1PNSB4.

DR. KENNETH PLOTKIN'S MYRIAD CONTRIBUTIONS TO THE NATIONAL AERONAUTICAL AND SPACE ADMINISTRATION'S SUPERSONIC MISSION

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ABSTRACT

- The world as a whole, and NASA in particular, owes a large debt of gratitude to Dr. Kenneth Plotkin for his decades of service in the field of sonic boom research and advancement of quiet supersonic transportation. This presentation will highlight the contributions of Dr. Plotkin to a myriad of NASA projects. One of the largest efforts was the assembly and continual improvement of sonic boom propagation software tools, collectively called PCBoom, which allowed the analysis of real and imagined vehicles from Mach cutoff conditions to the hypersonic. He was a driving force behind reshaping aircraft to demonstrate quieter sonic booms, first with the plans for a modified Firebee drone and SR-71, and then with the highly successful Shaped Sonic Boom Demonstrator series of flights. Dr. Plotkin's partnership with NASA Armstrong resulted in the development of the low boom dive maneuver to allow quiet sonic boom testing on structures and people using existing aircraft, as well as a sonic boom cockpit display that has recently been tested in flight. Dr. Plotkin was also instrumental in such research campaigns as SCAMP, WSPR, and FaINT. Throughout all, Dr. Plotkin's phenomenal intellect, tireless dedication, and irreverent humor made working with him a joy.

PCBoom

- Program to compute sonic boom times, locations, and pressures for arbitrary aircraft shapes, trajectories, and atmospheric profiles
- Converted Thomas's code to PCBoom3
- PCBoom (and similar MDBoom, etc.) used in design iterations for low boom designs
- Later versions added
  - Terrain effects
  - Over-the-Top raytracing
  - Mach cutoff
  - Burger's solution for loudness
  - Three dimensional earth and atmospheric effects
- Tweaked for use as a rapid flight planning tool in flight research

SR-71 Shaped Sonic Boom Plan

- Ken worked with McDonnel Douglas to design a glove for the SR-71 to reduce the boom
- Glove never flew due to budget, but baseline SR-71 sonic booms measured
- Design and testing methodologies paved the way for the SSBD

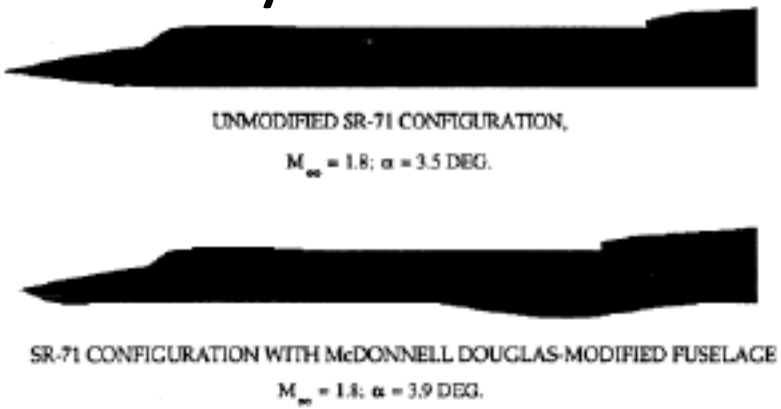
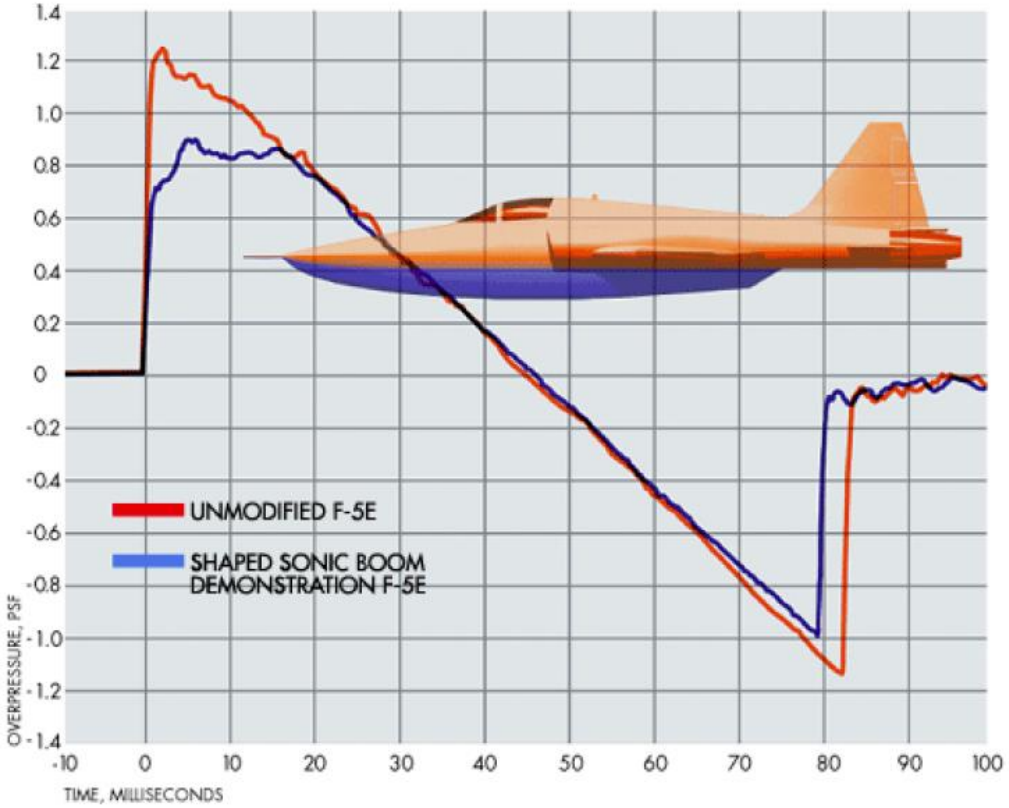


