

AET//Argent Energetics Technology, LLC

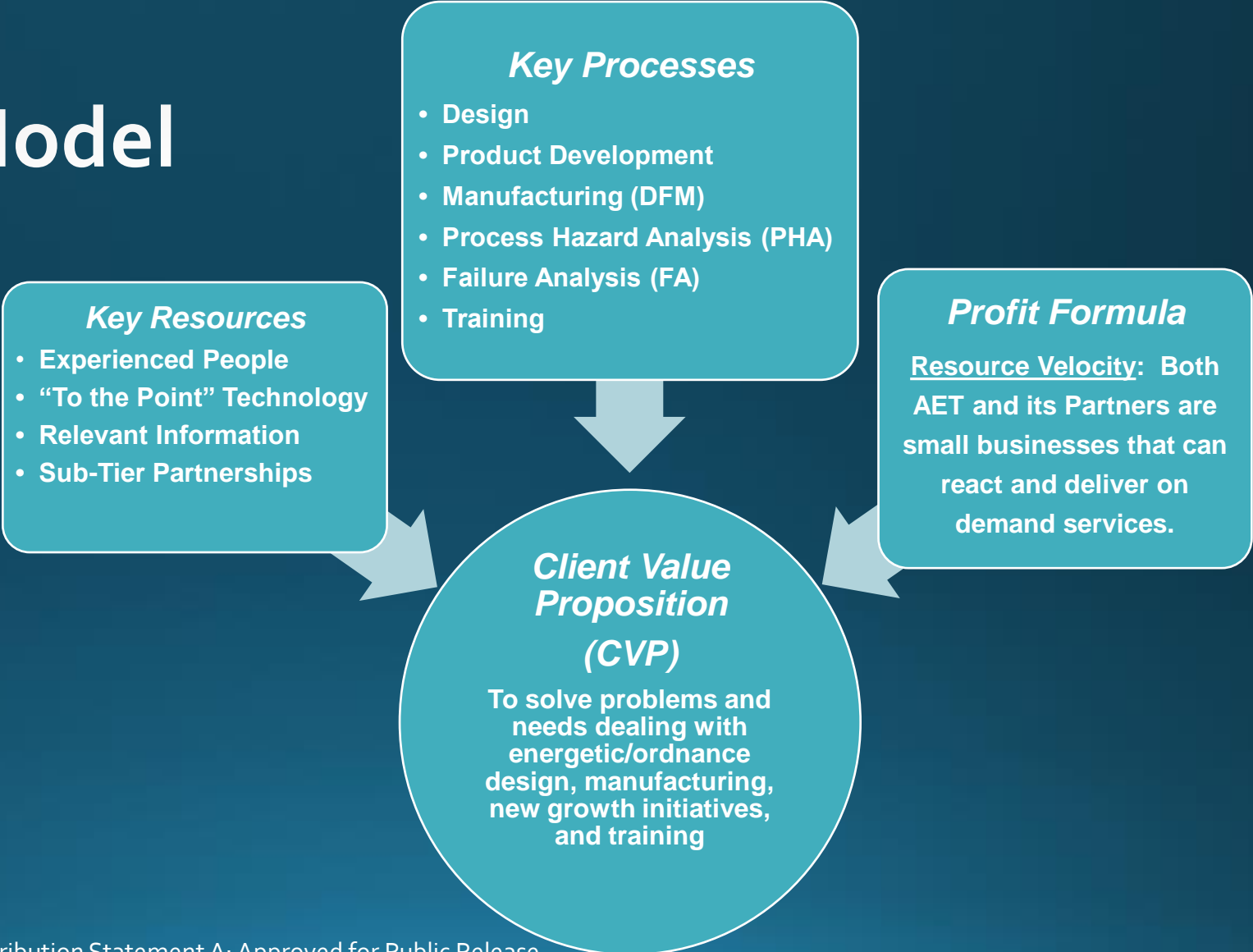
Modernization of the NSWC IHEODTD CADPROG Ballistic Computer Simulation Program

