USAF SINGLE-EVENT SONIC BOOM PREDICTION MODEL: PCBoom3

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ABSTRACT

The Air Force has developed PCBoom3, a general-purpose, single-event sonic boom prediction model. The model operates on an IBM PC or compatible, under DOS or Windows. It is accessed via an integrated environment which controls building of input cases, running boom calculations, displaying contours and signatures, and managing all associated data. The primary boom calculation is via a variation of FOBOOM, the focus-boom extension of Thomas's program. Aircraft input is either via a user-provided F-function, or simple N-wave F-functions tabulated for about 20 current aircraft. A fast boom calculation, based on Plotkin's SBORT algorithms, is included for simple N-wave F-functions in a windless atmosphere and flight altitudes up to 60,000 feet. After a run is complete, the user can access an index identifying significant events (focal zones, beginning of footprint, etc.), then plot boom amplitude contours and signatures or spectra at any point in the footprint. The primary uses of this program are expected to be operational planning and boom incident investigation. However, because of the commonality between FOBOOM and the MDBOOM program currently being used for low boom configuration design, this program is of interest to the HSCT community, especially as supersonic route planning activity increases.

The Air Force recently conducted a flight test program to evaluate the focal zone capabilities of PCBoom3. Initial results of that program validate the prediction of focal zone geometry, amplitudes, and waveforms.

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PCBoom was developed to satisfy three basic Air Force needs. The first is a tool to predict sonic booms for use in environmental assessments of proposed actions. The second is a planning tool to minimize impact to sensitive areas. An example of this type of planning is if the operators of an offshore supersonic range would like to set daily minima for how far out the range users must go. The third application is to quantify what happened when an unintended incident does happen.

These needs lead to the requirement for a program that is relatively easy to use, runs quickly, and can be hosted on a PC. It is essential that input is as flexible as possible, and that output be available in graphical format.

AIR FORCE REQUIREMENTS

- **Single-Event Sonic Boom Impact Prediction**
- **Planning Tool**
- **Sonic Boom Incident Investigation**

The program has several methods for specifying trajectories. First, there is a file structure similar to that of FOBOOM/MDBOOM. Second, there is a general "Maneuver Driver" which allows interactive description of a maneuver. This is aimed at the planner or airspace manager who must be able to work with virtually any description of a maneuver. The interactive form of "ManD" helps the user reconcile information that may be inconsistent. Third, the program can import trajectory data from sources such as radar tracking, ACMI, or pre-computed trajectories. The program is designed to import these from a relatively benign ASCII file format. A user with unique data forms can prepare a conversion routine to this specification.

The program uses standard sonic boom ray tracing theory, and includes focus analysis via Guiraud's similitude and the Gill-Seebass numeric focus signature. Use of this program for environmental planning and claim investigation requires that it employ state-of-the-art methods.

Outputs are contours of equal overpressure (or other metrics), isopemp charts which provide a good visual interpretation of footprints and focal zones, and signatures and spectra.

GENERAL FEATURES

- **General Flight Profile Input**
- **Full Ray Tracing Scheme**
- **Non-Standard Atmosphere, With Winds**
- **Focus and Post-Focus Boom Impact Regions**
- **Outputs: Contours, Footprints (Isopemps), Signatures, Spectra**

The user works primarily with a simple pull-down menu system. The goal of this module is to set up the data stream needed by the computational modules that actually do the work. When a computational module is ready, MIM writes a batch file to execute it, then exits. The batch file ends by re-running MIM, putting the user back in the menus. This program is PC specific, but would be fairly simple to replicate on other interactive systems.

PROGRAM STRUCTURE:
MASTER INPUT MODULE (MIM)

- **Manages All Data, User Inputs, Via Simple Menu System**
- **Sets Up Runs Stream for Computational Modules**
- **Initiates Computational Modules as Separate Processes**
- **PC-Specific Interface**

The real work is done in the computational modules. These are written in Fortran 77, and for the most part are portable. Graphics are done with a PC-specific Fortran-callable plotting library with "industry standard" call styles. ManD, PCBPlot, and SIGOUT have PC-specific interactive interfaces, but these are kept isolated from the computational parts.