Figure 4-9. Proposed SR-71 low-boom modification. (NASA)

Quieting the Boom

SHAPED SONIC BOOM DEMONSTRATOR

- Ken worked with Northrop-Grumman in the design of the SSBD
- First shaped sonic boom of a real aircraft in a real atmosphere



SSBD Ready For Flight

Armstrong Flight Research Center

Shaped Sonic Boom Demonstration, Field Team

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SSBD/E Turning Goals Into Reality Award

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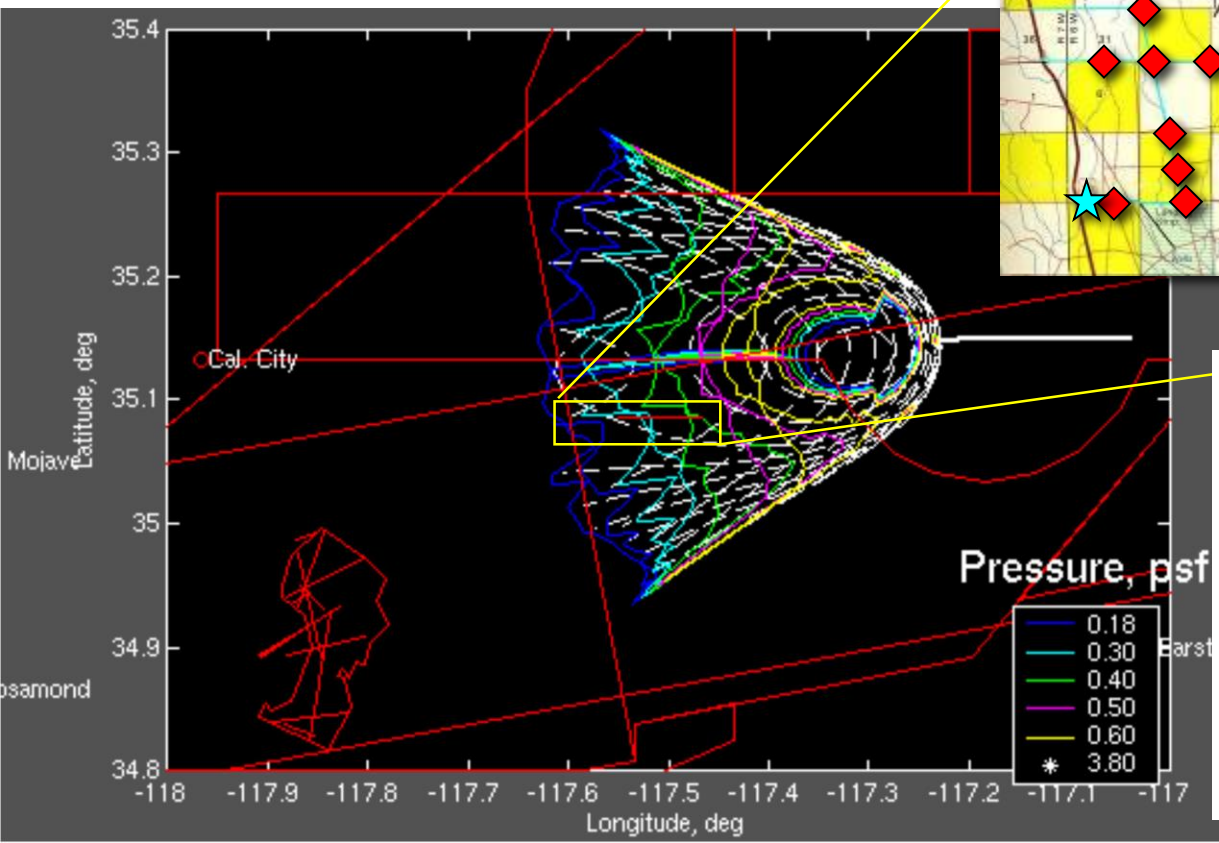
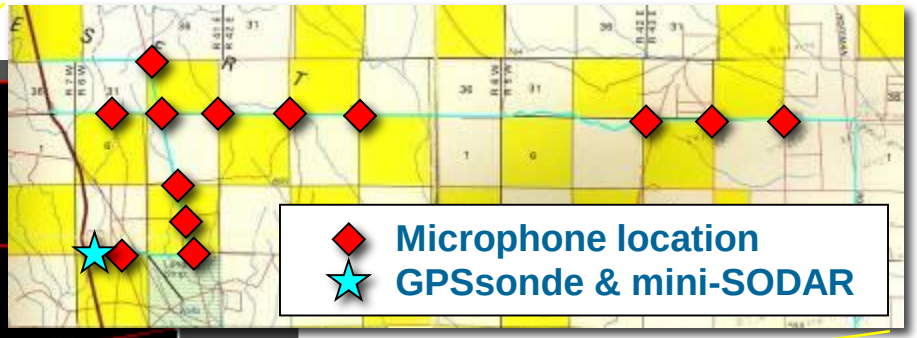
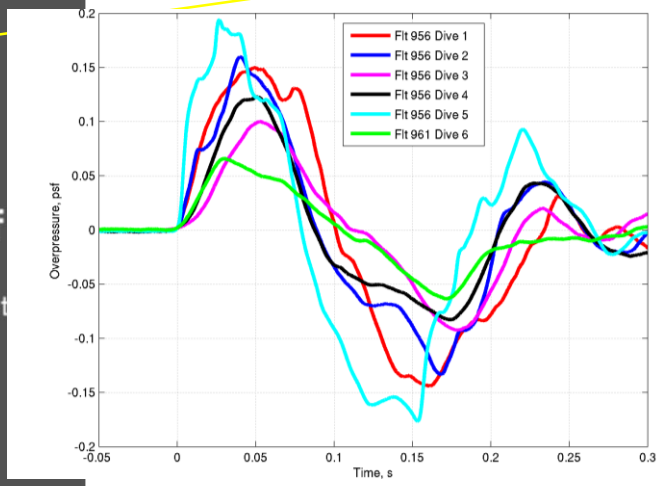
Low Boom Dive

- Inspired by quiet boom from SpaceShipOne
- Ken tweaked PCBoom to allow full azimuth analysis/predictions
- Opened up opportunity to do low boom testing on subjects before a demonstrator was ready (WSPR, WSPRRR, etc.)



