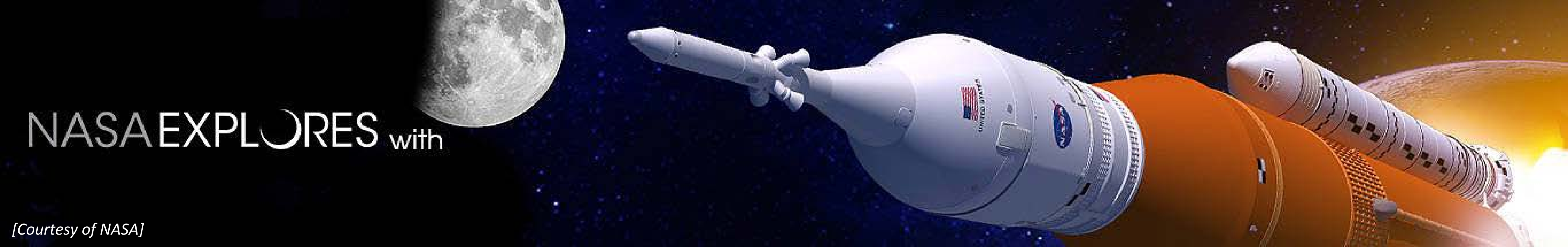


Analysis and Comparison of Surface Roughness Effects on Pressure Data from SLS Wind Tunnel Test

Presented By: Autumn N. Douthitt

Mentor: Nettie H. Roozeboom

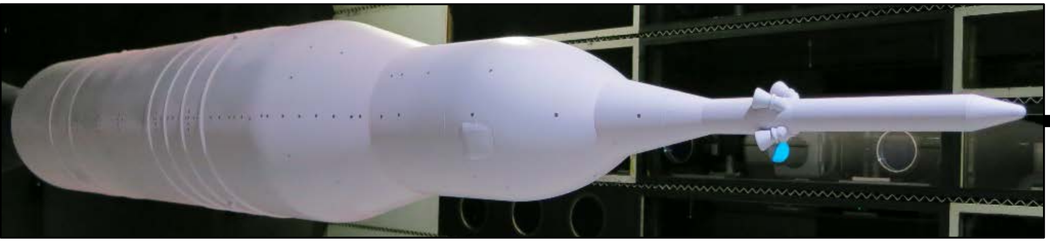
NASA Ames Summer 2019 Internship Branch Presentation

Fluid Mechanics Lab

Acknowledgements: Dr. Rabindra Mehta, Lara Lash, Thomas Steva (MSFC), NASA PSP Team, Jie Li, and Nick Garbe

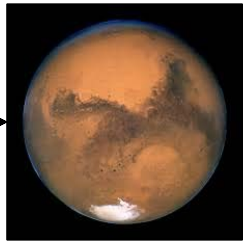
Mission Objective

December 2017



2024

Future



- Necessary to know flow field characteristics of SLS design configurations
- Does paint application affect signal?
- Does sanding of the paint affect signal?

Shoulder of paint around the Kulite

Sanded paint around the Kulite

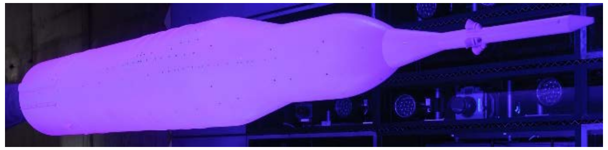
[SLS and Kulite images courtesy of NASA PSP Team] [Moon and Mars images courtesy of Google Images]

Timeline of Events

Configuration 17

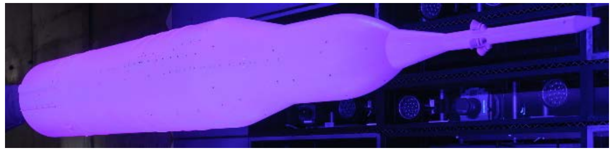
Day 0 (Dec. 1st)

- Clean Model
- Kulite Data



Day 1 (Dec. 4th)

- Epoxy, uPSP Base and Topcoat
- Test with no sanded Kulites



Day 2 (Dec. 5th)

- Refreshed uPSP Topcoat
- Test with 10 Sanded Kulites
    - 940, 952, 925, 998, 923, 416, 792, 779, 996, 738

Day 3 (Dec. 6th)

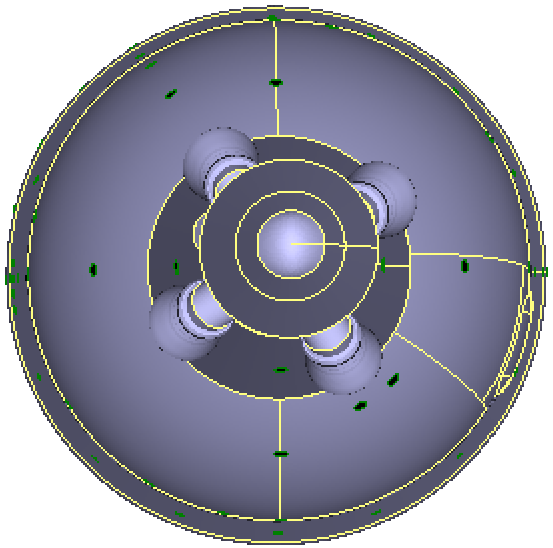
- No refresh of uPSP
- Test with 5 sanded Kulites
    - 414, 773, 763, 419, 404

All Days Tested at Mach
0.7
0.8
0.85
0.9
0.95
1.05
1.1
1.2
1.4

[SLS and Kulite images courtesy of NASA PSP Team]

Kulite Locations on SLS

#	Kulite	Zone	X	Phi
1	738	13	43.1	283
2	996	77	53.4	270
3	404	77	53.4	180
4	763	77	55.9	90
5	773	77	58.5	113
6	779	77	58.5	293
7	792	78	60.7	225
8	414	78	61.4	45
9	416	78	61.4	182
10	419	79	62.2	93
11	998	79	65.4	270
12	925	79	66.6	315
13	923	79	66.6	239
14	940	90	69.8	270
15	952	99	72.4	225



	Day 0	Day 1	Day 2	Day 3
Mach	Run Number	Run Number	Run Number	Run Number
0.7	1297	1322	1354	1406
0.8	1280	1323	1355	1407
0.85	1265	1324	1356	1408
0.9	1250	1325	1357	1409
0.95	1235	1326	1358	1410
1.05	1220	1327	1359	1411
1.1	1205	1328	1360	1412
1.2	1190	1329	1361	1413
1.4	1175	1330	1362	1414

[Run Log data courtesy of NASA PSP Team]

Tools for Mission Success

1. Notes, Pictures, and
   Run Log from Test

2. Reduced Kulite and uPSP
   Pressure Time History Data

3. Matlab➔Plot 3D and Modified
   uPSP Example Code

4. Dots

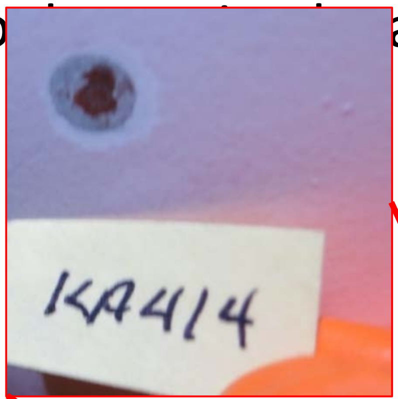
5. Requirements of SLS Customers

[SLS image courtesy of NASA PSP Team]

Processing the Kulite Data

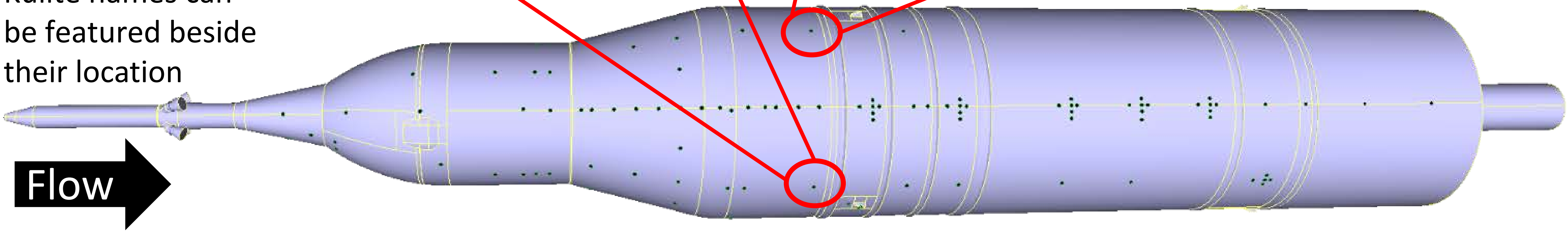
Locating Kulites on SLS using Dots

- Began with studying documentation taken during Kulite sanding (photos, notes, test run log)
- Using Dots, was able to ation of these model



Picture of one of the sanded Kulites

Kulite names can be featured beside their location



 [Dots image courtesy of NASA PSP Team and Thomas Steva of MSFC] [Kulite images courtesy of NASA PSP