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AET// Business Model

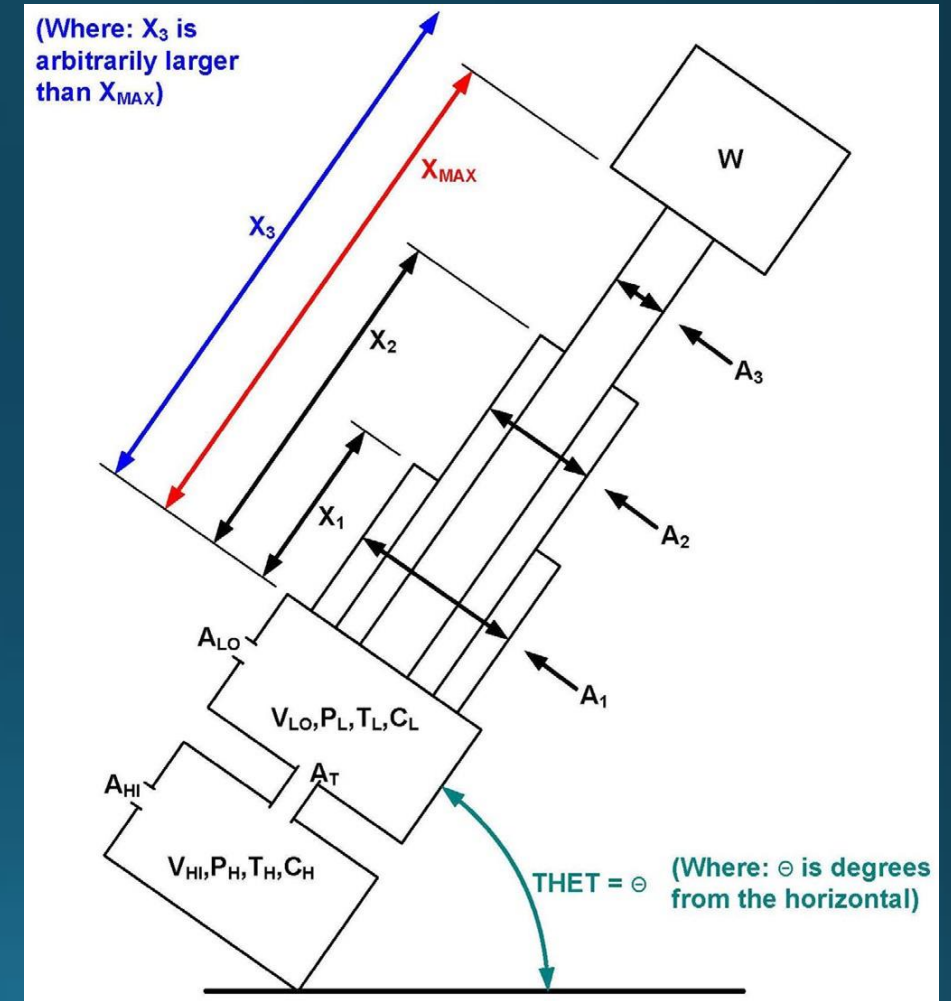


CADPROG, Updated

- Contract: Noo174-16-P-0052
 - AET is creating a ballistic cartridge modeler using the platform MATLAB by translating, updating and improving the Government Furnished Material (GFM) CADPROG ballistic modeling program.
 - The new ballistics modeler is the property of the Navy.

CADPROG, Basics

1. User supplied input parameters
2. "Hard-wired" parameters
3. Internally-computed parameters
4. Mass averaged thermodynamic properties of gas mixture
5. Model (time-dependent) variables

