustic noises**
  - **LMSC Developed, and produced 2 Experimental QT-2s in 6 months, then converted them to tactical QT-2PCs in 3 months; 11 Full-Scale-Development YO-3As within 2 years. They served military customers in Vietnam throughout most of 1968, 1970, and 1971. They also served in Law Enforcement (LDWF and FBI), Science (NASA) and education (USN Test Pilot School, Linn State College and U. Illinois)**
- **Conclusions:**
  - **QT-2 was the 1st aircraft designed with everything secondary to aural quietness.**
  - **Q-Star was the 1st Aircraft to use a "Wankel" Engine for primary power.**
  - **QT-2PC was the 1st aircraft to use "Starlight Scopes" and the 1st to survive a hostile environment by means of "low observables" now defined as "STEALTH"!**
  - **YO-3A was the 1st to use an integrated NOD/IRI/LTD Sensor**

We "Took the Night Away From Charlie"

Quiet Aircraft Association, Inc. Websites

- Additional information is available of our websites:
- quietaircraft.org
- prizecrew.org
- YO-3A.com

Quiet Aircraft Specifications

Aircraft Type	X-26A (SGS 2-32)	X-26B (QT-2)	QT-2 PC
Manufacturer	Schweitzer Aircraft	Lockheed Missiles & Space	Lockheed Missiles & Space
Sponsor	USN	DARPA, USA, USN	DARPA, USA, USN
Number Built	5	2	2
First Flight	3 July 1962	15 August 1967	10 December 1967
Length	26 feet 9 inches	30 feet 9 inches	30 feet 9 inches
Wing Span	57 feet 1.5 inches	57 feet 1.5 inches	57 feet 1.5 inches
Wing Area	185 square feet	185 square feet	185 square feet
Aspect Ratio	18:1	18:1	18:1
Height	7 feet 2 inches	9 feet 3 inches	9 feet 3 inches
Empty Weight	857 lb	1,576 lb	1,894 lb
Gross Weight	1,430 lb	2,182 lb	2,500 lb

Quiet Aircraft Specifications (continued)

Aircraft Type	X-26A (SGS 2-32)	X-26B (QT-2)	QT-2 PC
Engine	—		
- Manufacturer		Continental	Continental
- Type		O-200A	O-200A
- Horsepower		100 @ 3,000 RPM	100 @ 3,000 RPM
- Weight		237 lb	237 lb
Propeller	—		
- Manufacturer		Fahlen	Fahlen
- Blades		4	4
- Diameter		100 inches	100 inches
- Chord		8 inches	8 inches
- Tip Speed		0.3 Mach	0.3 Mach
- Pitch		Fixed	Fixed
Reduction System	—		
- Type		V Belt	V Belt
- Ratio		3:1	3:1
- Belts		6	6
Muffler	—	GM/Buick	GM/Buick

Quiet Aircraft Specifications (continued)

Aircraft Type	X-26A (SGS 2-32)	X-26B (QT-2)	QT-2 PC
Fuel	——		
- Capacity		**25**	**24**
- Type		**80 - 85 Octane**	**80 - 85 Octane**
Max Rate of Climb	——	**300 fpm**	**200 fpm**
Endurance	——	**4 hours @ 80 Knots**	**4+ hours**
Maximum Speed	**137 Knots**	**100 Knots**	**100 Knots**
Stall Speed	**30 Knots**	**54 Knots**	**54 Knots**
Quiet Cruise	——	**65 Knots**	**65 Knots**
Max "G"	**6**	**3.4**	**2.4**
Maximum Altitude	**18,500 feet**	**13,000 feet**	**11,000 feet**
Avionics		**Commercial**	**Commercial**
- Comm		**VHF-AM**	**VHF-AM&FM; UHF-AM**
- ADF			**Low Band**
- DF			**VHF-AM**
Transponder			**X-Band**
- IFF/Ident			**L-Band**

References/Further Reading:

- **DARPA AGILE RACIC BAT-171-49 Feasibility of Developing an airplane having a Silent Mode Of Operation. Battelle Memorial Institute. July 22, 1966**
- **ACTIV ACA-18/68I Operational Evaluation the QT-2PC Quiet Aircraft Jan 16,1968**
- **Detail Specification Y0-3A Observation Aircraft (u)**
- **AFAPL AD779773 USAF/CALAC Low Noise Propeller Technology Demonstration. E.D. Griffith, et al. CALAC/AFAPL Jan 197411/3,AB,K/13 (Item 10 from file: 6) 0574741 NTIS Accession Number: AD-876 095/1/XAB**
- **USAASTA-70-09 Army Preliminary Evaluation III YO-3A Airplane May-Jun 1970 Rundgren, I. W. ; Deel, A.**
- **ACTIV ACA-30/68I YO-3A Final Report. By W. V. Bournes, Ltc Infantry**
- **Redstone Scientific Information Center https://rsic.amrdec.army.mil**
- **LMSC 699041 Q-Star**
- **NASA-CR-155002; AAE-77-12-PT-1 Quiet Propeller Illinois Univ., at Urbana-Champaign. Dept. of Aeronautical and Astronautical Engineering.**
- **Ormsbee, A. I. Jul 77 16p**
- **USN Capt (Ret) Leslie J. Horn (various) Presentations**
- www.sengpielaudio.com

Quiet Aircraft Systems

Sensors:

QT-2PC (aka X-26B):

1st Generation Night Optic Device (NOD) 4 and 7 Degree FOV "Starlight Scopes.

(The first aircraft to have them)

YO-3A:

Night Vision Aerial Periscope (NVAP):
2nd Generation Stabilized 10 Degree FOV NOD
100 W Infrared Illuminator (IRI)
75 mJoule NdYAG Laser Target Designator (LTD)

(The first integrated airborne NOD/IRI/LTD)

Quiet Aircraft System Goal:

Resolve/Identify a human at 2000' slant range in moonlight; which determined the Quiet Aircraft "no aural detection" stand-off-range and its acoustic requirements. Quiet Aircraft are silent only to the extent of their aural detection range.