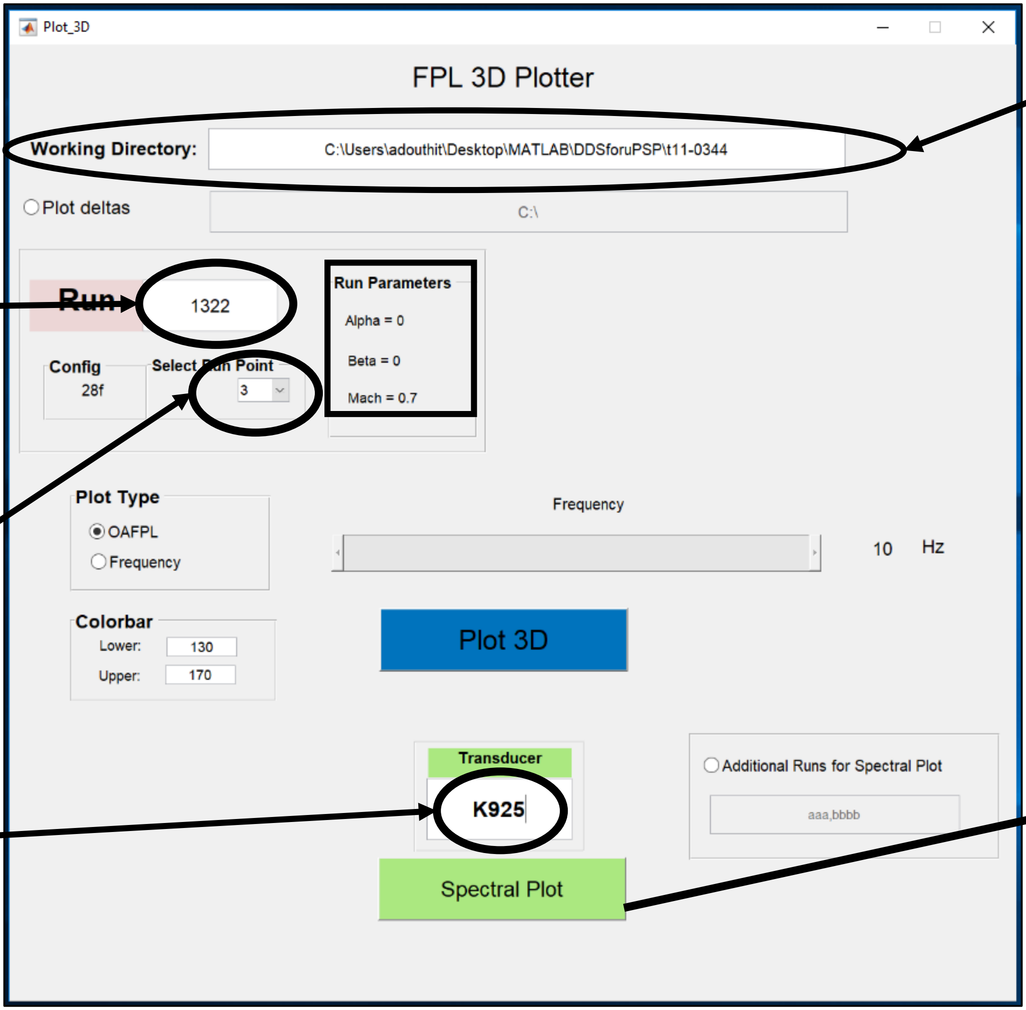
Data Processing Method for Kulites

- 15 Kulites, 9 Mach Numbers, 4 Days of Testing

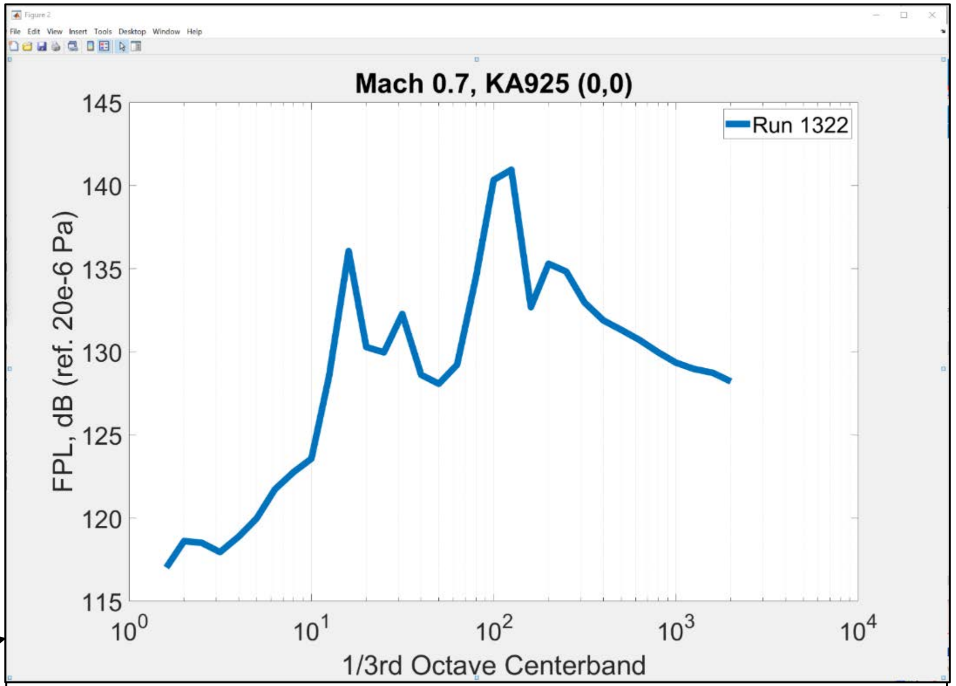
Enter Desired Run Number

Enter Desired Sequence #

Enter Desired Kulite



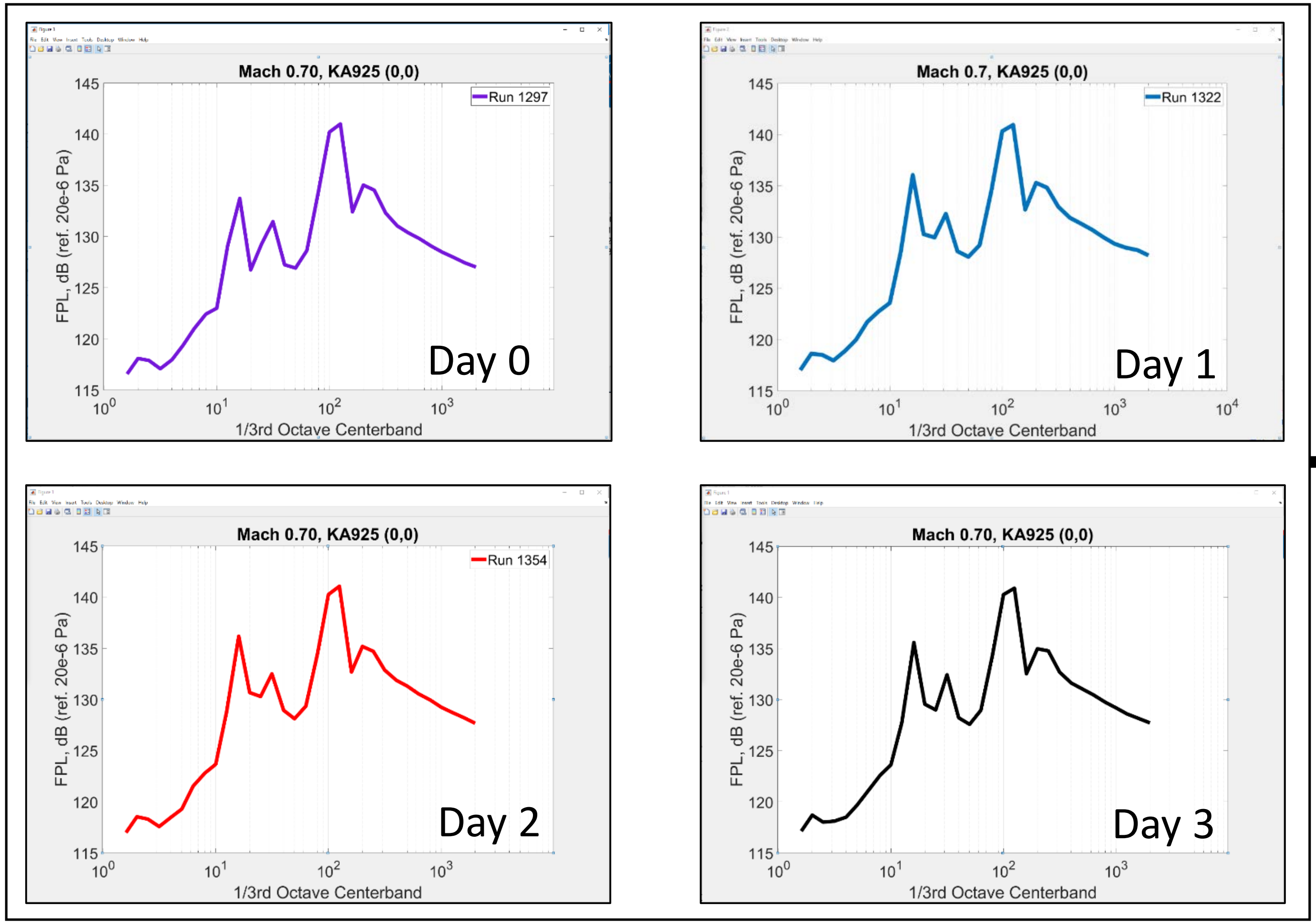
Input working directory

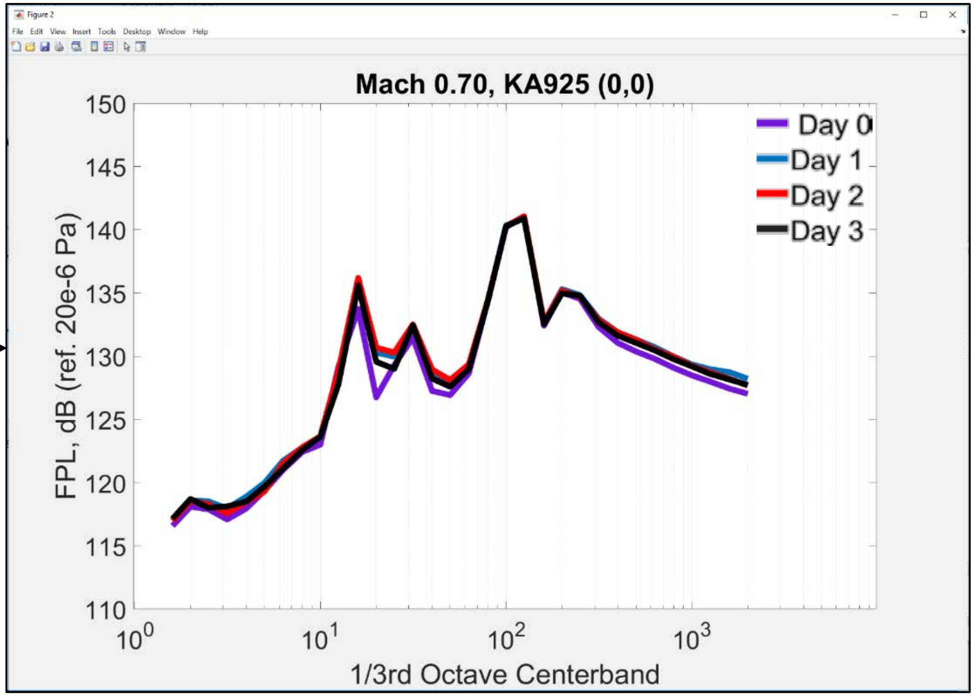


Result is FPL of Kulite at that Mach number and Model Orientation

Comparing the Kulite Data

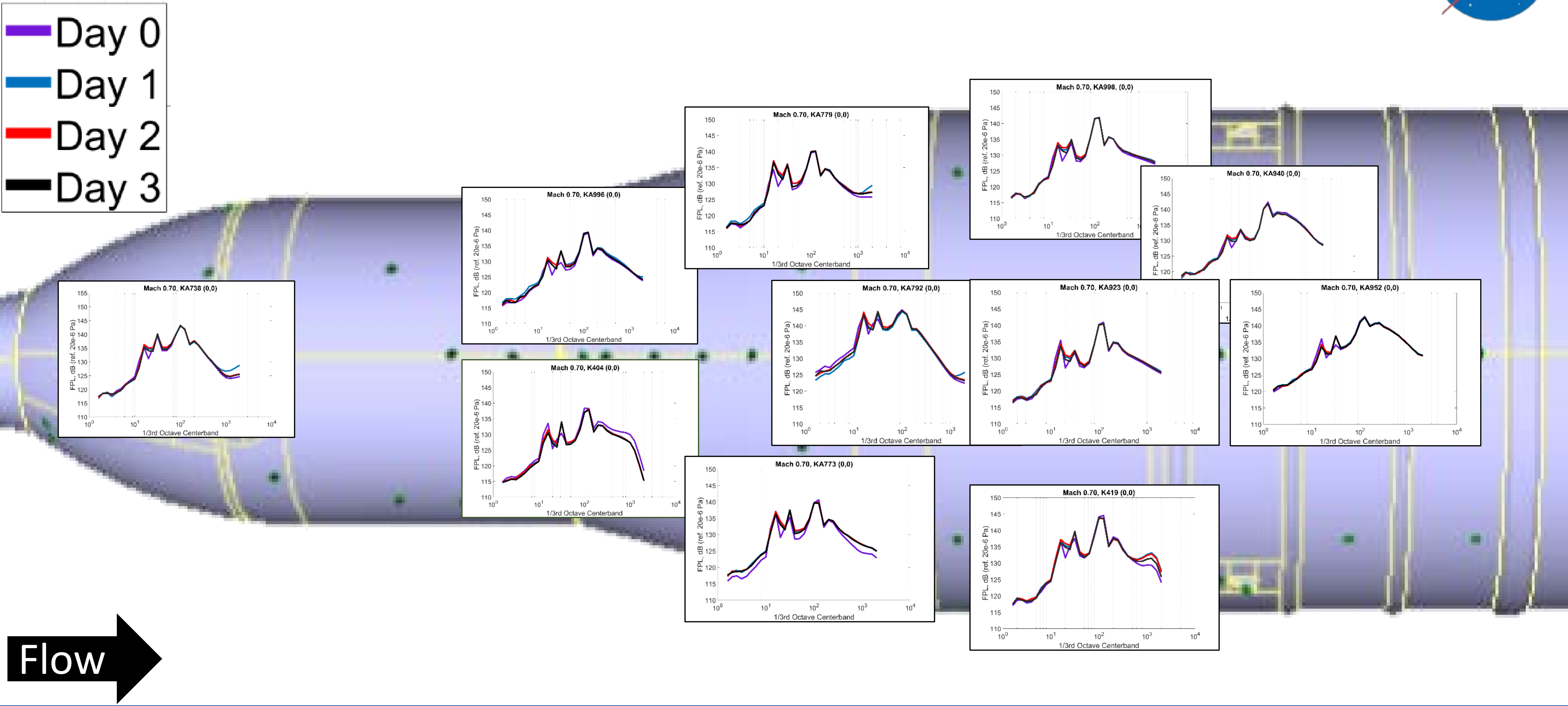
- Combined the plots for all four days for each Mach number