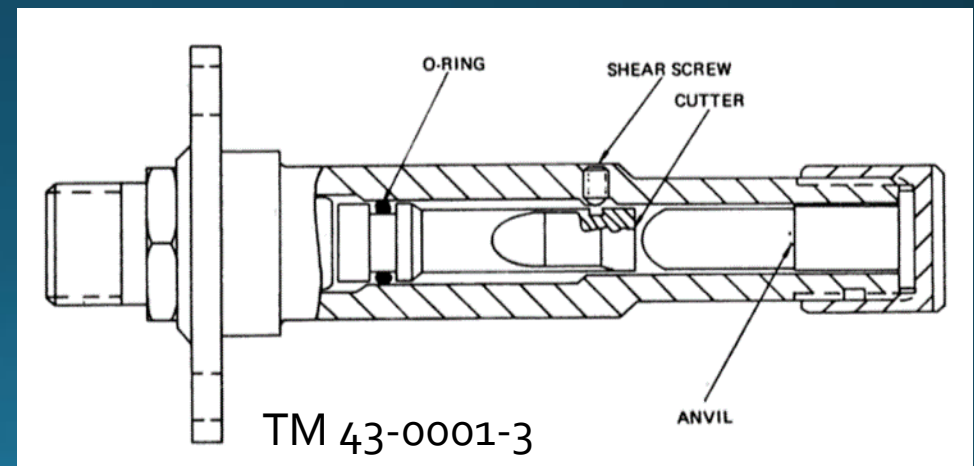


CADPROG, V9

- Lumped Parameter Model for the interior ballistic performance of CAD's and PAD's
- Source Code is FORTRAN 77
- Platform: UNIX (SGI)
- Uses a 4th Order Runge Kutta integration scheme to calculate the dynamic responses from the initial conditions.
- Input, Interactive, CADPROG file, or ASCII Text File
- Output, ASCII Table (Unstructured Data) and External Graph, No Edit, "Picture"



<http://www.navair.navy.mil/index.cfm?fuseaction=home.displayPlatform&key=FC59DB4C-5B6A-43F2-BD52-1D010A5847F5>



CADPROG, FORTRAN Version Generic Guillotine Cutter

```

gcutter.txt - Notepad
File Edit Format View Help

guillotine cutter
0.00      0.          0.          499.8      .15E-04
10.       0.          .1899E+6    .0          .0
0.        .9368E-5     .473E-01   28.1       .0
.57E-01   600.         0.00      0.         5000.
1.        0.0         .57        1.         5.00
1.5       0.0         0.         0.         0.
.150      25.         .280      100.       .36
500.      .56         750.      .90        1250.
1.500     2000.       0.         0.         0.
.0009     0.01       0.         .0075     .0015
0.        .003        2000.     0.         0.
0.        0.         0.         0.         0.
0.        0.         0.         0.         0.
0.        0.         0.         0.         0.
0.        0.         0.         0.         0.