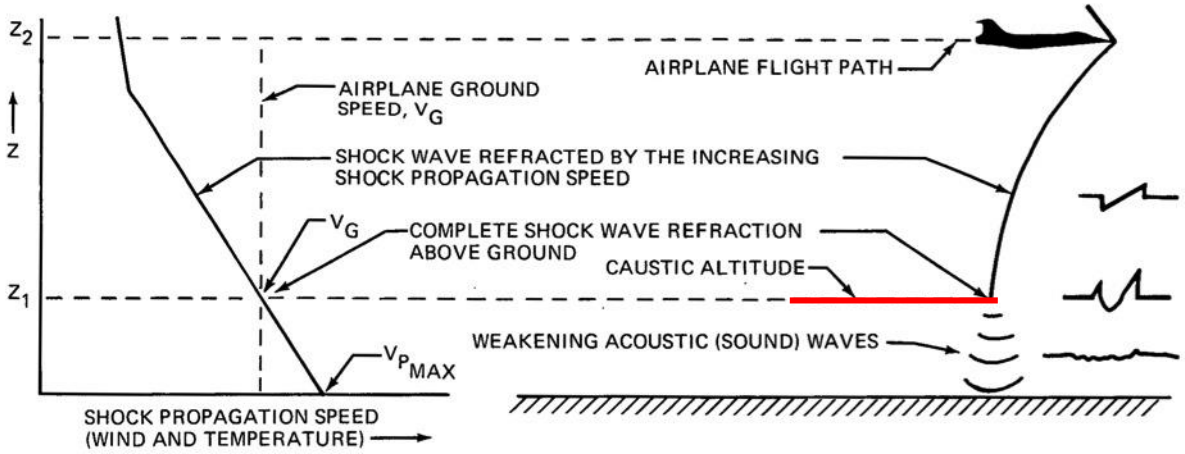


Aug. 25-31 2005

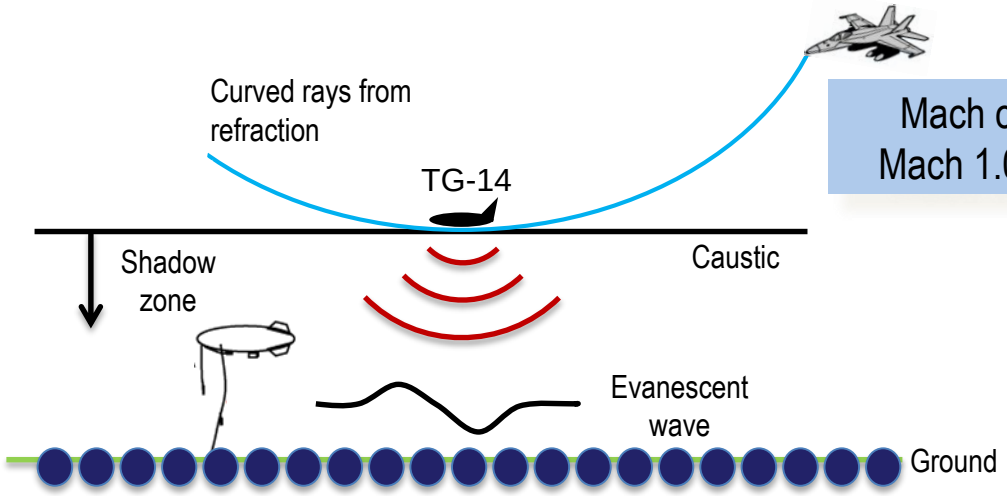


MACH CUTOFF

- Shock wave propagation speed changes with altitude (wind/temp effects)
- N-wave (double-boom) completely refracts at Caustic Altitude
- Evanescent waves (low rumble) heard below
- Typical caustic altitudes – 1,300 to 7,200 ft AGL



FaINT Measurements



Mach cutoff
Mach 1.07-1.3

HYPERSONIC BOOM OF STARDUST

- Concept 28 Dec 2005
- Stardust sample return reentry 15 Jan 2006, maximum Mach 45
- Ken used PCBoom (Tiegerman's hypersonic boom equation) to predict 0.0524 psf @ Mach 19.43
- Two NASA engineers drove to Elko, NV with recorders
- Notified 12 hours before boom, local teacher and student measured boom 0.052 psf