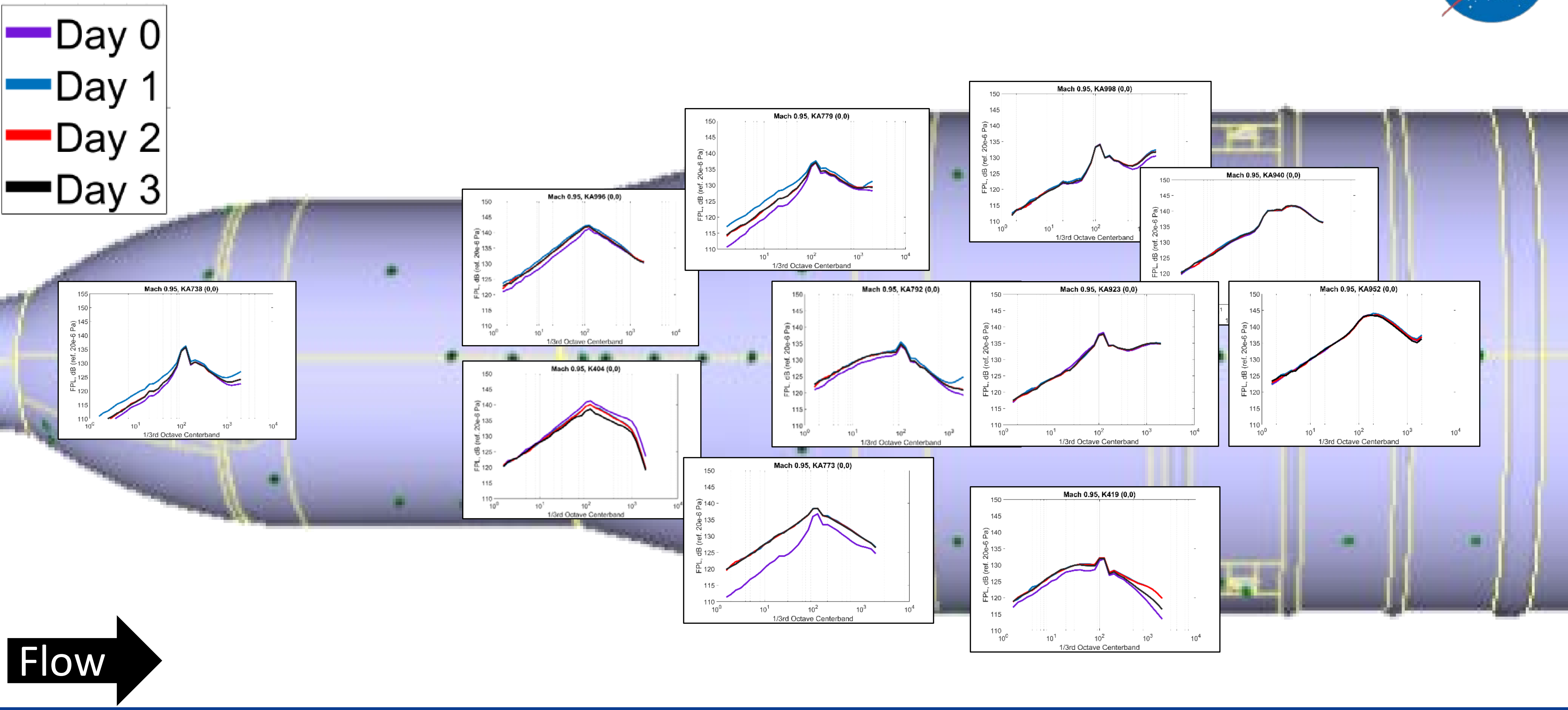
Results of Sanded Kulite Data

11 DDS Results Along SLS at Mach 0.7, α=0 β=0



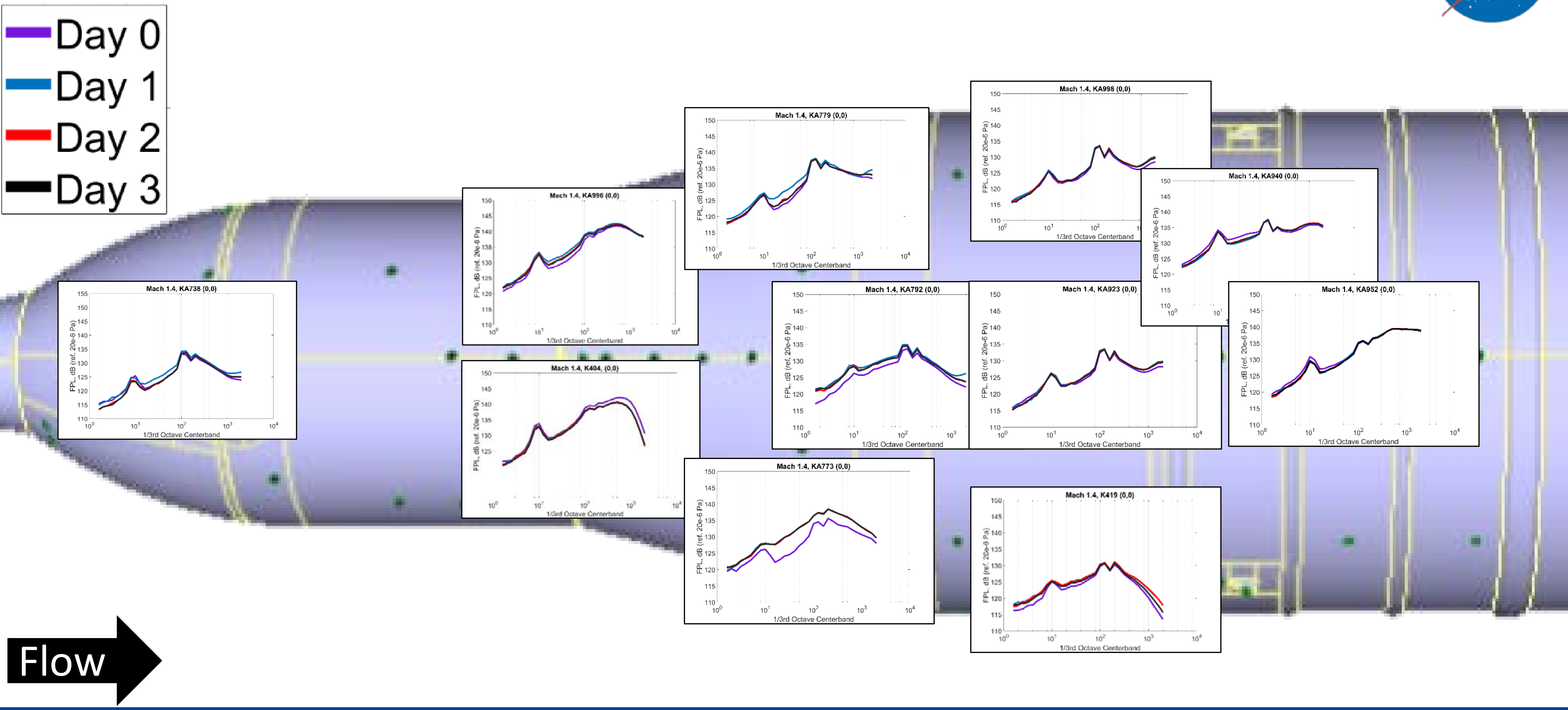
 [Dots image courtesy of NASA PSP Team and Thomas Steva of MSFC]

11 DDS Results Along SLS at Mach 0.95, α=0 β=0



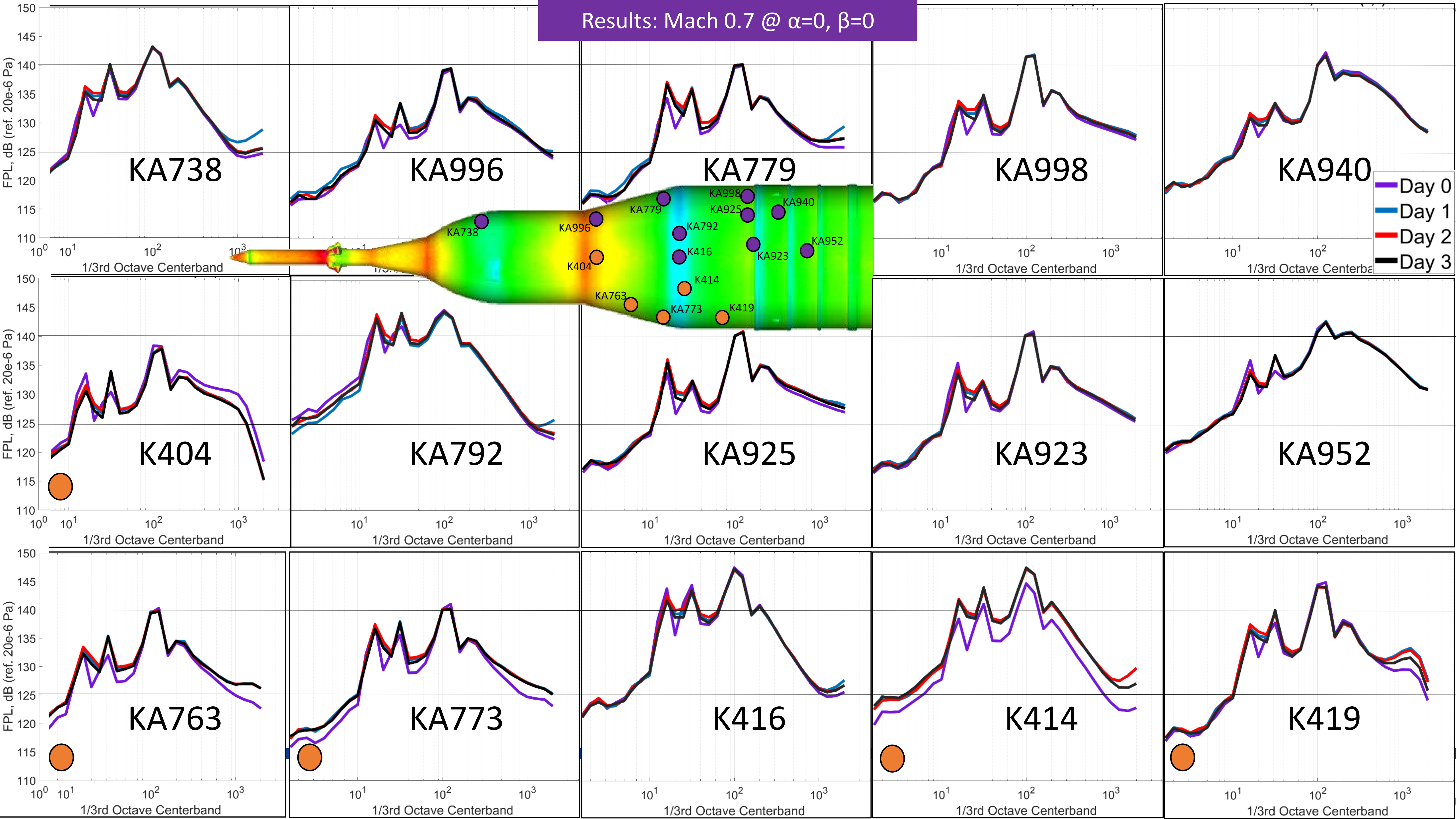
 [Dots image courtesy of NASA PSP Team and Thomas Steva of MSFC]

11 DDS Results Along SLS at Mach 1.4, α=0 β=0

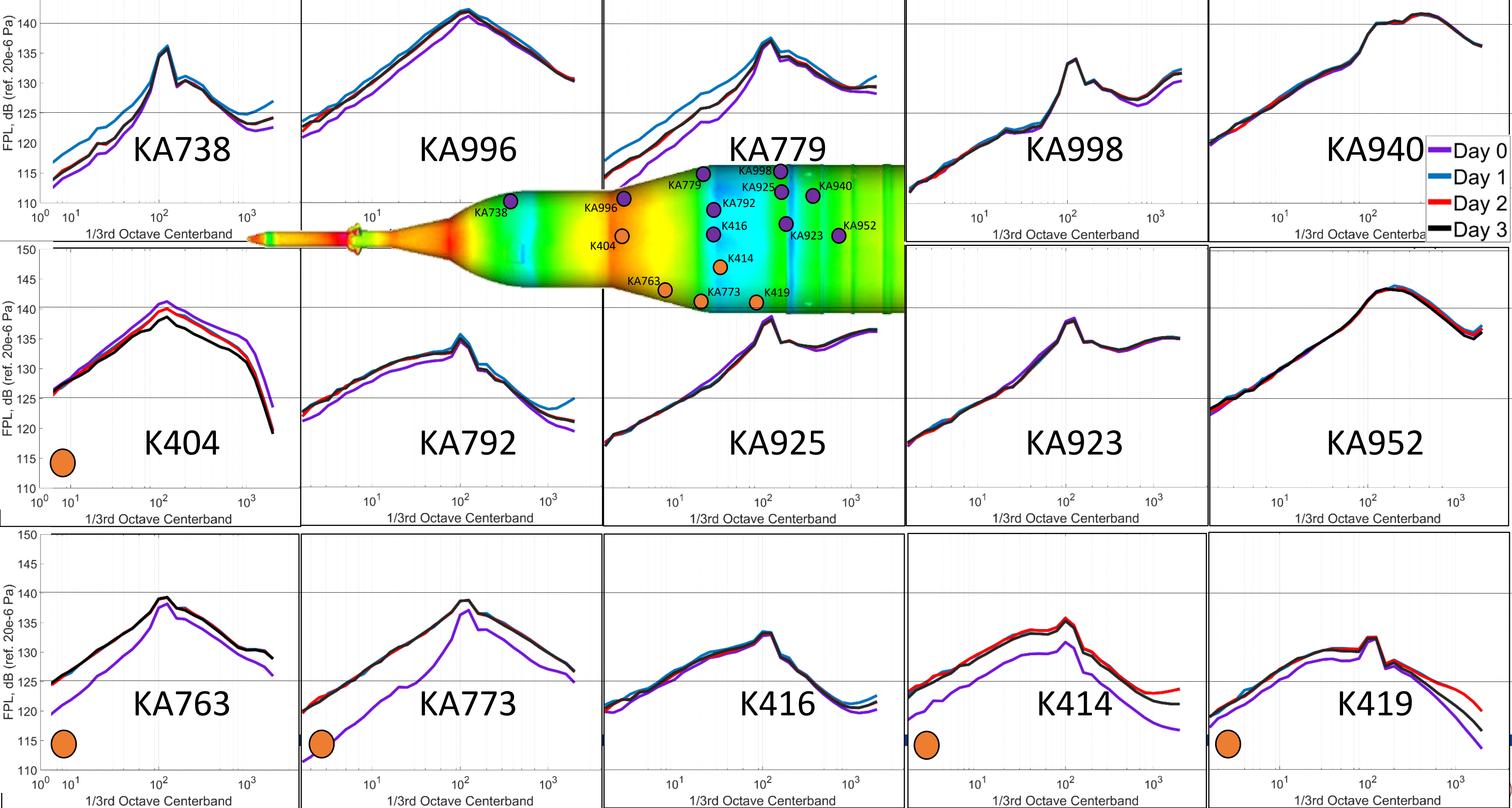


 [Dots image courtesy of NASA PSP Team and Thomas Steva of MSFC]