```

```

----- SINGLE CHAMBER SIMULATION -----

TIME      PRESS      TEMP      FRACTION  DISP      VEL      ACCEL
SEC       PSIA       DEG-K     BURNED    IN        FT/SC    G

0.0000    22.        5000.     0.0000    0.00     0.00    0.00
0.0001    367.       5000.     0.0478    0.00     0.00    0.00
0.0003    893.       4997.     0.1210    0.00     4.50   2350.62
0.0004    1889.      4966.     0.2692    0.02     21.59  4972.23
0.0006    3287.      4889.     0.5234    0.09     54.38  8649.16
0.0007    4148.      4744.     0.8091    0.23    102.76 10916.95
0.0009    3874.      4530.     0.9996    0.46    154.70 10193.70
0.0010    2819.      4240.     1.0000    0.78    196.85  7418.65
0.0011    2352.      4083.     1.0000    1.00    216.22  6189.36

PMAX =   4176. AT TIME =  0.0008 SEC

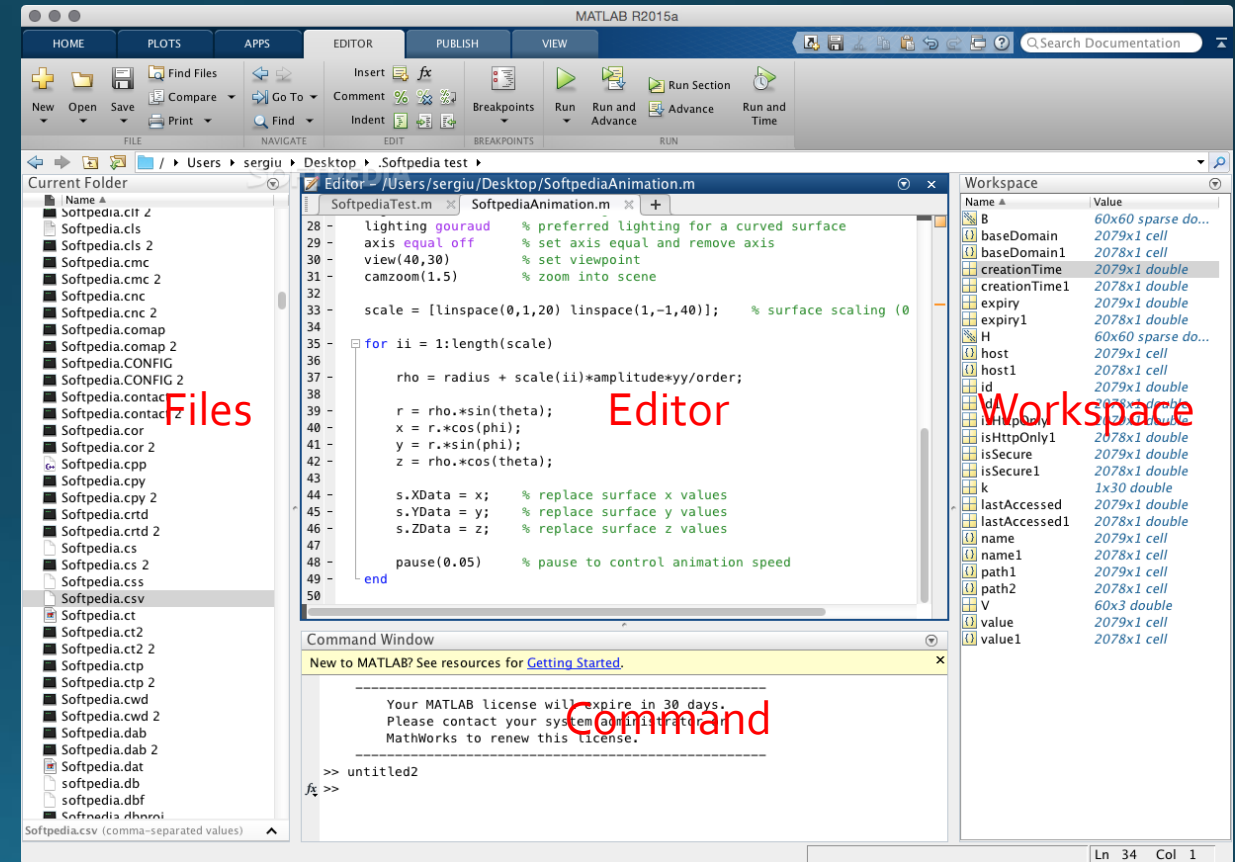
MAX ACCEL = ***** AT TIME =  0.0008 SEC

DYNAMIC RESPONSE INDEX =   3.329 AT TIME =  0.0010 SEC

```

MATLAB R2016a Workspace Workflow CADPROG V10

- Add Workspace Variables
 - Chamber Model
 - Propellant Model
 - Granulation Model
- Run Simulations
 - Simulation Model
 - Create tables and graphs
- Automate Analysis
 - Maximum Conditions
 - Dynamic Response Index

