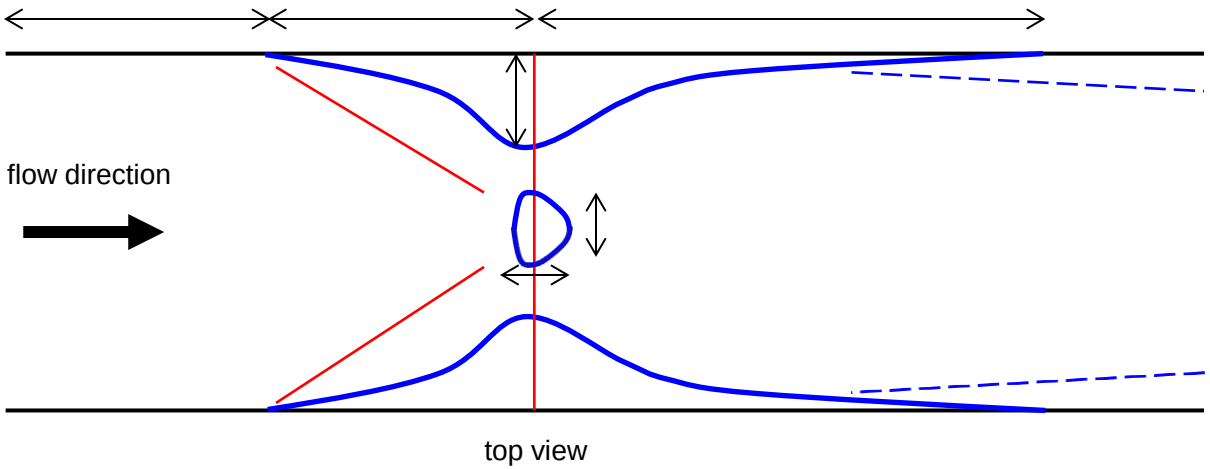
SLU Dimensional Analysis: A Request for Data



Outline:

- Rectangular test section flow structure (3)
- Dimensional analysis variables (2)
- A request for data (1)

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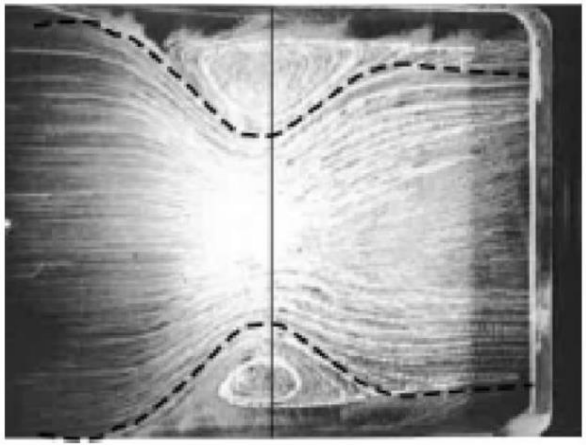
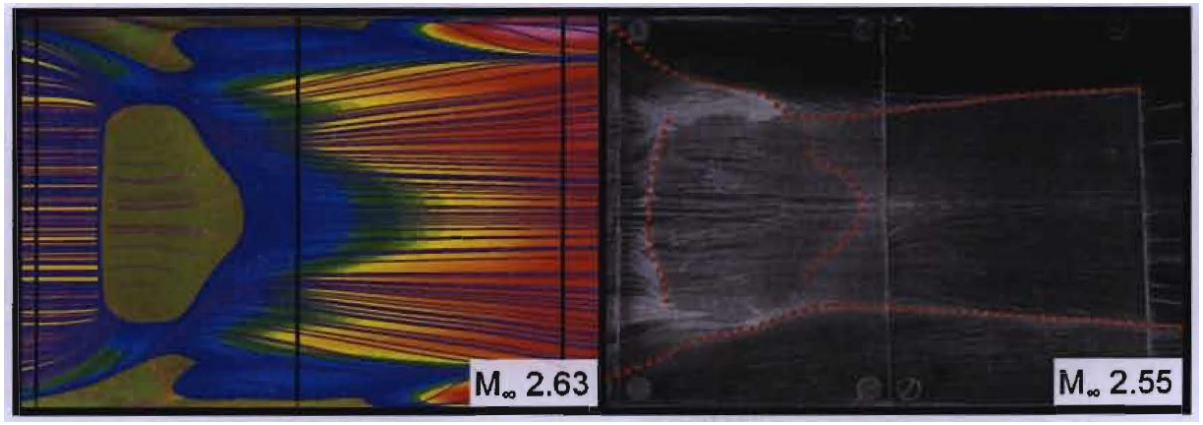
Rectangular test section flow structure (1)