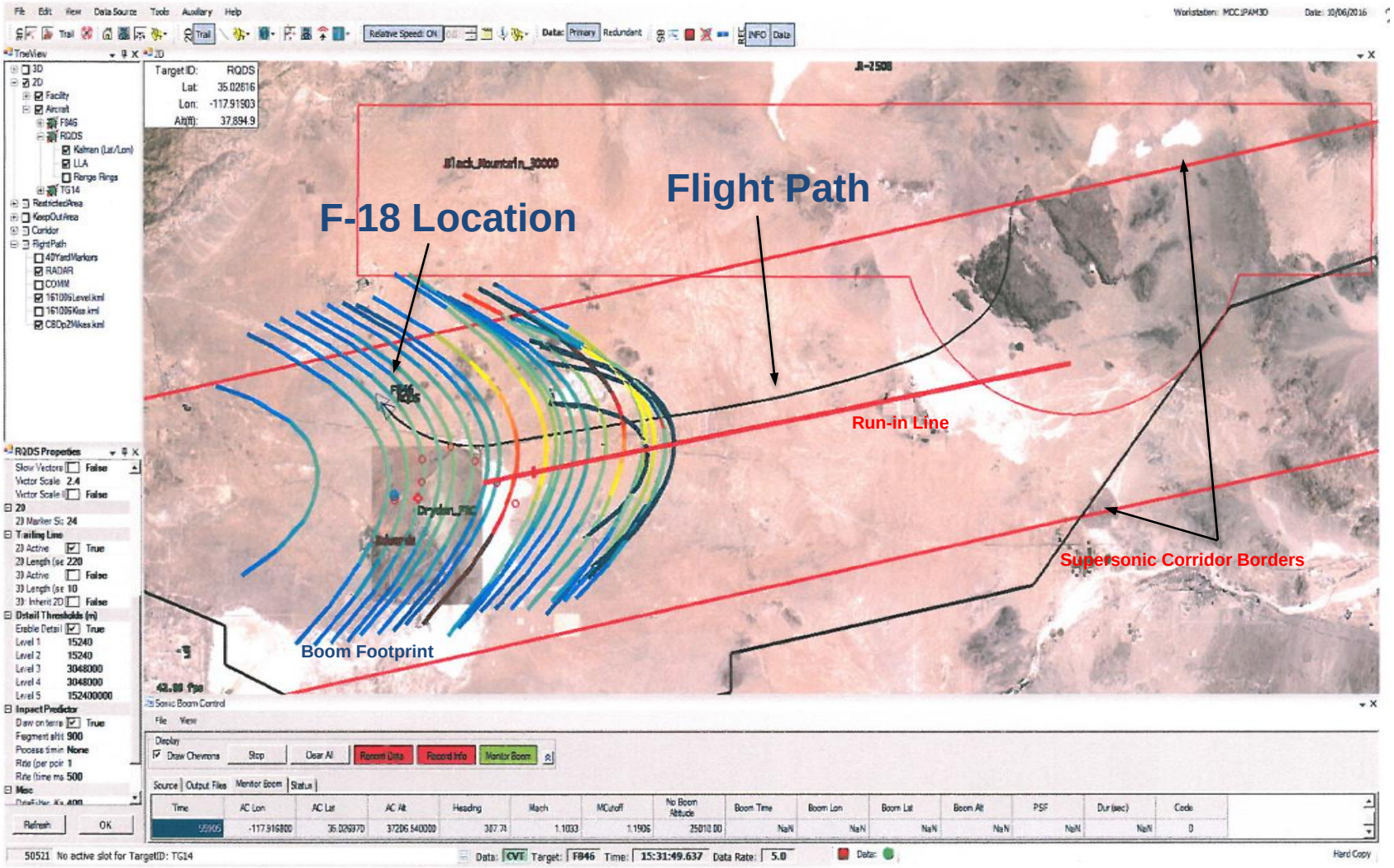
Teacher Nancy Wood and student Tucker Elsner operate a NASA Dryden BASS sensor as the Stardust capsule reenters near Elko, Utah. Photo by Ross Andreson, Elko Daily Free Press.