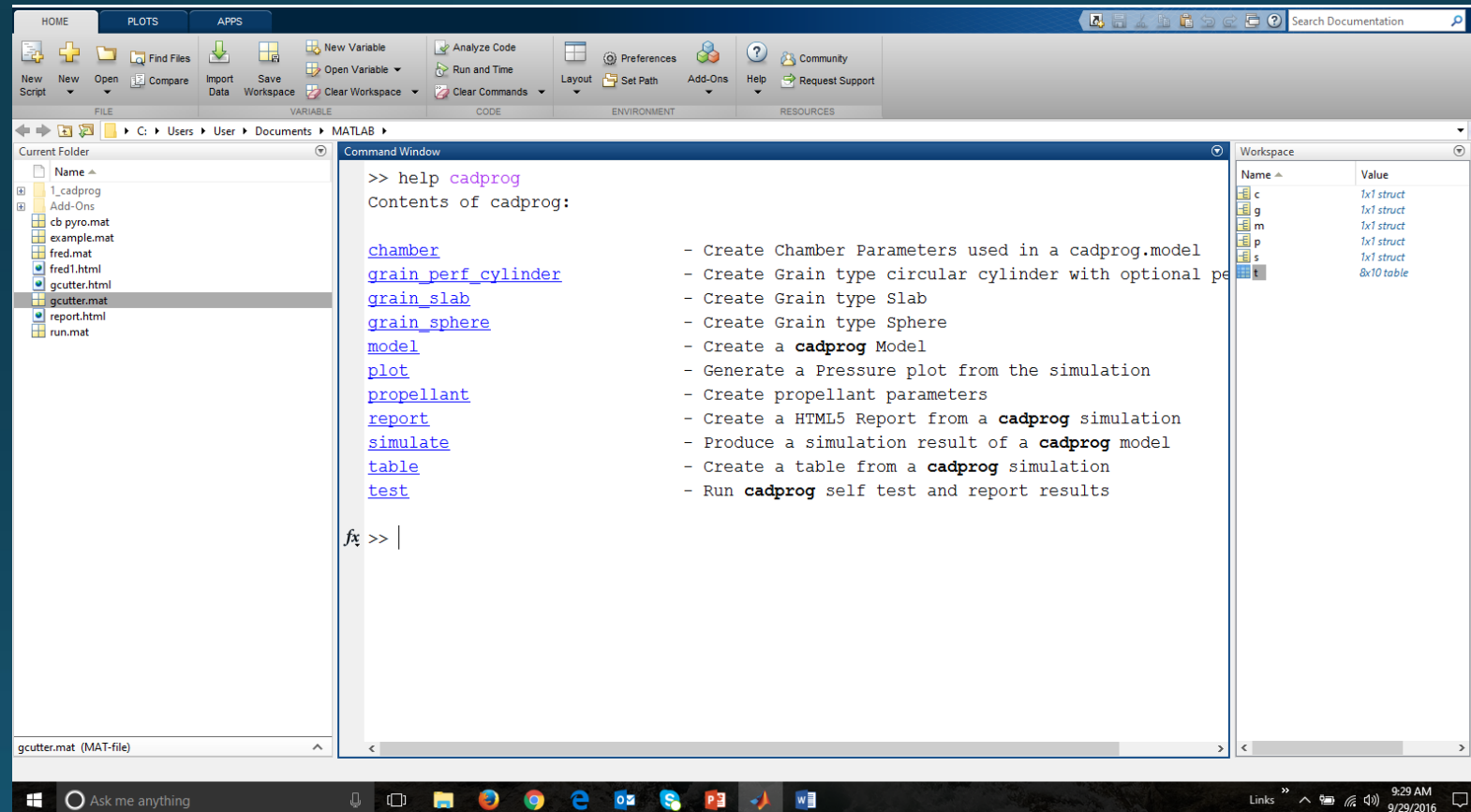


CADPROG, V10

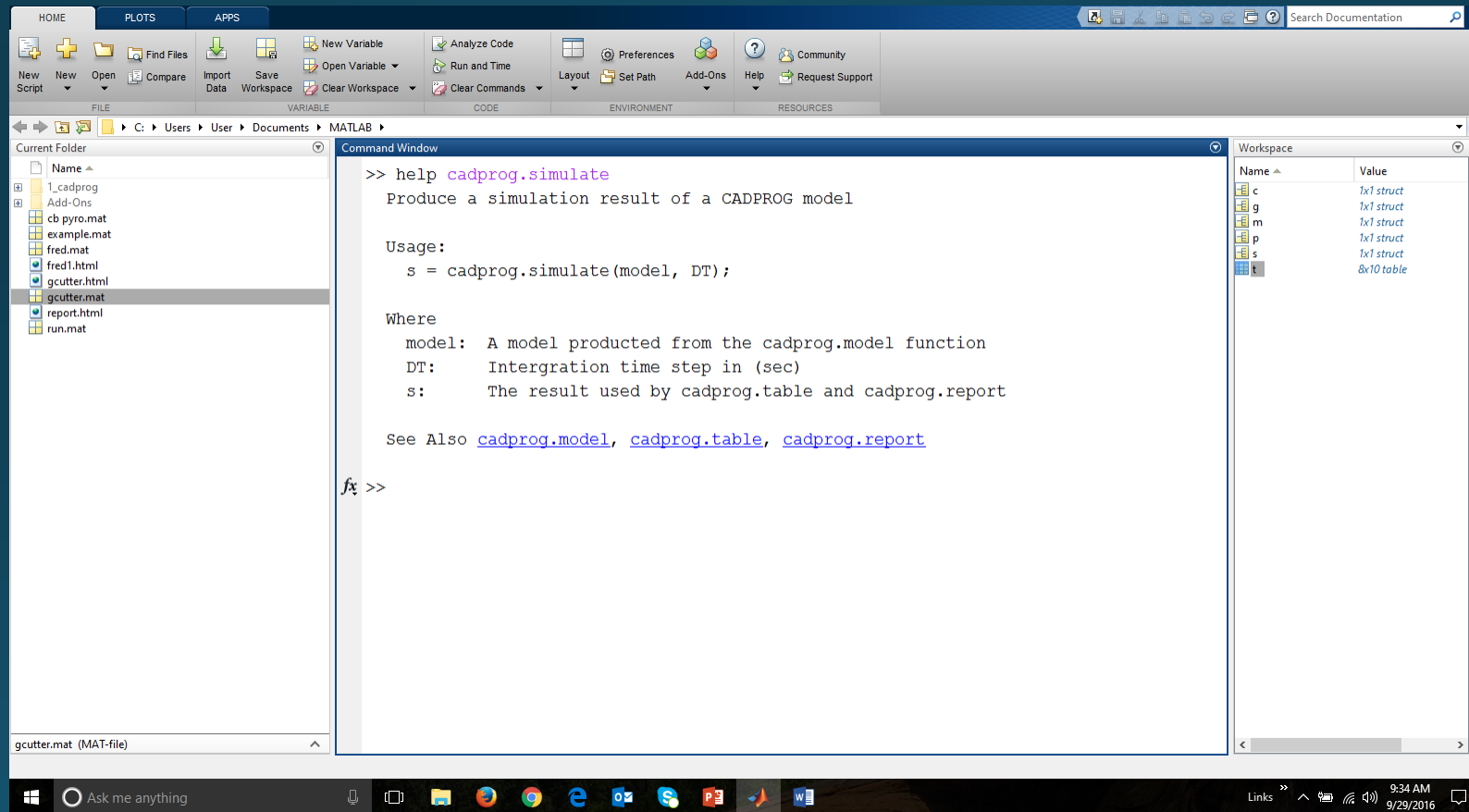
- Lumped Parameter Model for the interior ballistic performance of CAD's & PAD's, and Closed Bomb Test Fixtures
- Source Code is MATLAB, R2016a
- Uses a 4th Order Runge Kutta integration scheme to calculate the dynamic responses from the initial conditions.
- Input, Program Interactive, with "Help Function" or MATLAB file
- Output:
 - MATLAB Table Format, structured
 - HTML Report, structured
 - Plots, Edit Capable