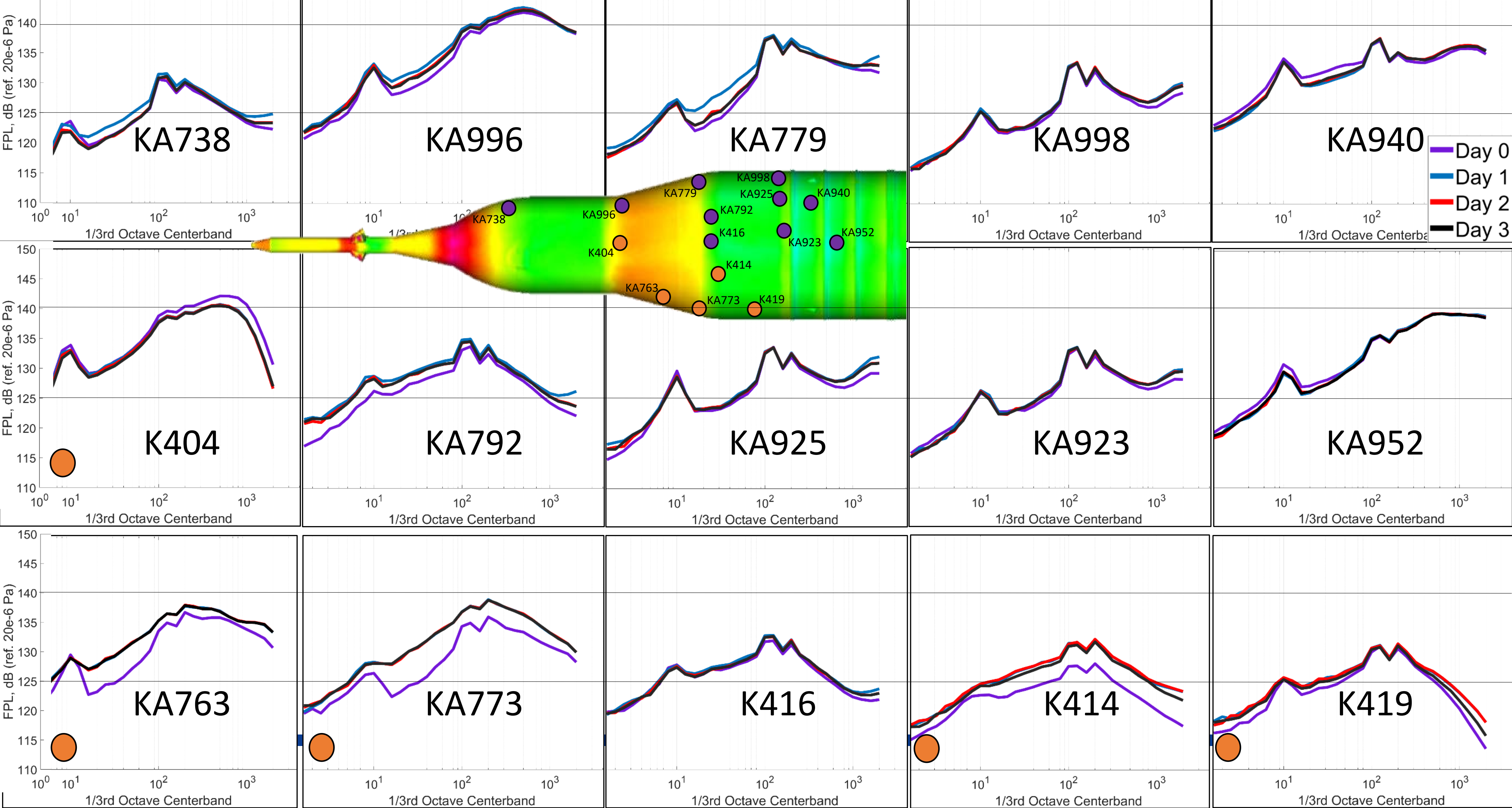
Results: Mach 0.7 @ α=0, β=0



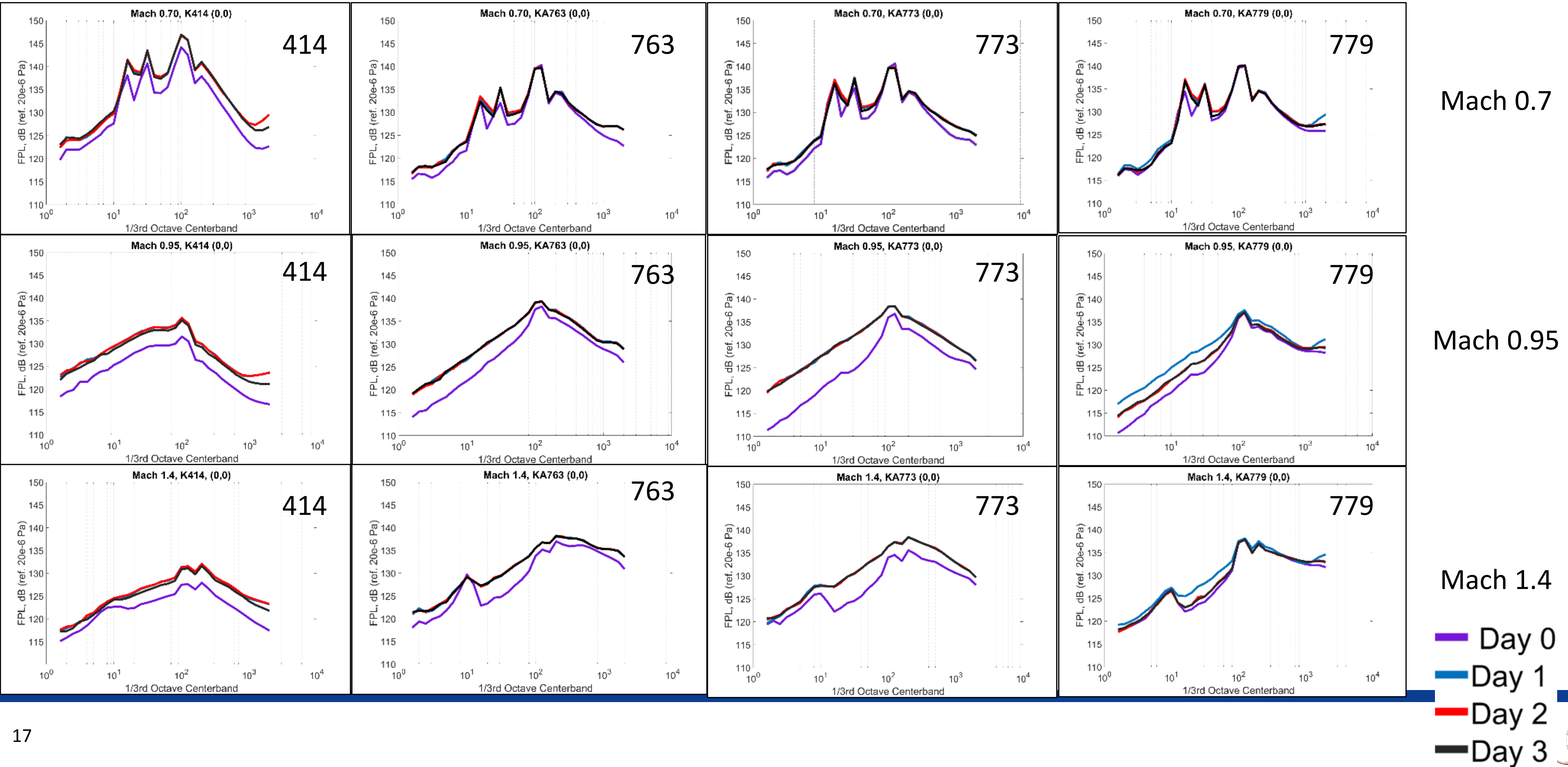
Results: Mach 0.95 @ α=0, β=0



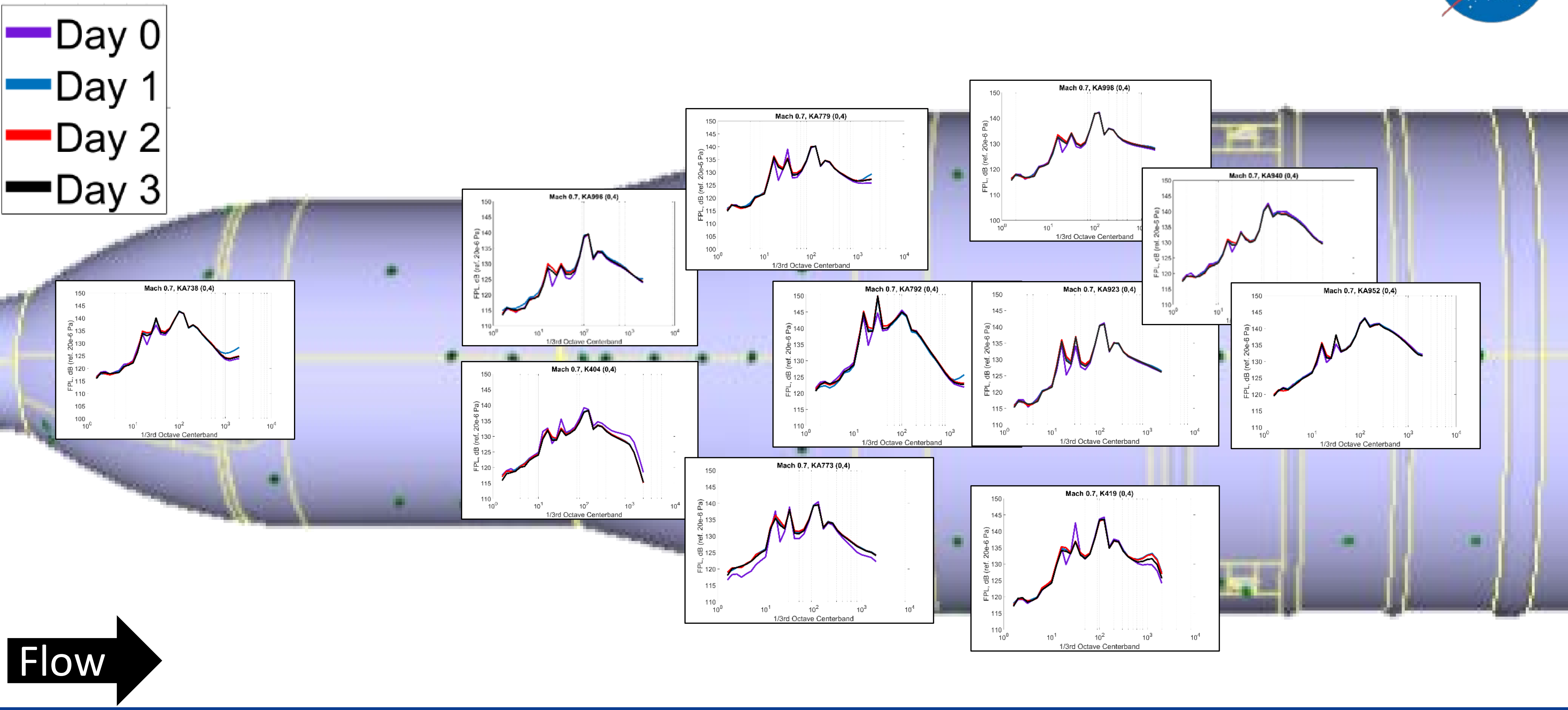
Results: Mach 1.4 @ α=0, β=0



Results with Large Differences in FPL, α=0 β=0

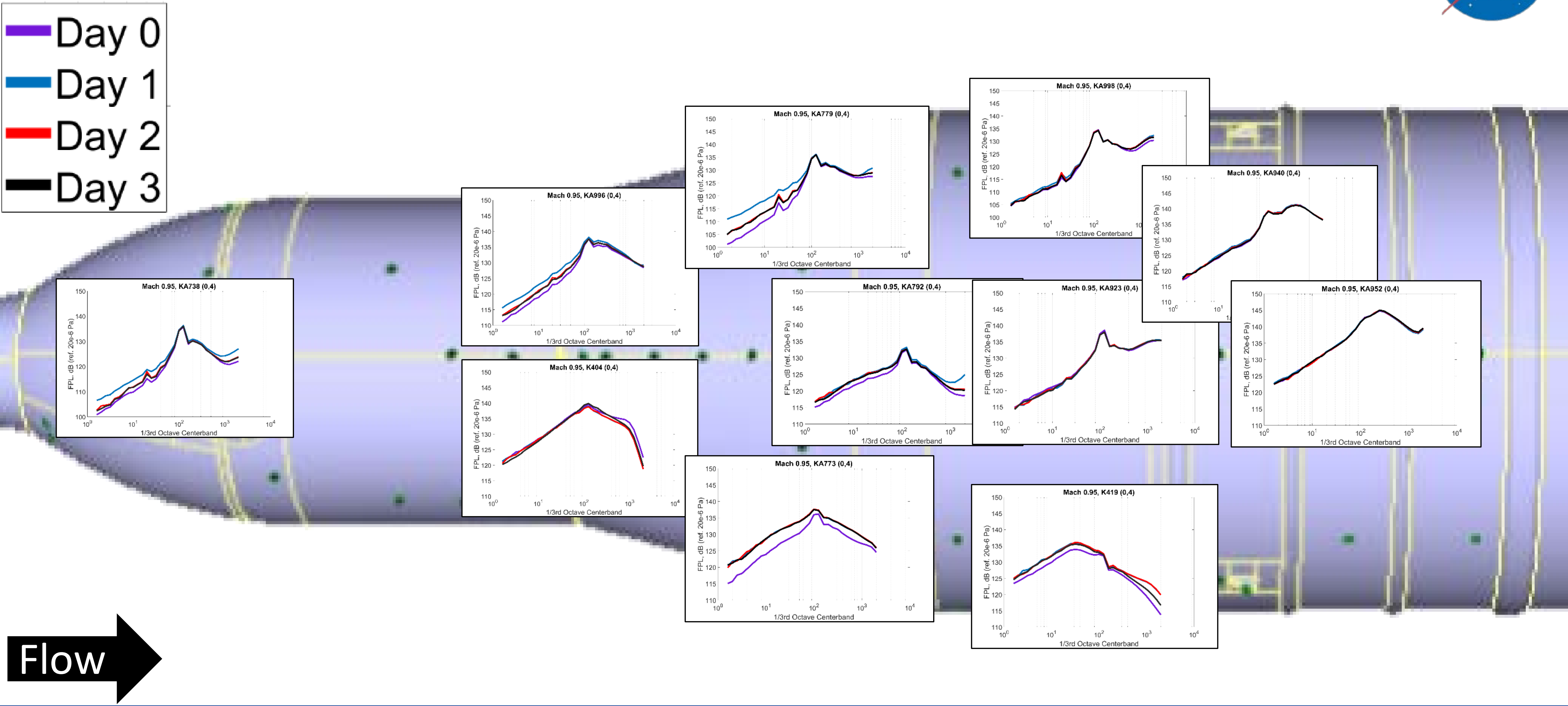


11 DDS Results Along SLS at Mach 0.7, α=0 β=4



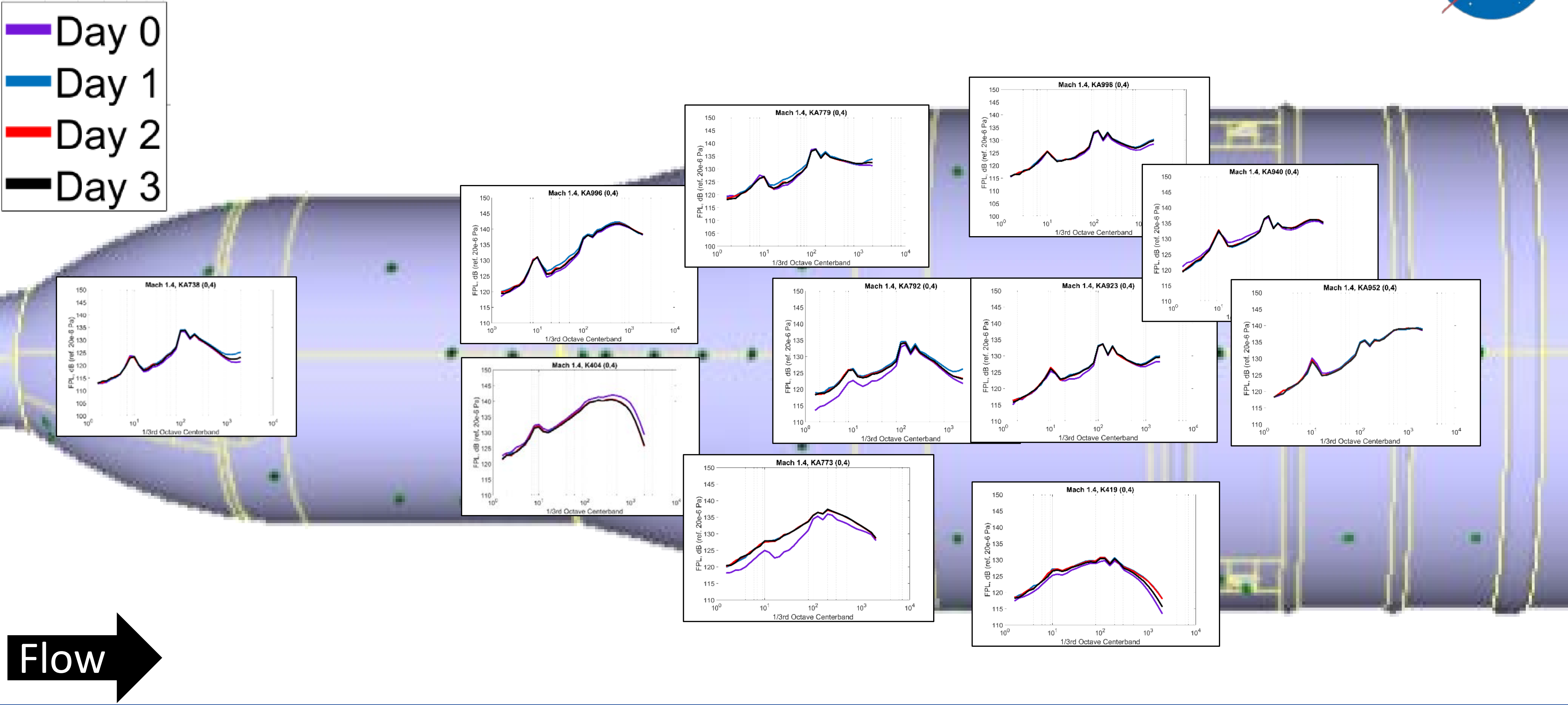
[Dots image courtesy of NASA PSP Team and Thomas Steva of MSFC]