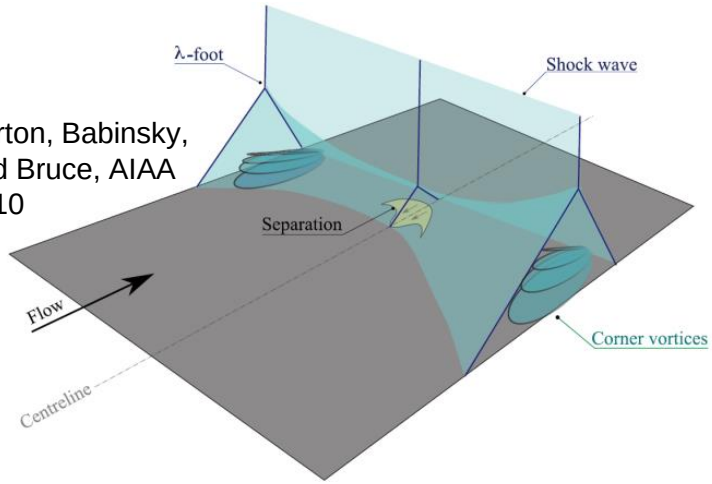
- **well known**: rectangular test sections exhibit “corner flows” under influence of shock waves
  - boundary layers merge in corners = larger near-wall region of reduced momentum
  - shock’s adverse pressure gradient separates corner flow
  - bulk fluid displacement causes compression shock fan leading to 3D flow