Boom calculations are done by either the full-theory FOBoom3 module or, for applications requiring very fast analysis, a scheme based on the rapid SBORT algorithms. Both schemes yield a file of boom signatures on the ground. This file is processed by a "footprint processor" which organizes it and indexes it for use by the output modules PCBPlot and SIGOUT.

It is worth noting that the FOBOOM3 module is derived from the same code from which MDBOOM was developed. It does not contain the proprietary configuration analysis tools, but those have been removed by blocking out subroutine calls and removing the corresponding modules. MDBOOM users may find it useful to adapt some of the new features to their work. As many routines as possible have been kept identical between the two programs, which will be of long-term benefit to maintenance of both.

COMPUTATIONAL MODULES

- **Maneuver Driver (ManD)**
- **FOBoom3 Boom Calculator**
- **SBORT Simple Boom Calculator**
- **Footprint Processor**
- **PCBPlot Footprint/Contour Output**
- **SIGOUT Signature and Spectrum Output**
- **All Written in Fortran 77**
- **"Industry Standard" Plotting Calls**

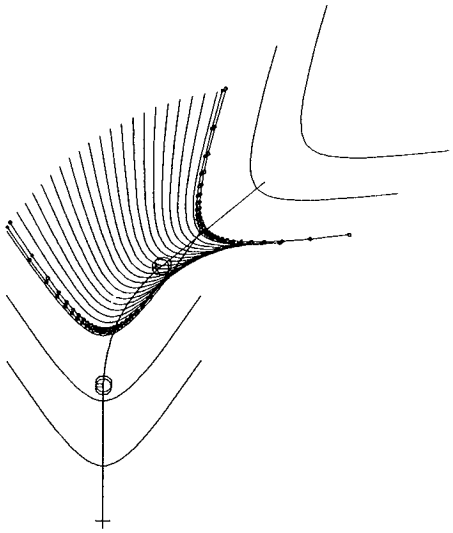
The contour plotting module will draw isopemps and contours. The isopemps – the ground intercepts of boom generated at specific times – are very useful for seeing where the boom footprint lies, and in interpreting focal zone geometry. The contours quantify the boom amplitude. Loudness is computed by the methods used by NASA–Langley, with a 125 msec auditory time constant.

PCBCont CONTOUR/FOOTPRINT MODULE

- **Isopemps (Ray/Ground Intersections)**
- **Contours of P_{max}, CSEL, ASEL, PL**
- **Interactive User Control of Plot Format**

This is an isopemp plot for a supersonic turn at constant Mach number. There is a "+" marking the beginning of the calculated maneuver, and "o"s marking the entry point. The caustic location during the turn is apparent, and the multi-valued region around the turn entry cusp can be seen.