11 DDS Results Along SLS at Mach 0.95, α=0 β=4



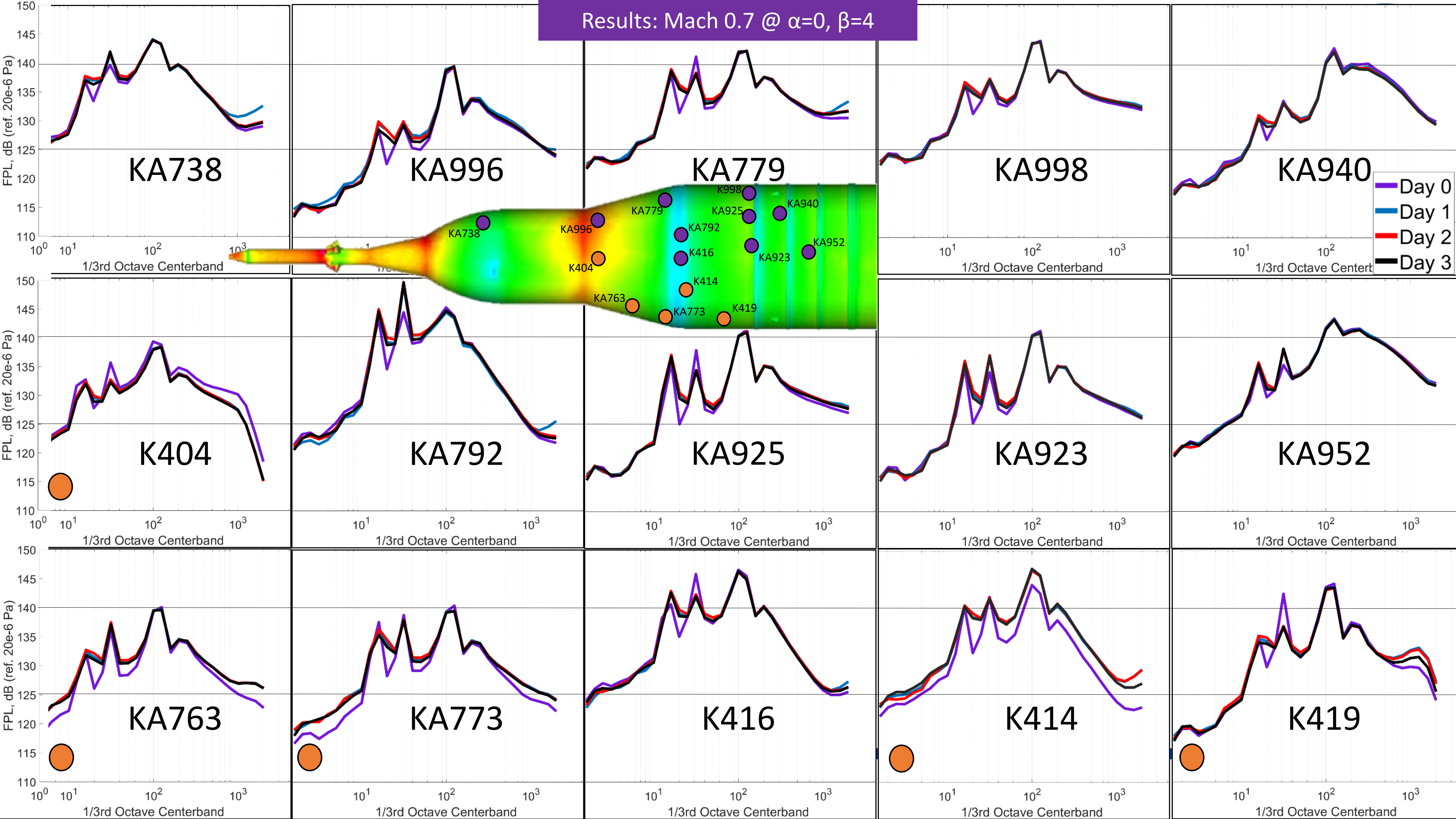
 [Dots image courtesy of NASA PSP Team and Thomas Steva of MSFC]

11 DDS Results Along SLS at Mach 1.4, α=0 β=4

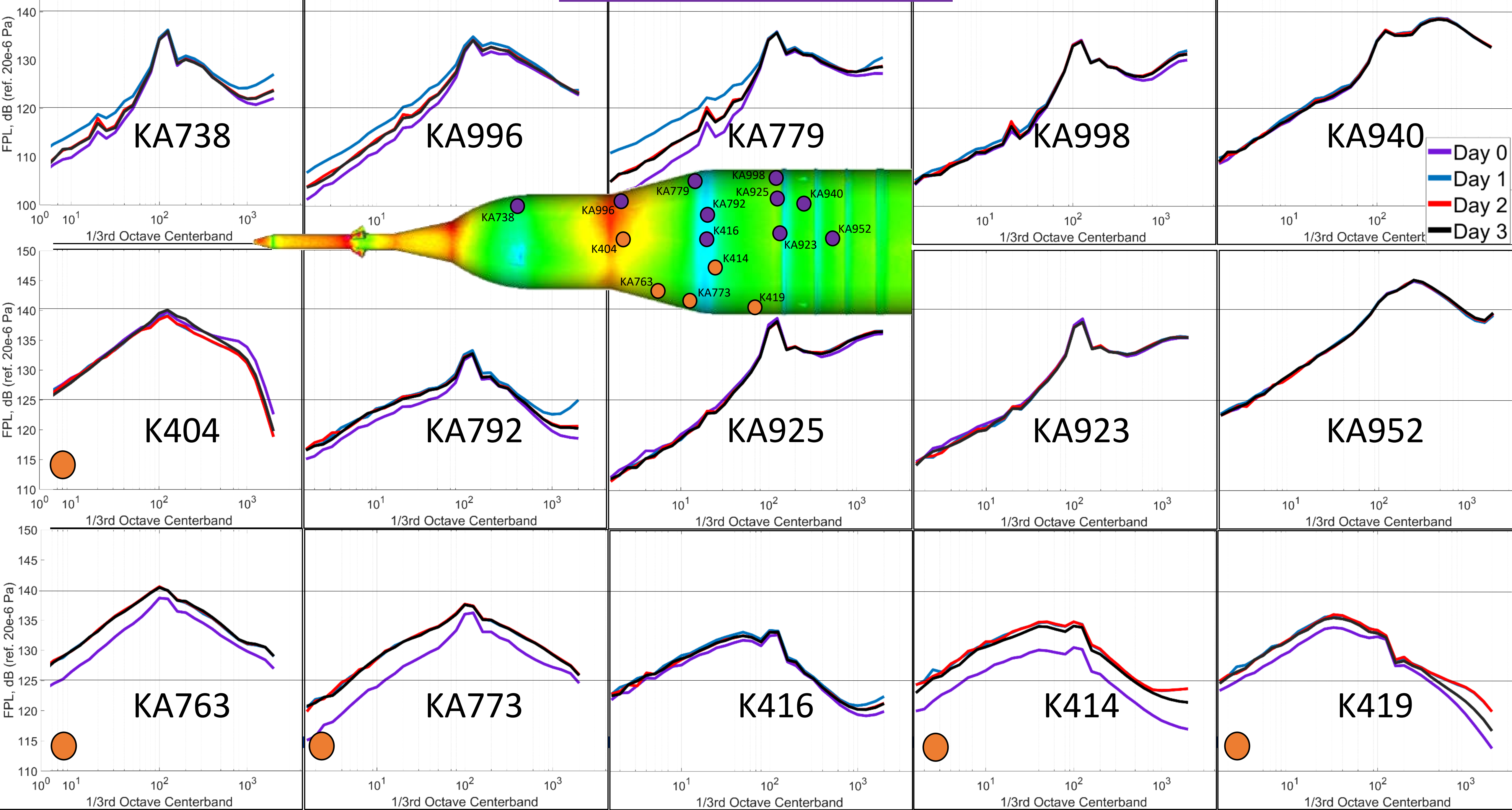


 [Dots image courtesy of NASA PSP Team and Thomas Steva of MSFC]