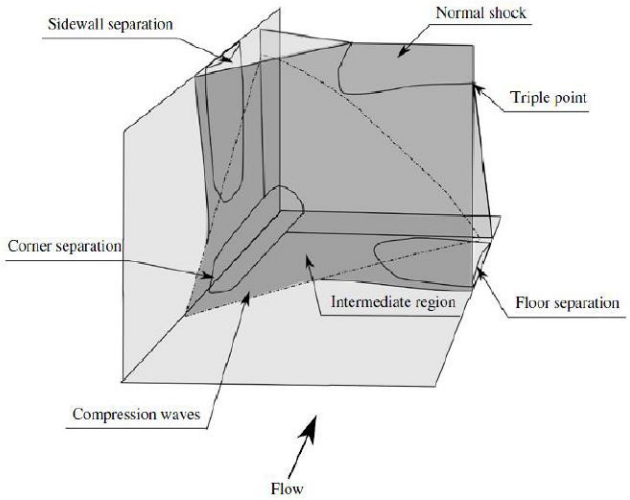
Chriss et al., NASA 1989, M=1.59 normal



Barruzini et al., AIAA 2012, M=2.6 oblique



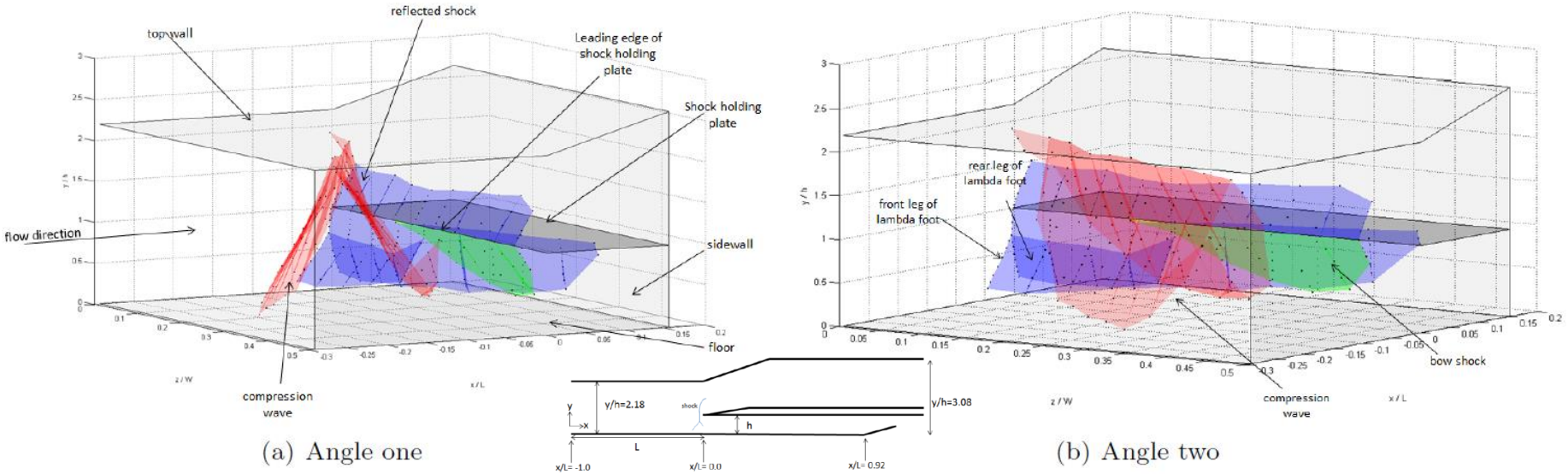
Burton, Babinsky, and Bruce, AIAA 2010



Burton and Babinsky, JFM 2012

Rectangular test section flow structure (2)

- Pizzella et al. (AIAA 2016) - RANS illustrates 3D shock structure of M=1.6 normal shock, 4.3 AR



- Benek, Suchyta, and Babinsky (AIAA 2013) propose 3 ranges of aspect ratio effects

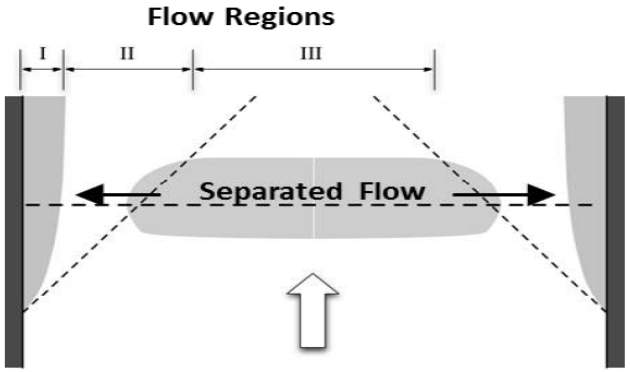


Figure. 1a. Large W/H

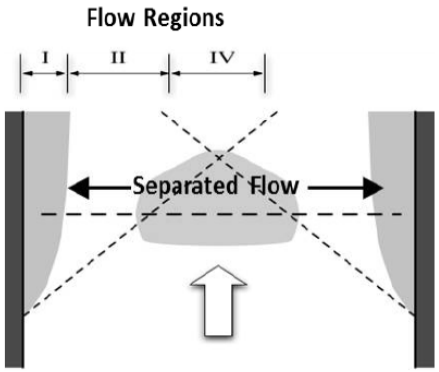


Figure 1b. Moderate W/H

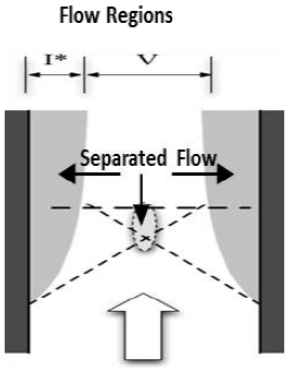


Figure 1c. Small W/H

Rectangular test section flow structure (3)

- Benek, Suchyta, and Babinsky (AIAA 2016) found correlation between a viscous aspect ratio (δ/W) and the streamwise length of centerline separation ($\Delta x/\delta$)
  - used two scaling factors g and f that were functions of shock strength