CISBoomDA

- Cockpit Interactive Sonic Boom Display Avionics
- First proposed 1999
- Ken rewrote elements of PCBoom3 for realtime Fortran in 2000, running in control room in 2001
- Ken made more improvements in 2005, including Mach cutoff
- Patent US 8,145,366; 27 March 2012
- 1st flown in F-18 cockpit 07 Aug 2015
- Rockwell-Collins and Honeywell incorporating into modern avionics

CISBoomDA in F-18

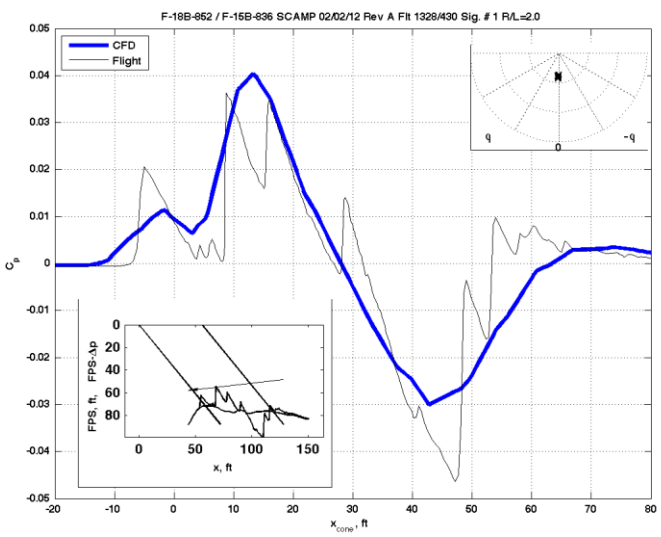
- Checkout flight at Edwards AFB
- Hope to use at Kennedy Space Center

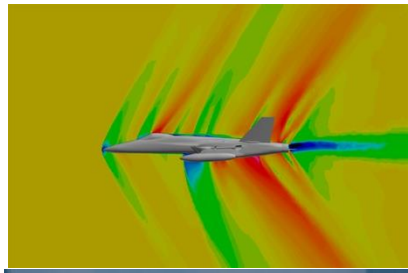


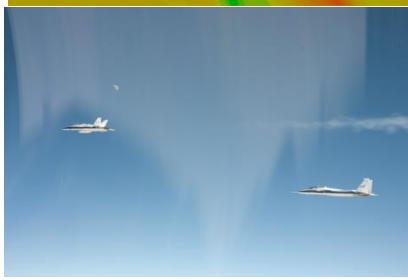
SUPERBOOM CAUSTIC ANAL. & MEAS. PROJ.: SCAMP