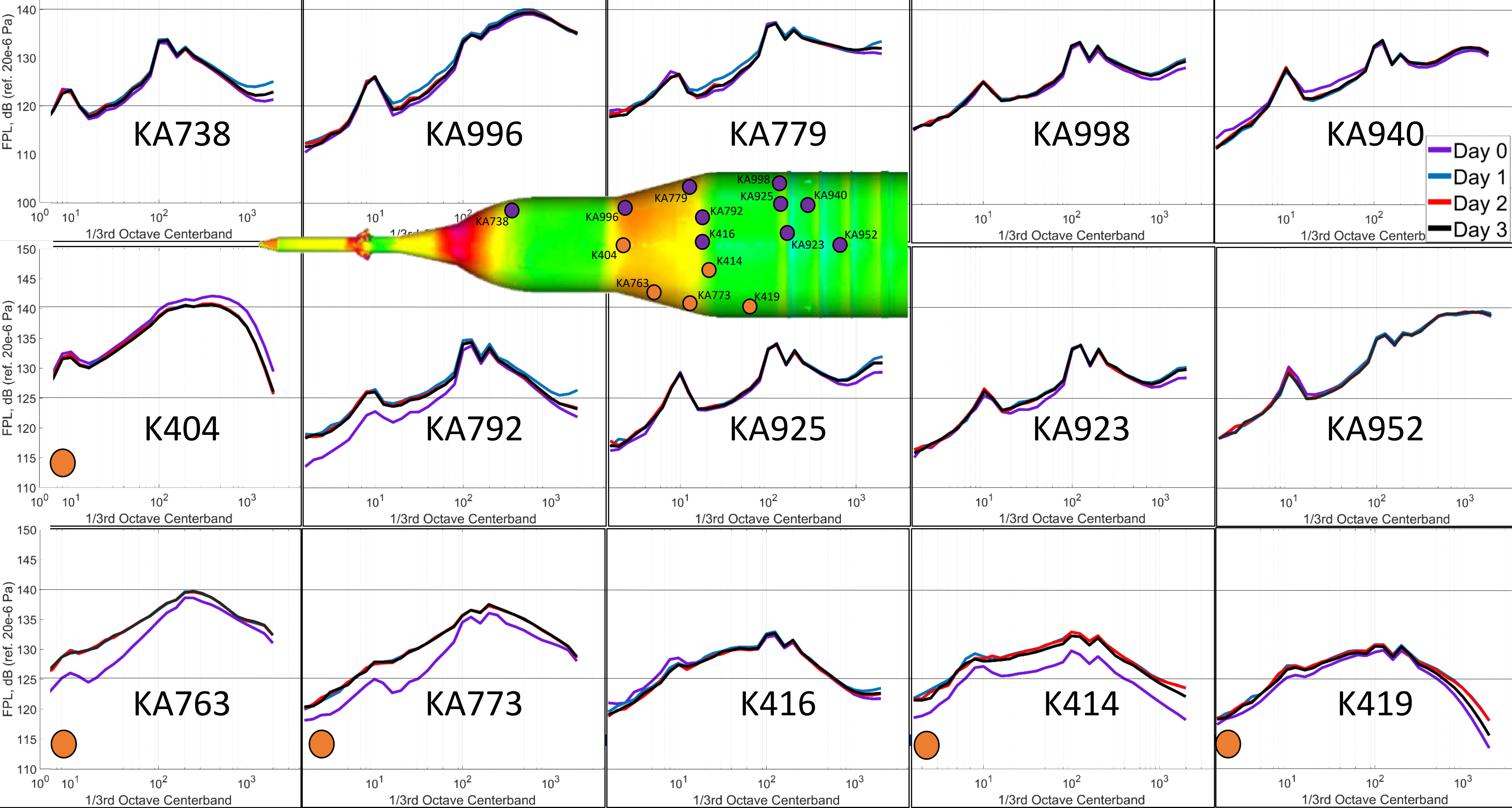
Results: Mach 0.7 @ α=0, β=4



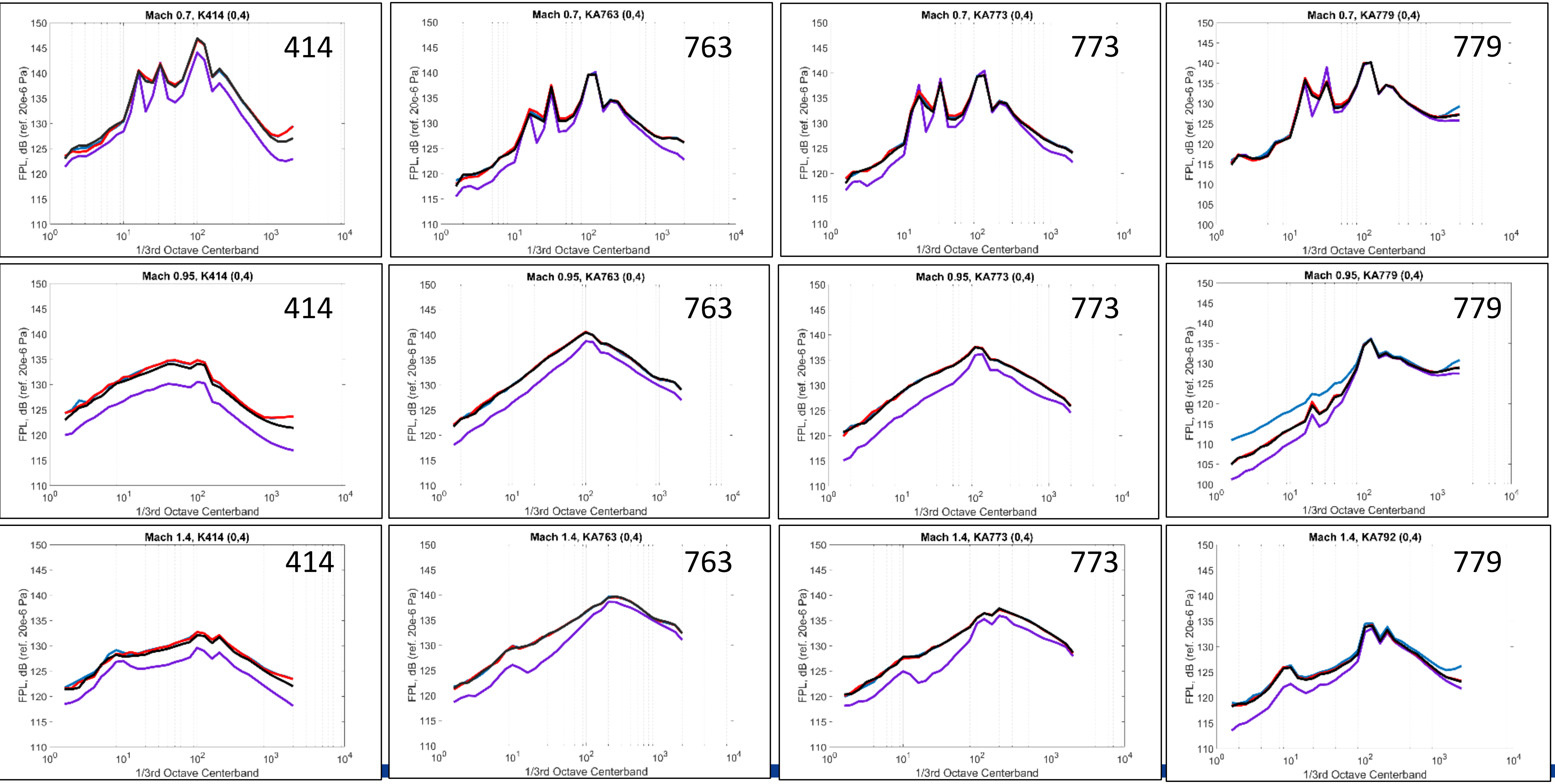
Results: Mach 0.95 @ α=0, β=4



Results: Mach 1.4 @ α=0, β=4



Results with Large Differences in FPL, α=0 β=4



Mach 0.7

Mach 0.95

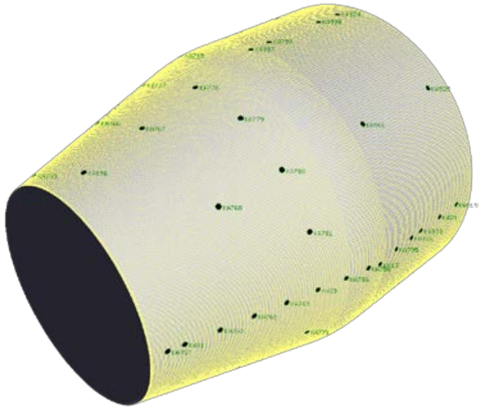
Mach 1.4

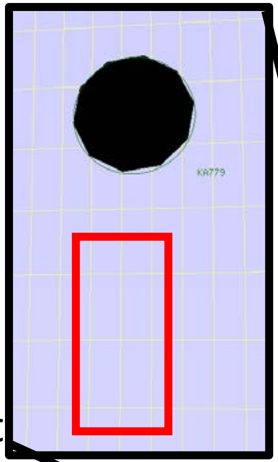
Day 0
Day 1
Day 2
Day 3

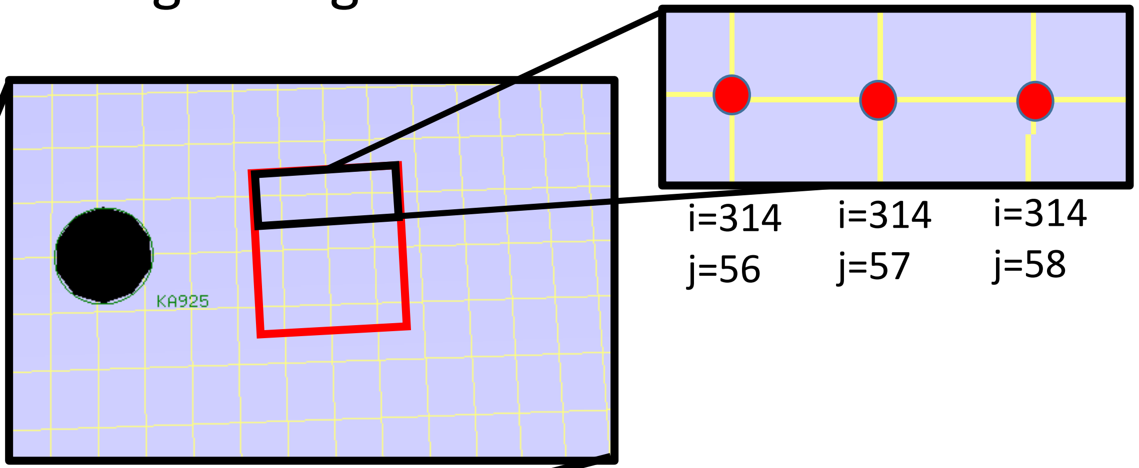
Processing the uPSP Data

Locating Nodes on SLS using Dots

- SLS is defined by PSP grid ➔ each grid has multiple zones ➔ each zone has nodes
- Selected a 3x3 section of nodes near a sanded Kulite using Dots grid

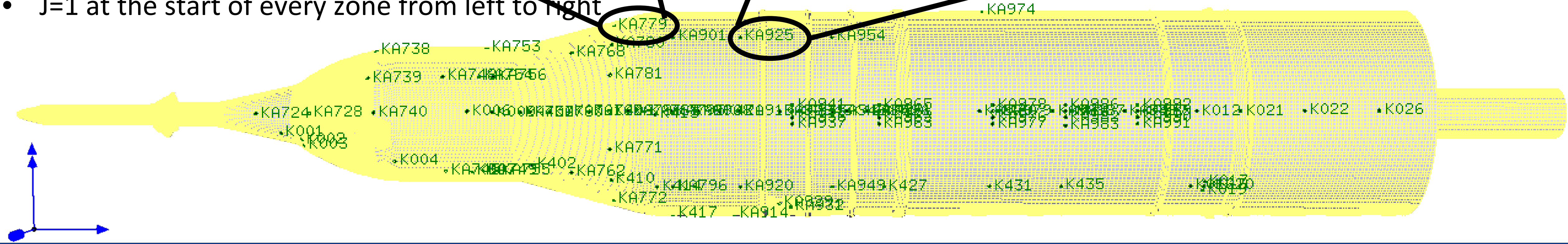






Each node has an i and j coordinate

- i coordinate goes around from 1-361 for every line of nodes in the grids for the larger parts of the model
- J=1 at the start of every zone from left to right



 [Dots image courtesy of NASA PSP Team and Thomas Steva of MSFC]

Data Processing Method for uPSP

- Converted the 3 x 3 section of chosen nodes into a virtual Kulite

```
%Read HDF5 file
file = '132506_trans.h5'
zone = 13;

obj.X = h5read(file, '/X'); %retrieves all X data for h5 file
obj.Y = h5read(file, '/Y');%retrieves all Y data for h5 file
obj.Z = h5read(file, '/Z');%retrieves all Z data for h5 file
obj.GridSizes = h5read(file, '/Grid_Sizes');
jmax = obj.GridSizes(1,zone);
kmax = obj.GridSizes(2,zone);

nodes = 0;
for i = 1:zone-1
    nodes = nodes + (obj.GridSizes(1,i)*  obj.GridSizes(2,i));
end
node_start = nodes + 1;
nodes_zone = obj.GridSizes(1,zone)* obj.GridSizes(2,zone);
node_end = node_start + nodes_zone -1;
numOfNodes = node_end-node_start +1
clear nodes;
X = obj.X(node_start:node_end,1);
Y = obj.Y(node_start:node_end,1);
Z = obj.Z(node_start:node_end,1);

dim1 = 176; %j-value or i-value in DOTS
dim2 = 25; %k-value or j-value in DOTS
%NZone = [(jmax*i) + dim1];
NZone = [(jmax*(dim2-1)) + dim1]
KuliteNode = node_start + NZone -1

KuliteX = obj.X(KuliteNode)
KuliteY = obj.Y(KuliteNode)
KuliteZ = obj.Z(KuliteNode)
```

Specified h5 file and zone of nodes

Extracted h5 file information and Grid Sizes;
"jmax" is max of "i" and "kmax" is max of "j" in Dots program for specified zone

Extracting Node Information:
node_start→ first node in zone in relation to all nodes
nodes_zone→ number of nodes in specified zone
node_end→ last node in zone in relation to all nodes
numOfNodes→nodes_zone

Specified (i,j) location of node to obtain node number in specified zone and in relation with all the nodes in Dots program

Data Processing Method for uPSP Cont.

```
T = h5read(file,'/frames',[1 52607],[56095 16168],[1 1]);

A = T(:,15323:15325);
B = T(:,15409:15411);
C = T(:,15495:15497);

A = reshape(A,[3,1,length(A)]);
B = reshape(B,[3,1,length(B)]);
C = reshape(C,[3,1,length(C)]);

%Combine the matrixes above into a 3 x 3 x time matrix
D = cat(2,A,B,C);

%average these to create a virtual Kulite
K = mean(mean(D),2);

%to reshape into a 2D matrix...
K = reshape (K,[1,length(K)]);

f = 10e3;
ffts = 512;
overlap = 0.75;
dt = 1/f;
df = f/ffts;
N = size(K);
nn = N/1;
t = 0:dt:(N-1)*dt;

DK = detrend(K,'constant'); %Subtract the mean before FFT
[PSD,F] = pwelch(DK(1,:),hann(ffts),round(overlap*ffts),ffts,f); % [Hz^-1]
PSD = PSD .* df / var(DK);

figure
semilogx(F,PSD,'LineWidth',7)
xlabel('Frequency (Hz)')
ylabel('$P_{xx}(f)\cdot df/\sigma^2$','interpreter','latex')
set(gca,'FontSize',30)
title('Mach 0.9, KA738 uPSP (0,4)')
grid on
```

Extract the Frame x Node Data from h5 file
Isolate chosen nodes in columns perpendicular to flow for 3 vectors
Reshape these into 3x1xtime matrices

Combine the matrices into one 3x3xtime matrix
Average matrix to create virtual Kulite, now a 1x1xtime matrix
Reshape into 2D matrix (1xtime)

Processed uPSP data to obtain Power Spectral Density plot
Sampling Rate → 10kHz
FFT size → 512
Overlap → 0.75
Detrended virtual Kulite (although not needed)
Normalized by variance of detrended data

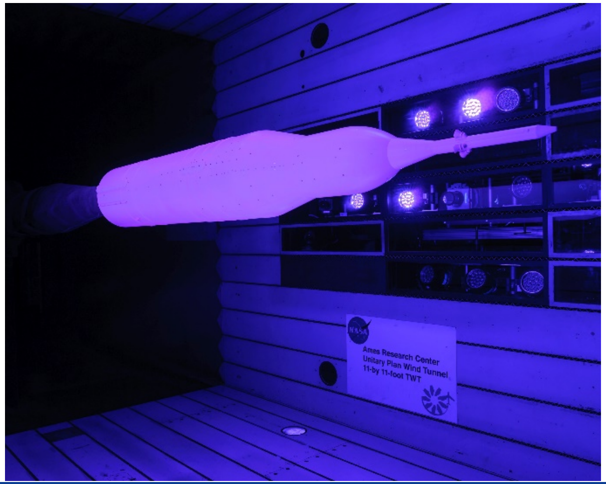
Plotting PSD in semilog fashion

Conclusions Gathered to Help Complete the Mission

- No right or wrong answer
- Changing the roughness of a model will affect the flow
- Positive Note: uPSP not creating tones➔not translating to design change
- uPSP surface roughness does affect flow, magnified at areas of high fluctuating pressures (do see offset but consistent across days)

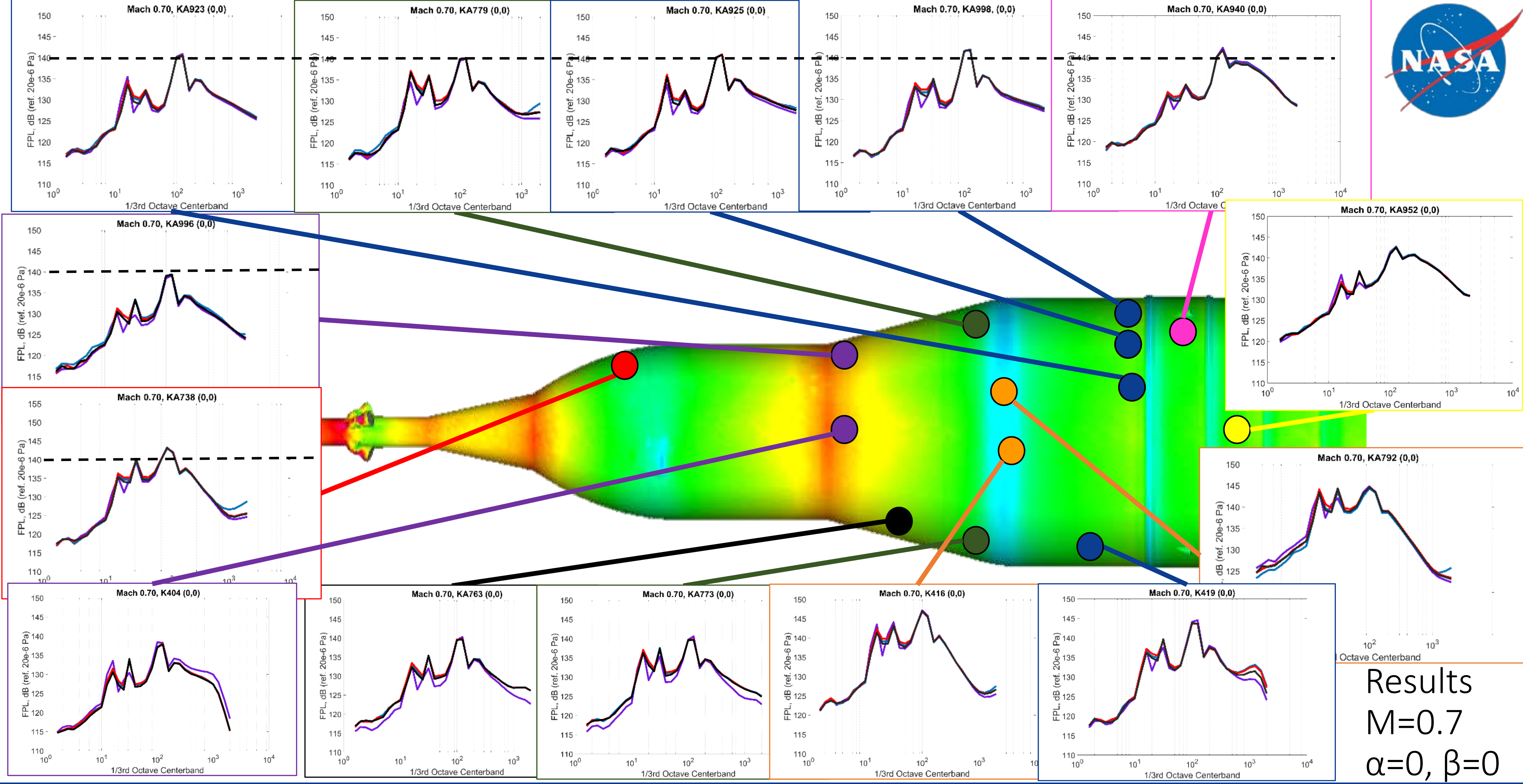
Future Work Towards Mission Accomplishment

- Process uPSP data for same runs
- Prepare for September uPSP demonstration
  - Only sanding in areas of high fluctuation
  - Painting over Kulites➔does uPSP damage the Kulite?