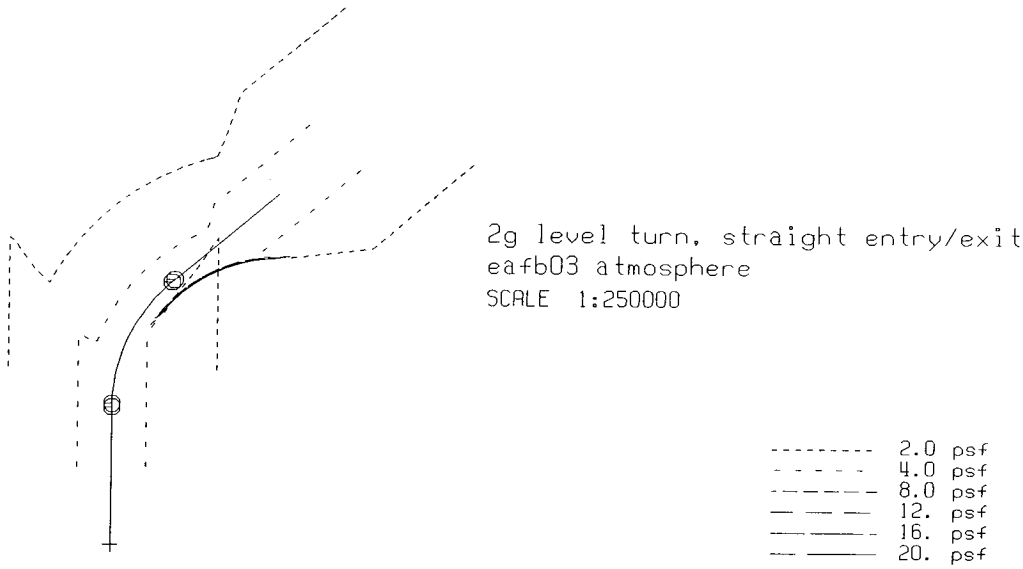
TYPICAL FOOTPRINT ("ISOPEMP") OUTPUT



2g level turn, straight entry/exit
eafb03 atmosphere
SCALE 1:250000

This is the corresponding overpressure contour.

TYPICAL CONTOUR OUTPUT

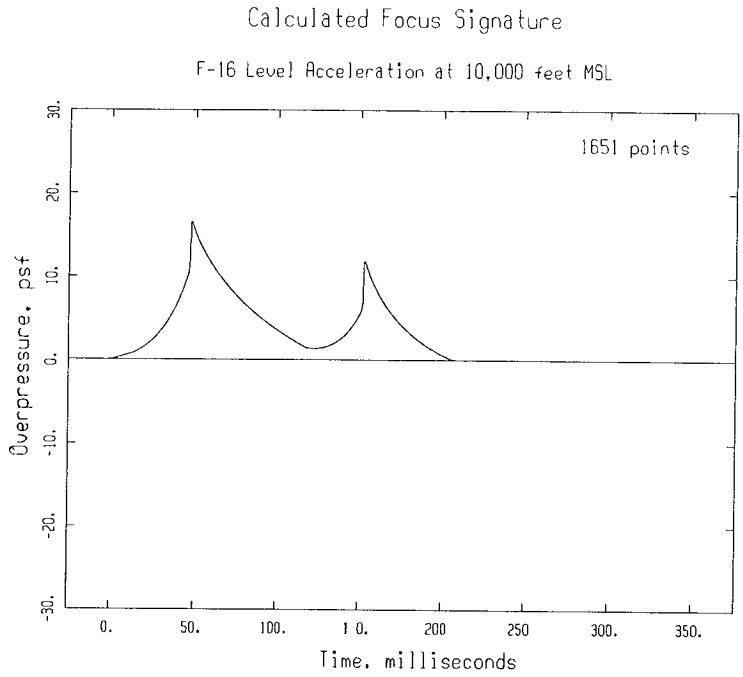


The signature output module allows plotting signatures and spectra at an arbitrary location in the footprint. It interpolates signatures between the actual computed grid points. It is aware of multiple sheets in focal regions, and the absolute phase, so it can assemble complex N–U signatures seen near focal zones. The module plots energy density spectra and residual shock spectra. Spectra can be either narrow or one-third octave band. The one-third octave band spectra are normalized by the 125 msec auditory time constant.

SIGOUT SIGNATURE/SPECTRUM MODULE

- **Plots Time History Signatures**
- **Complex "N–U" Signatures in Focal Zones**
- **Spectra and Residual Shock Spectra**

This is an example signature output. This particular one is the maximum focus condition under the flight track for an F-16 performing maximum-power level acceleration at 10,000 feet. The peak pressure is 17 psf, and the CSEL is 121.5 dB.