CADPROG V10: Program Help Screen Shot

Generic Guillotine Cutter



CADPROG V10: 'cadprog.simulate' Help Screen Shot



The screenshot shows the MATLAB interface with the Command Window open. The Command Window displays the help text for the `cadprog.simulate` function. The text includes the function's purpose, usage, and parameters.

```
>> help cadprog.simulate
Produce a simulation result of a CADPROG model

Usage:
    s = cadprog.simulate(model, DT);

Where
    model: A model produced from the cadprog.model function
    DT:    Intergration time step in (sec)
    s:     The result used by cadprog.table and cadprog.report

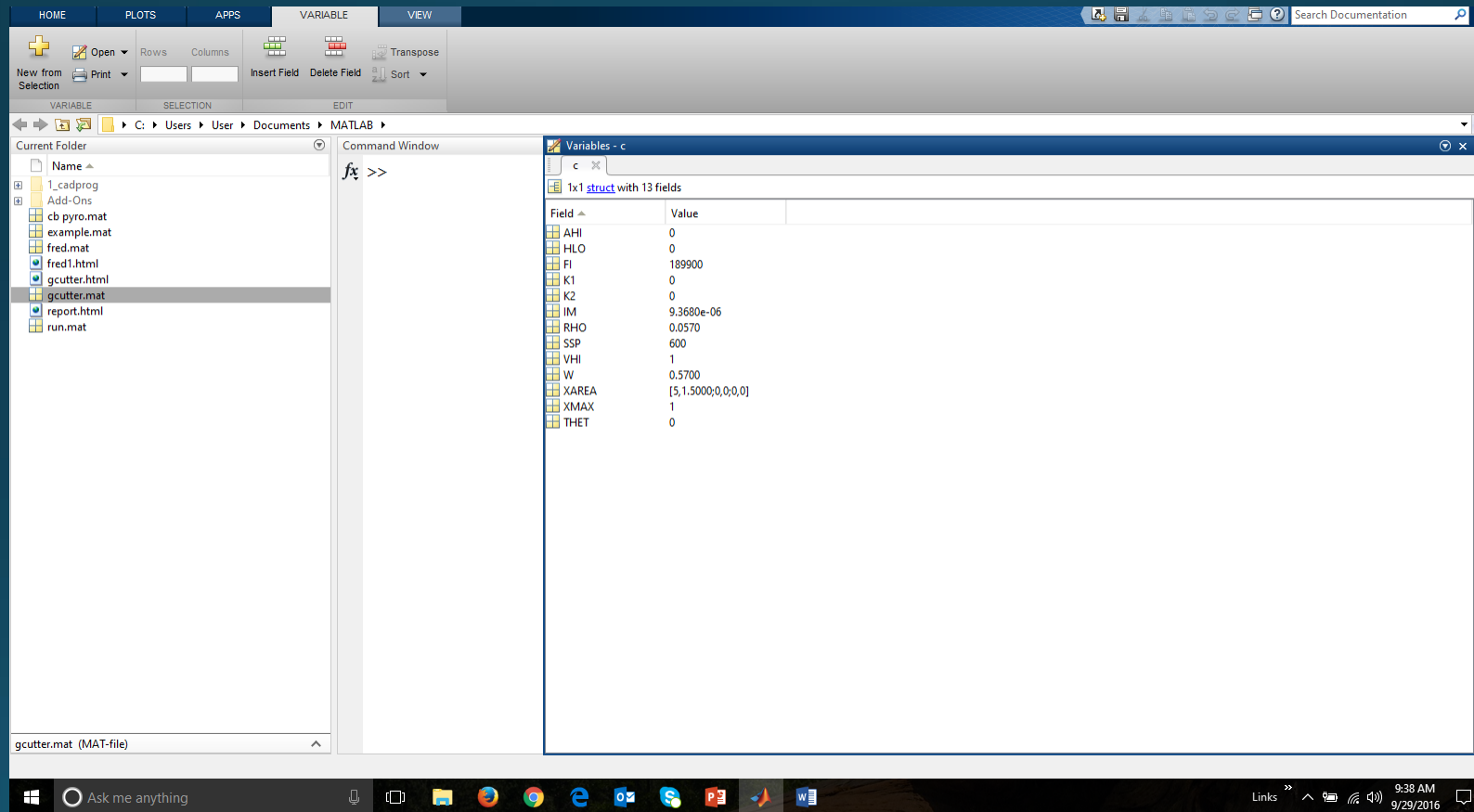
See Also cadprog.model, cadprog.table, cadprog.report

fx >>
```

The Workspace window on the right shows the following variables:

Name	Value
c	1x1 struct
g	1x1 struct
m	1x1 struct
p	1x1 struct
s	1x1 struct
t	8x10 table