Thank You! Any Questions?

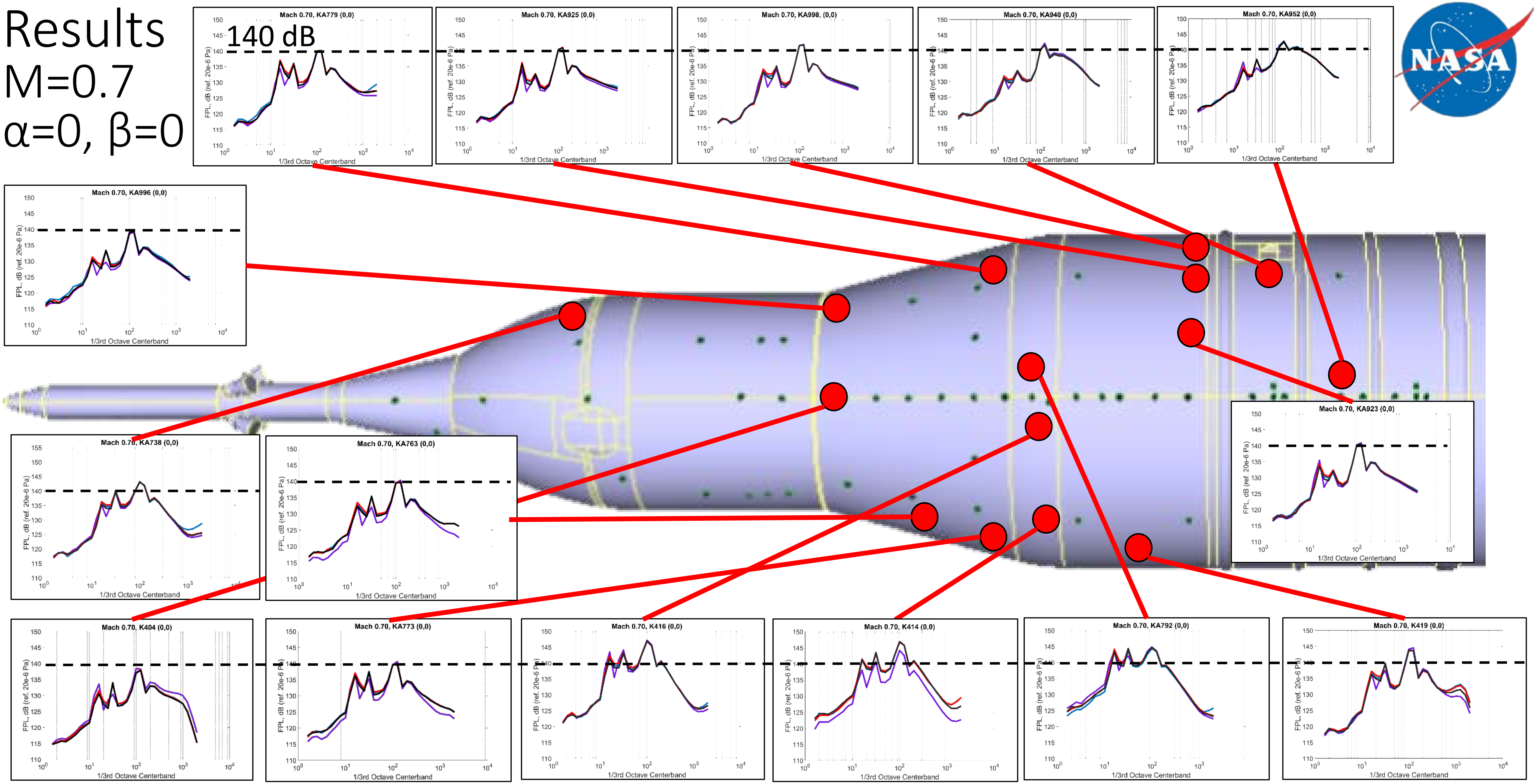
Power of Pink!



Results
M=0.7
α=0, β=0

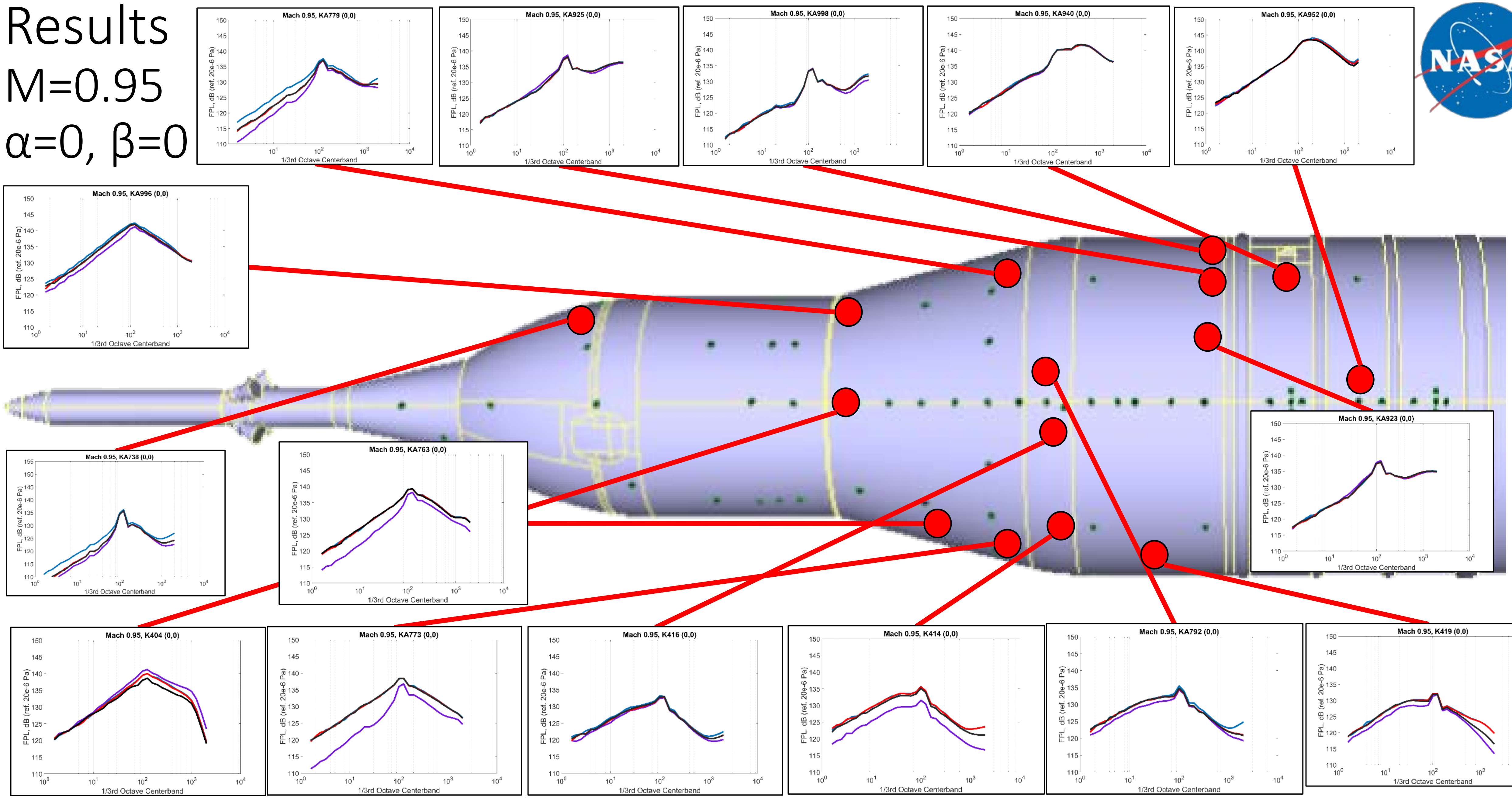
 [Steady State PSP image courtesy of NASA PSP Team]

Results
M=0.7
α=0, β=0



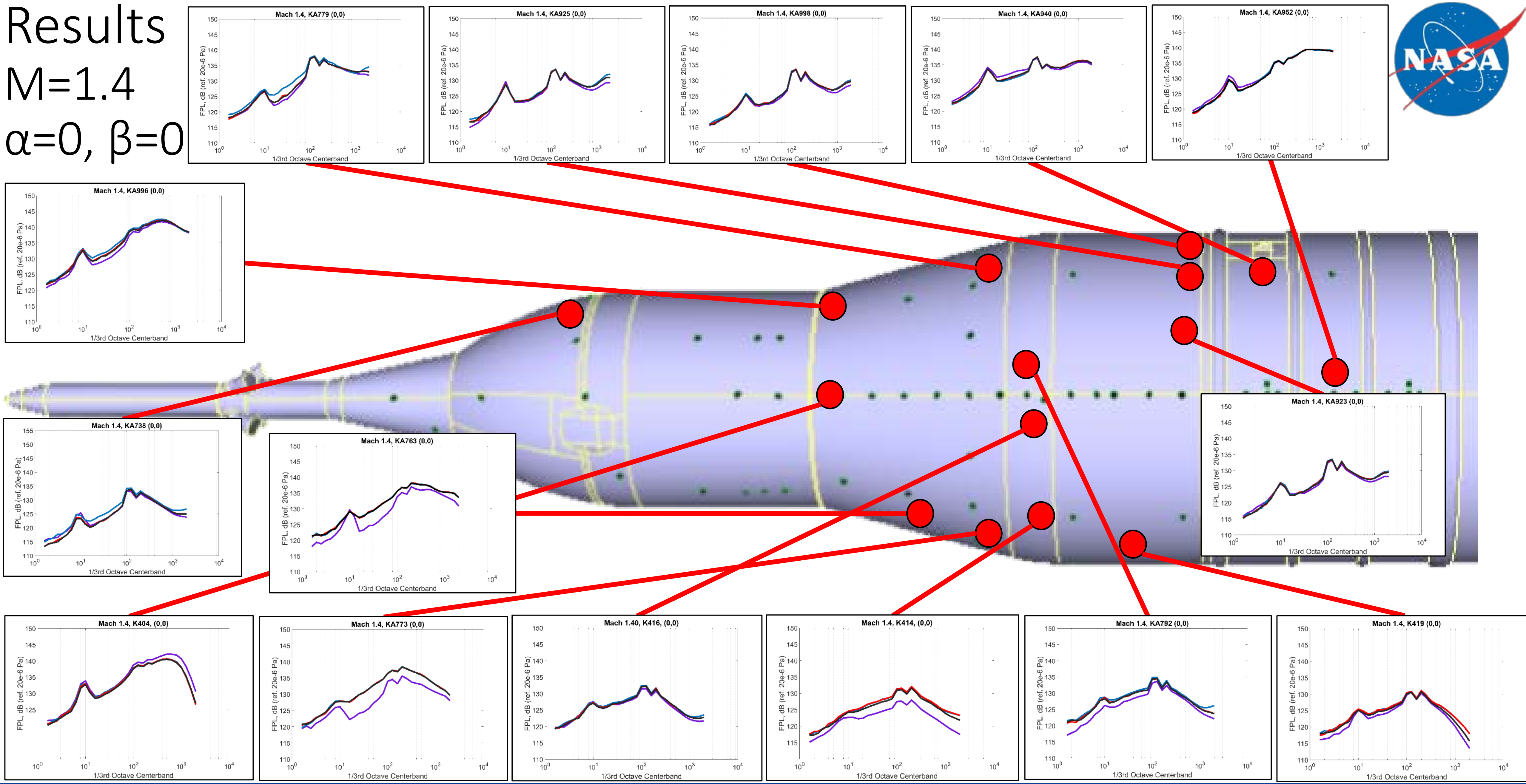
[Dots image courtesy of NASA PSP Team and Thomas Steva of MSFC]

Results
M=0.95
α=0, β=0



 [Dots image courtesy of NASA PSP Team and Thomas Steva of MSFC]