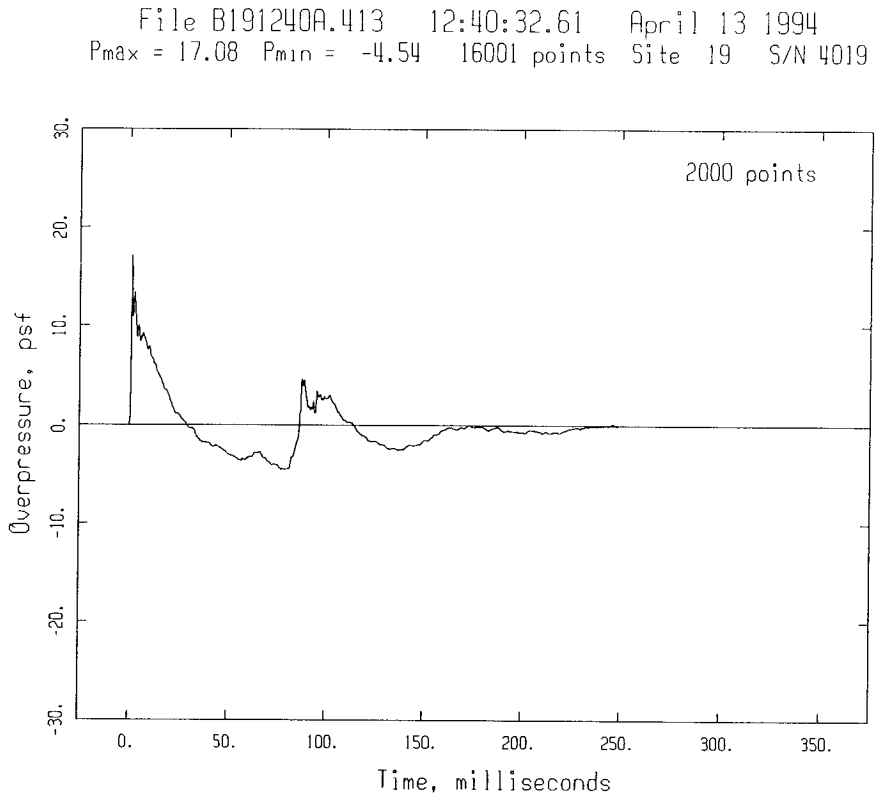


Focal zone flight tests were recently conducted. An array of BEARS with 500- to 1,000-foot spacing was placed across calculated focal zones. Observers were also located along the arrays, and the audible sensations of "distant thunder" on the shadow side, "BANG-BANG" at the focus, and "carpet boom with afterpops" filled expectations. There were 49 passes over the arrays, with a good mix of maneuver types. Except for a very few anomalous runs that missed altogether, all of the foci intercepted the expected locations. The behavior away from the focal zone itself – with N and U waves separating – agreed well with predictions. Boom amplitudes also agreed with predictions.

FLIGHT TEST VALIDATION:
Project Have BEARS

- **USAF AL/OEBN and TPS effort, April 1994, Edwards AFB**
- **F-16 Performing Level Acceleration, Diving Acceleration, Steady Turn, Pullup/Pushover Focusing Maneuvers**
- **Signatures Recorded With Arrays of USAF BEARs**
- **Excellent Results for Focal Zone Location, Geometry, Boom Amplitude**

This is a typical measured boom at the focus condition. This is for a full-throttle acceleration, corresponding to the calculated signature shown earlier. The peak pressure is 17 psf, and the CSEL is 123.8 dB. Both are in very good agreement with prediction. The shape differs somewhat, and there are spectral differences, so the scaling of the Gill-Seebass solution needs to be examined, but the result is generally quite good. Having the recorded data in digital form from the BEARs provides the first real opportunity for a detailed comparison of theory with flight test.



C-3.

CONCLUSIONS

- **PCBoom3 Is Nearing Completion**
- **Provides Simple Access to State-of-the-Art Sonic Boom Prediction**
- **Validation by Recent Flight Tests**
- **Commonality With MDBOOM Will Benefit the HSCT Community**
- **Expected Release in Fall 1994. Will be Available From AL/OEBN**