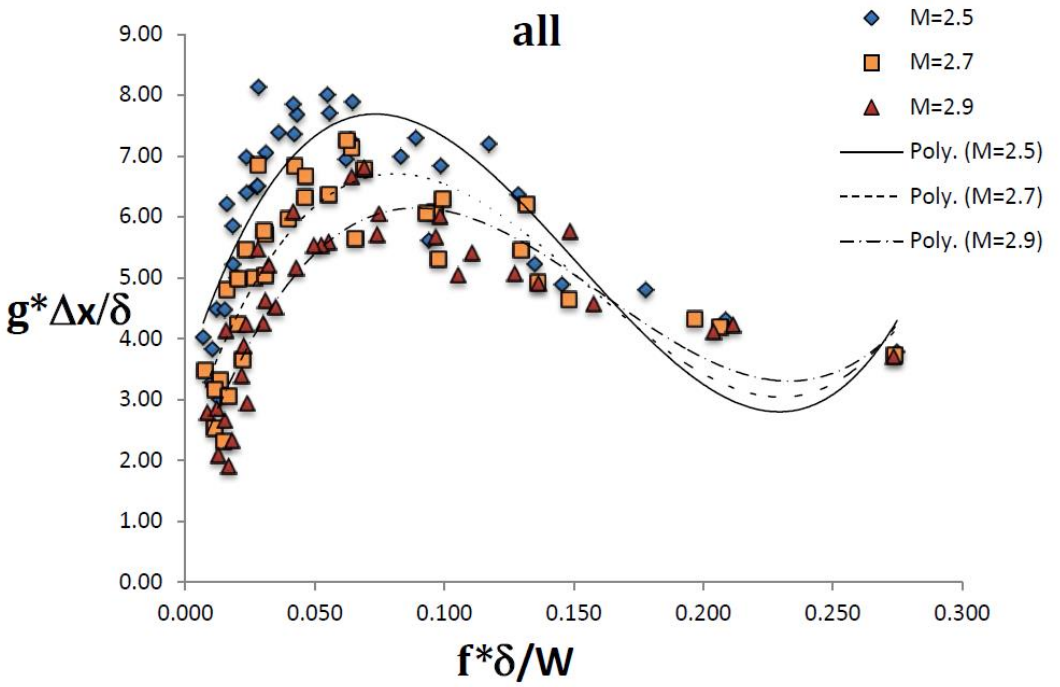


Figure 11d. All scaled.

- *Is it possible to find physics-based relationships among more of the 3D phenomena?*

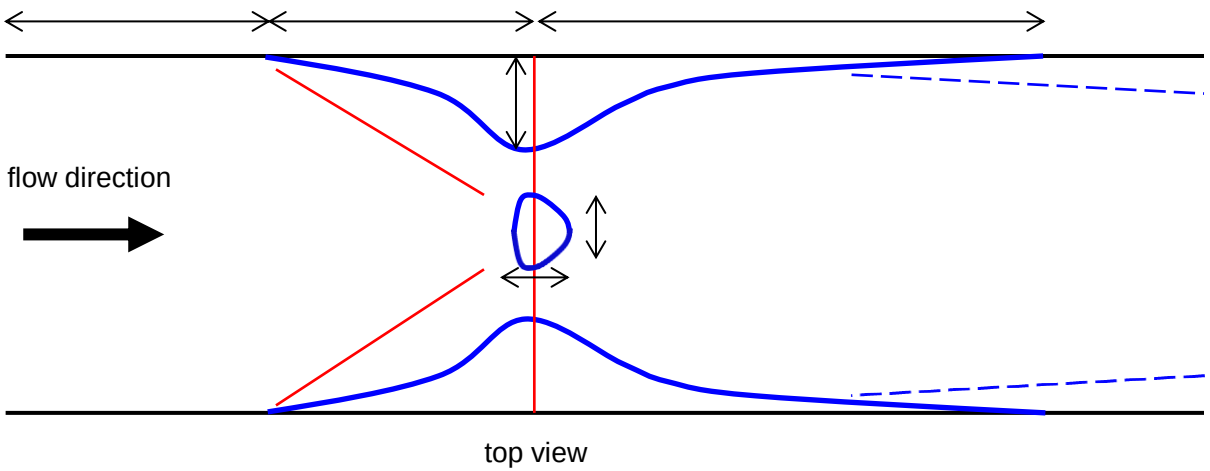
Dimensional analysis variables (1)