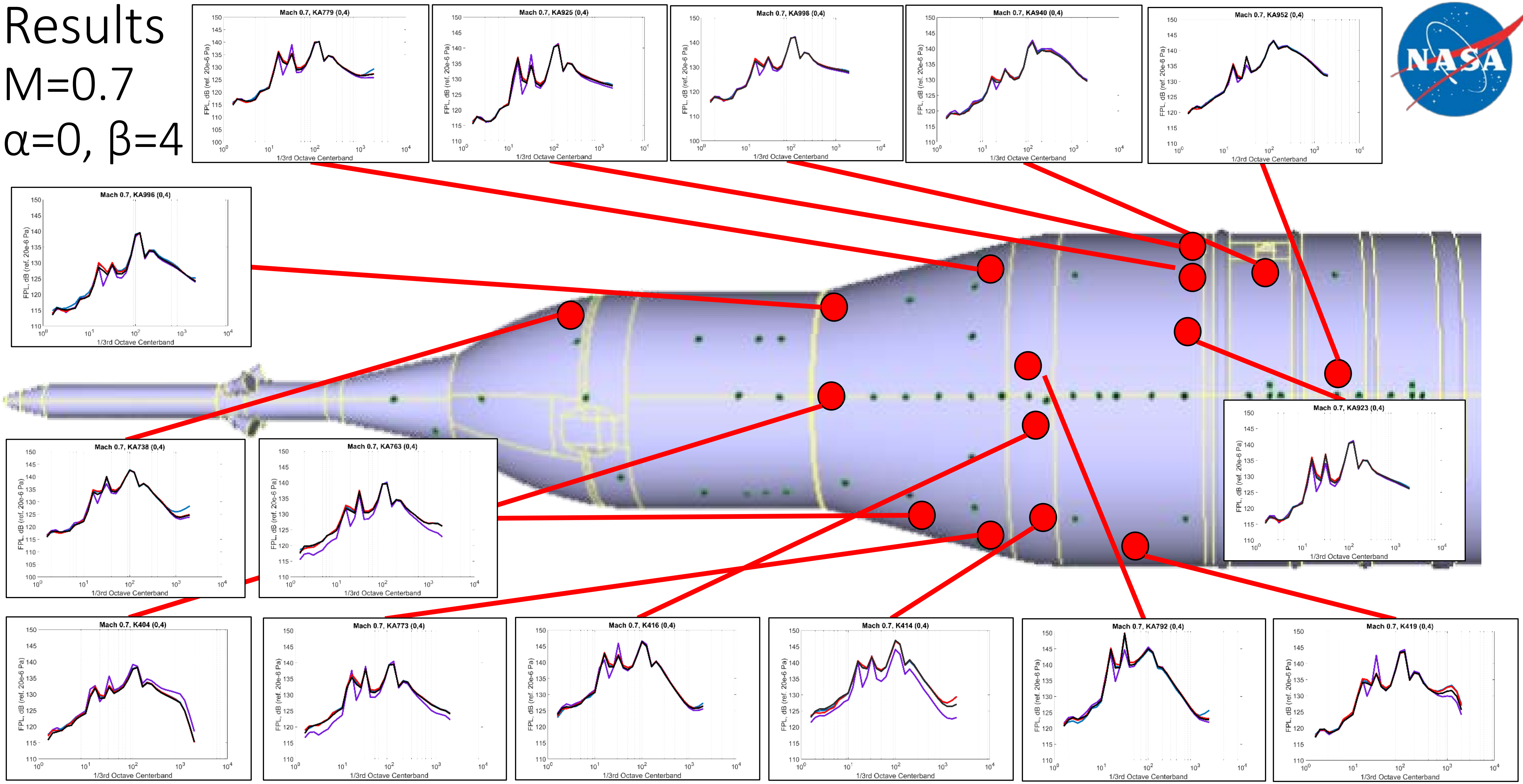
Results
M=1.4
α=0, β=0



[Dots image courtesy of NASA PSP Team and Thomas Steva of MSFC]

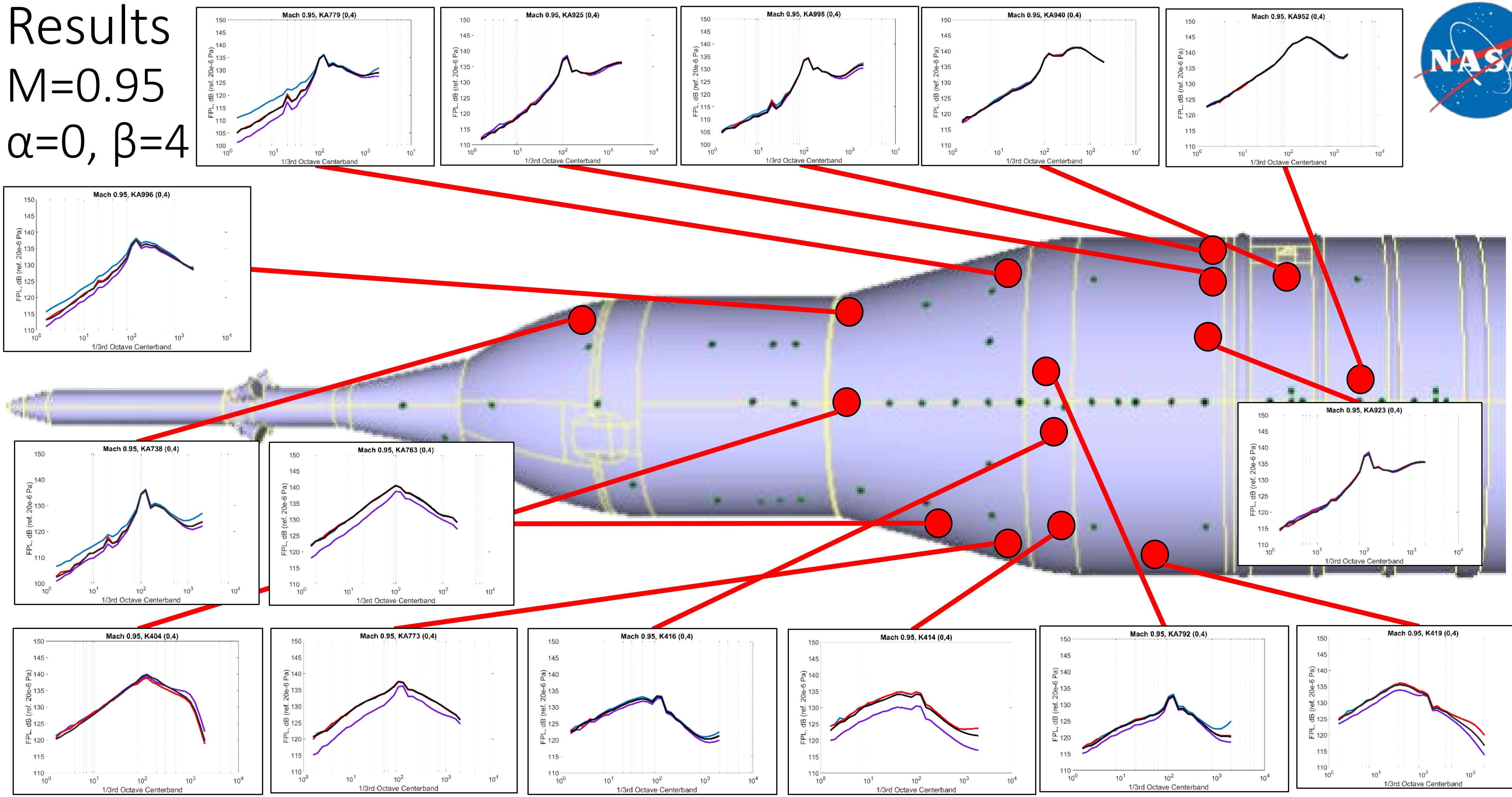
Fluid Mechanics Lab

Results
M=0.7
α=0, β=4



 [Dots image courtesy of NASA PSP Team and Thomas Steva of MSFC]

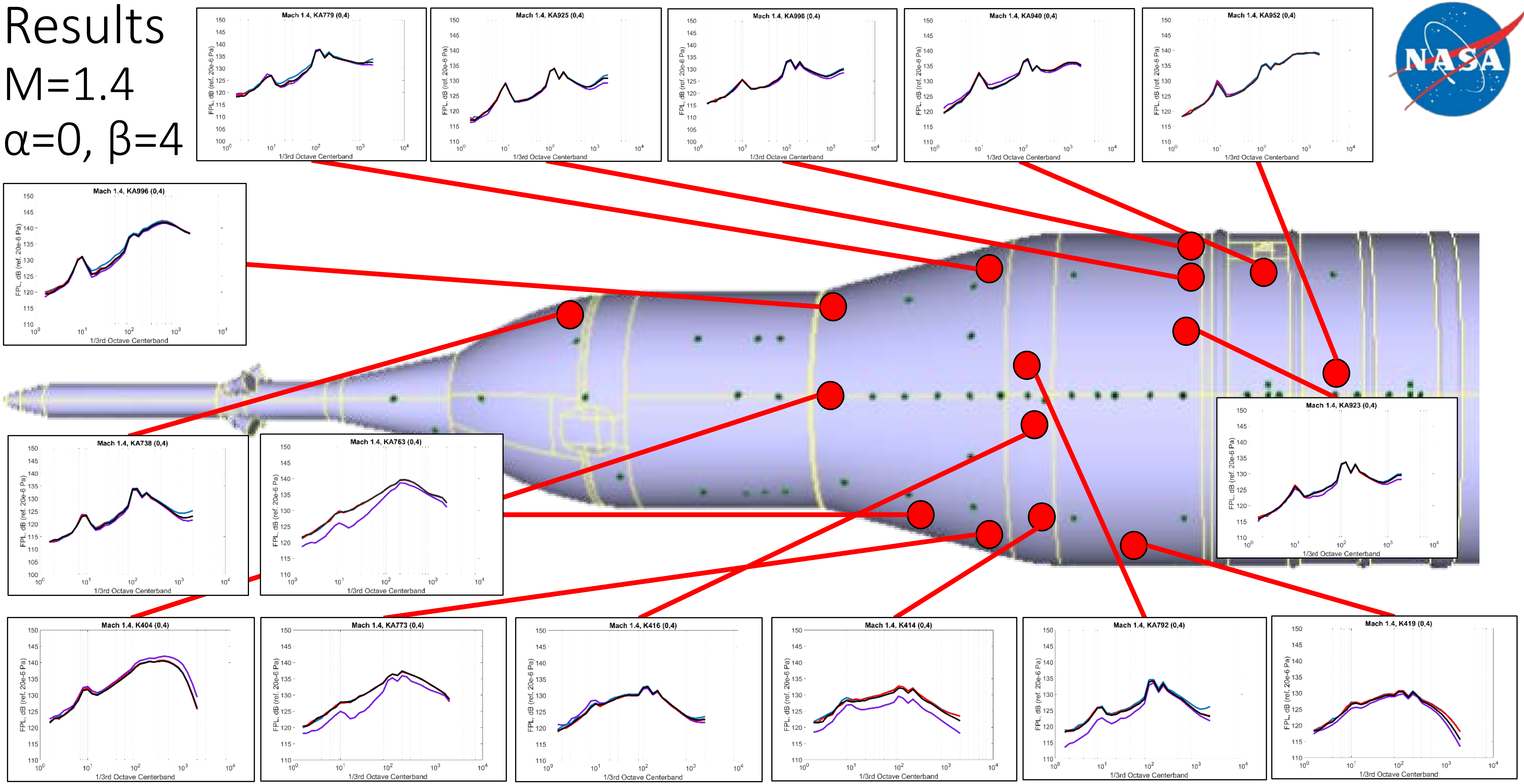
Results
M=0.95
α=0, β=4



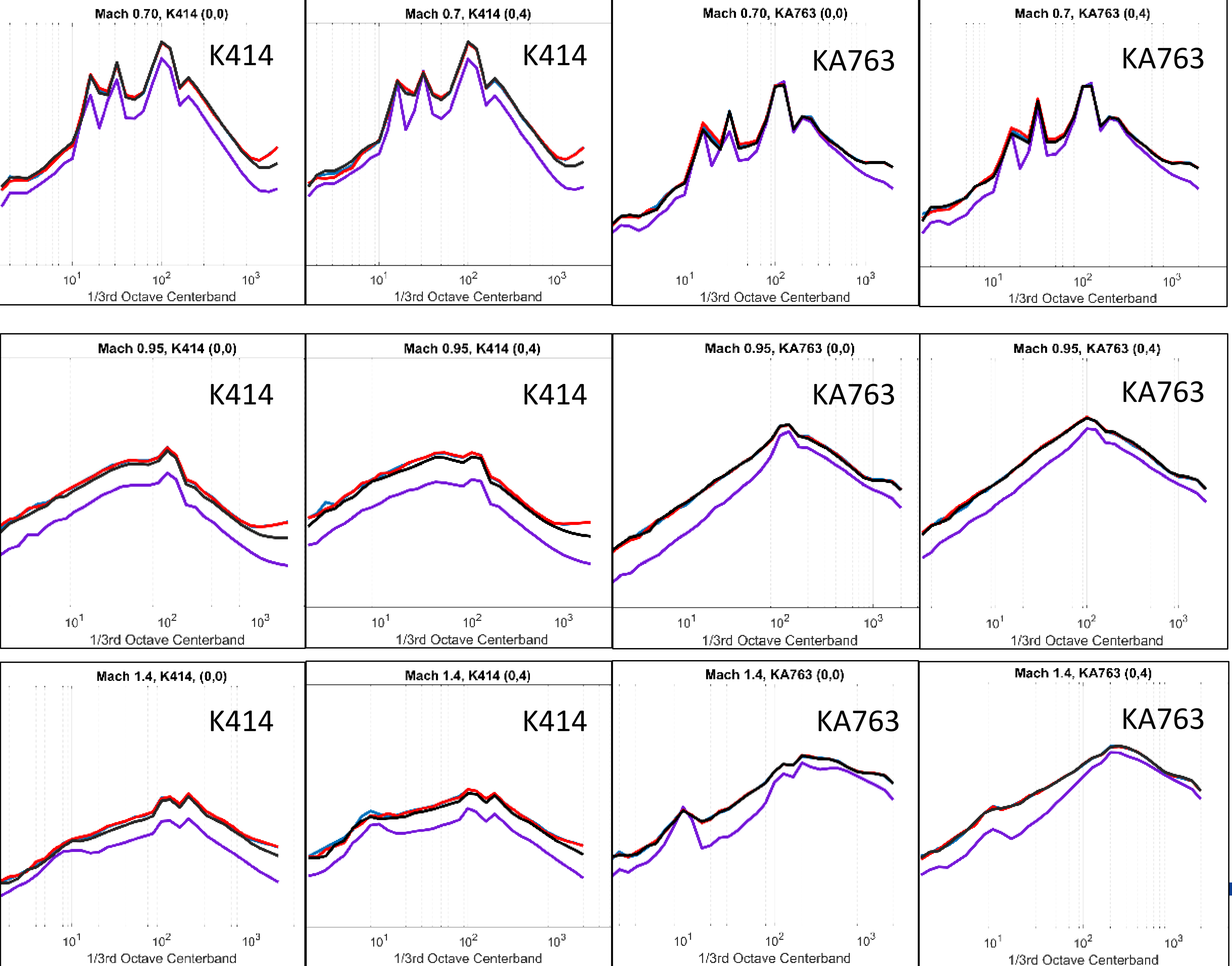
 [Dots image courtesy of NASA PSP Team and Thomas Steva of MSFC]

Fluid Mechanics Lab

Results
M=1.4
α=0, β=4



 [Dots image courtesy of NASA PSP Team and Thomas Steva of MSFC]



Mach 0.70, K414 (0,0)
K414
Mach 0.7, K414 (0,4)
K414
Mach 0.70, KA763 (0,0)
KA763
Mach 0.7, KA763 (0,4)
KA763
Mach 0.95, K414 (0,0)
K414
Mach 0.95, K414 (0,4)
K414
Mach 0.95, KA763 (0,0)
KA763
Mach 0.95, KA763 (0,4)
KA763
Mach 1.4, K414, (0,0)
K414
Mach 1.4, K414 (0,4)
K414
Mach 1.4, KA763 (0,0)
KA763
Mach 1.4, KA763 (0,4)
KA763
10^1
10^2
10^3
1/3rd Octave Centerband