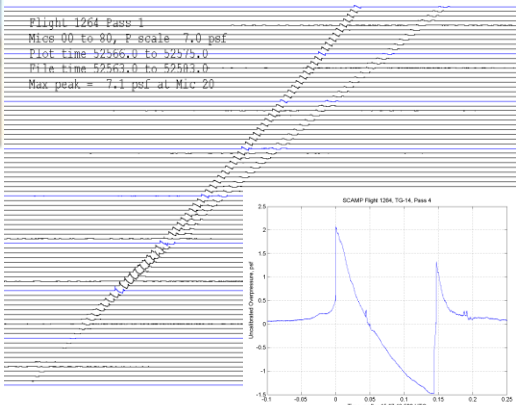
Armstrong Flight Research Center

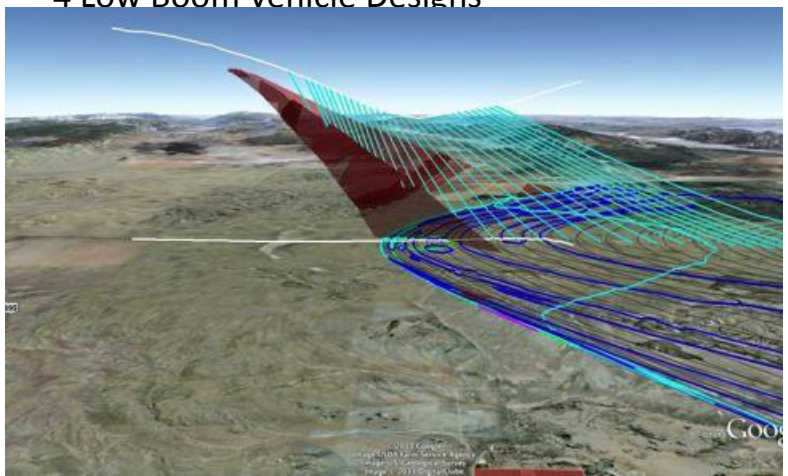
- Objective: Develop/Validate Four Focused Sonic Boom Codes
  - PCBoom6: Gill & Seebass Method (Single Shock, fast, low resolution)
  - Pseudospectral Tricomi Method (lossless)
  - Numerical Tricomi Solution with losses (entire signature, ~100 hr run time, most accurate)
  - Nonlinear Progressive Wave Equation
- F-18 Generates Focused Booms with Range of Caustic Curvatures
- Computational Fluid Dynamics of F-18 test points
- Flight Database: 13 flights, 70 supersonic runs, 81 ground mikes (10,000 ft array, 125 ft apart), 3 airborne mikes (sailplane & blimp), weather sensors, seismometers, cameras, 44 nearfield probings on 4 flights to validate CFD
- Exercise Four Focused Boom Codes with 4 Low Boom Vehicle Designs





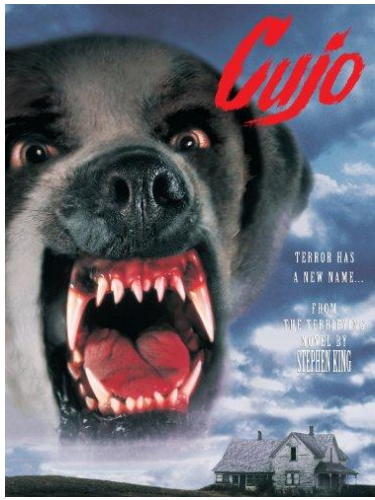






BACRONYMS AND HUMOR

- CUJO – Caustic Undertrack Jacobian Operator: analysis for SCAMP



- POTTI – Plotting Over-The-Top Isopemps

```
C Look out, Mr. Bill.  Here comes Mr. Hand.  Ooooh noooo....
C Never mind about Mr. Bill.  Think about poor Mr. Array et al.
C DIMENSIONS HAVE BEEN OVERRUN - ABORT THE RUN
```

```
call wmessagebox(0,0,1,'OTTER Memory Test'//cr//cr//
     +     'Who was the fourth President'//cr//
     +     'of the United States?'
     +     ,'OTTER Version 5.02')
```

James Madison

```
C a test is made for cusp.  Very bad bananas if a cusp condition exists.
ckjp March 2010 v6.502 Added "primary" test to exclude rays whose first
c    ground intercept happens after serpentining: almost hitting the ground,
c    then going over the top.  No snakes on a plane for us.
```

- Many more not appropriate for this forum…

CONCLUDING REMARKS

- Ken's contributions were critical to get where we are today; close to a low boom demonstrator.
- We are all going on to our next field test, sooner or later

BACKUP SLIDES

COCKPIT INTERACTIVE SONIC BOOM DISPLAY AVIONICS

Armstrong Flight Research Center

Performing Center: AFRC

Phase 2 Flight Objective:

- Demonstrate the real-time display of the sonic boom carpet in the cockpit of a supersonic aircraft, including use by the pilot

Approach:

- Instrumented F-18 used to generate sonic booms
- Aircraft data, GPS position and weather data fed into a cockpit tablet PC
- Tablet PC with CISBoomDA program calculates and displays boom footprint to the flight test engineer in the rear cockpit; repeater monitor for the pilot in the front
- 8 ground microphones over a 7 mile area recorded a sample of booms

Status:

- 2 F-18 TN 846 flights were flown on October 5-6 at Edwards AFB (AFRC)
- 8 sonic boom generating passes were recorded
- Parallel effort under way with NRA partners to study integration with commercial flight management software

Significance:

- Data acquired during the flights used to assess accuracy of real-time display to compute sonic boom arrival time, overpressure, and Mach cutoff speed and altitude by comparing display output to ground-level recordings
- Received pilots feedback on using the display to control the location and intensity of sonic booms on the ground to improve future displays

Partners: Honeywell, Rockwell-Collins

CISBoomDA Phase 2 Team and Aircraft

Cockpit Display