• **Main idea** - Perform dimensional analysis to find relationships among geometric and fluid dynamic variables related to SWBLI in rectangular test sections

- primary goal - identify combinations to predict corner flow separation onset location to answer the question: *Why do corner flows separate where they do?*

• **The variables** - the following variables have been selected for study:

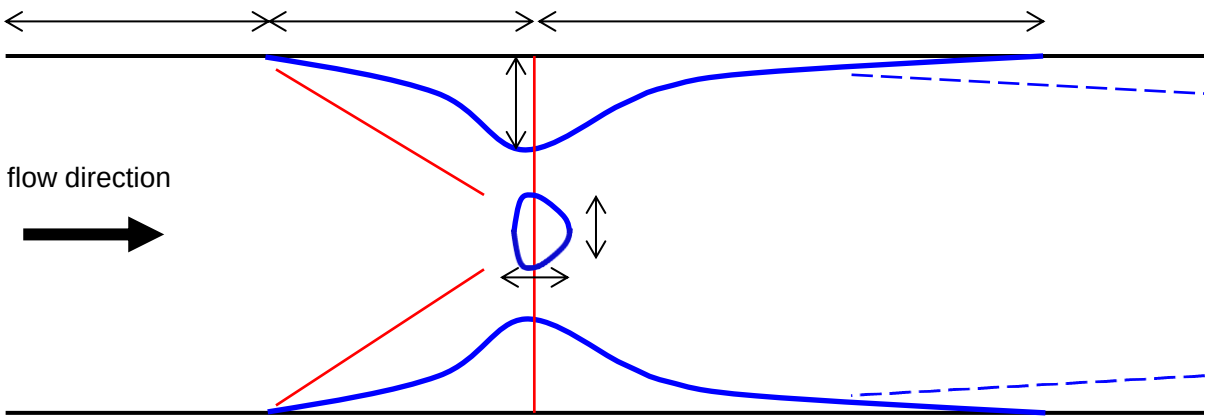
- geometric:
  - (1) tunnel height
  - (2) tunnel width
- freestream:
  - (3) Mach #
  - (4) velocity
  - (5) density
  - (6) viscosity
- shock:
  - (7) oblique or normal
  - (8) static pressure rise P_2/P_1
  - (9) static pressure difference P_2-P_1
  - (10-13) boundary layer height, displacement thickness, momentum thickness, and shape factor



Dimensional analysis variables (2)

- **The variables** - the following variables have been selected for study:

- centerline separation:
  - (14) streamwise length
  - (15) spanwise width
- corner flow:
  - (16-19) boundary layer height, displacement thickness, momentum thickness, and shape factor just upstream of corner shock and taken at 45deg angle
  - (20) streamwise distance between corner separation onset and nozzle exit/where no-slip begins
  - (21) streamwise distance between corner separation onset and inviscid shock location
  - (22) does corner flow reattach? YES/NO
  - (23) if reattaches, streamwise distance from separation onset to reattachment
  - (24) maximum bottom wall width
  - (25) maximum side wall height



top view

A request for data (1)

• **Our request**: Since we believe additional data can help reinforce and improve our analysis and resulting conclusions, we would like to make an open request to supply data for our argument

• computational and experimental data accepted
- if computational, please list approach (turbulence model)

• authors have an Excel sheet that can be shared to facilitate organized collection of data
- **please email Mark McQuilling at mmcquil2@slu.edu if interested in sharing your data**

• Results to be presented at AIAA SciTech in January 2017
- all who supply data will be acknowledged in the paper introduction

• *Thanks very much to all who can contribute!*