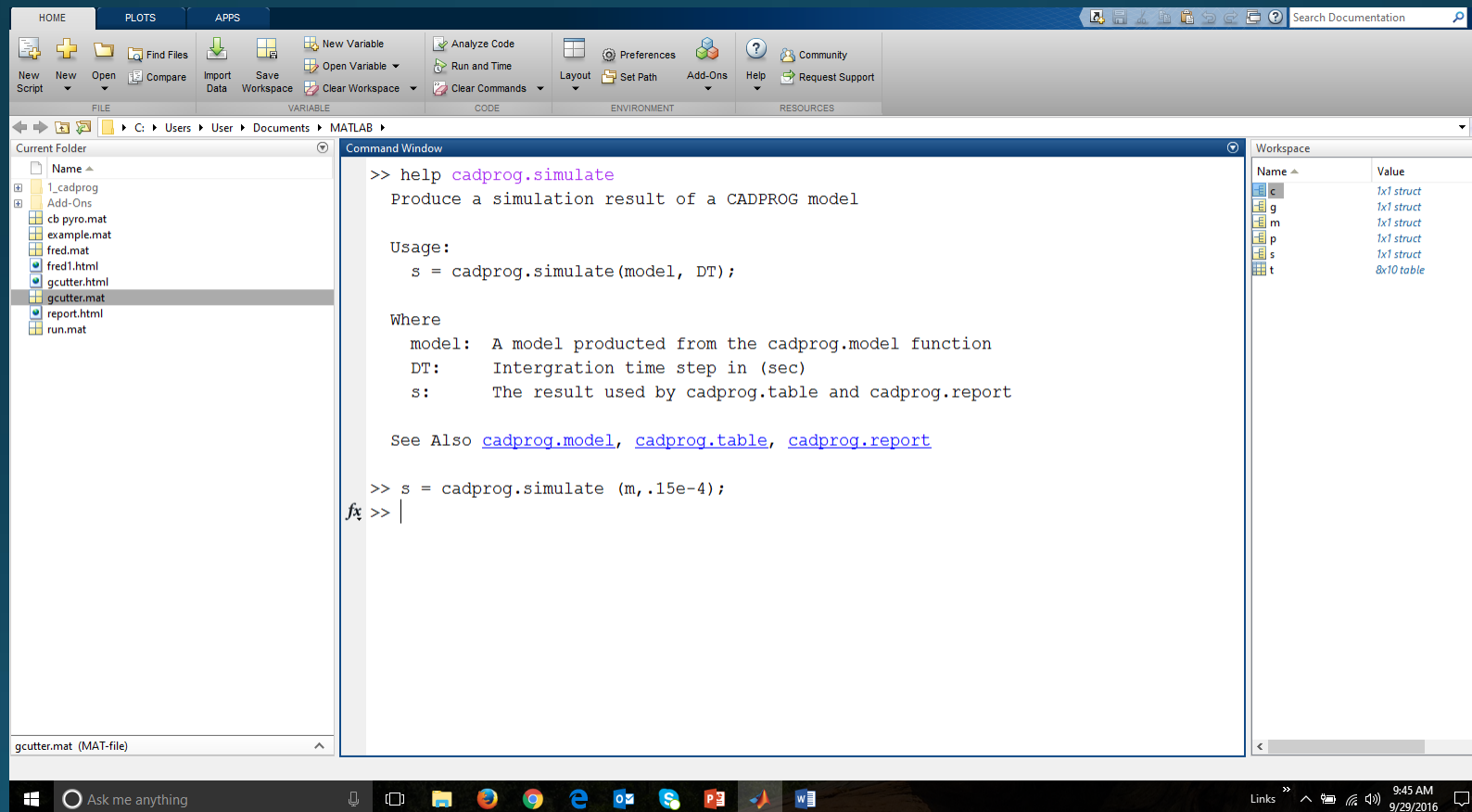
CADPROG V10: 'cadprog.chamber' variable Screen Shot



The screenshot displays the MATLAB Variable Editor window for a variable named 'c'. The variable is a 1x1 struct with 13 fields. The Command Window shows the prompt 'fx >>'.

Field	Value
AHI	0
HLO	0
FI	189900
K1	0
K2	0
IM	9.3680e-06
RHO	0.0570
SSP	600
VHI	1
W	0.5700
XAREA	[5,1.5000;0,0;0,0]
XMAX	1
THET	0

CADPROG V10: 'cadprog.simulate' Screen Shot



The screenshot shows the MATLAB Command Window with the following content:

```
>> help cadprog.simulate
Produce a simulation result of a CADPROG model

Usage:
    s = cadprog.simulate(model, DT);

Where
    model: A model produced from the cadprog.model function
    DT:    Intergration time step in (sec)
    s:     The result used by cadprog.table and cadprog.report

See Also cadprog.model, cadprog.table, cadprog.report

>> s = cadprog.simulate (m,.15e-4);
fx >> |
```

The Workspace window on the right shows the following variables:

Name	Value
c	1x1 struct
g	1x1 struct
m	1x1 struct
p	1x1 struct
s	1x1 struct
t	8x10 table

CADPROG V10, MATLAB

Generic Guillotine Cutter Simulation Output

The screenshot shows the MATLAB interface with the following components:

- Command Window:**

```

>> load('gcutter.mat')
>> t = cadprog.table(s,10)

t =

    
```

Time	Pressure	Temperature	Fraction_Burned	Displacement	Velocity
0	21.692	5000	0	0	0
0.00015	366.66	5000	0.047753	0	0
0.0003	893.24	4996.8	0.12099	0.001823	4.5024
0.00045	1889.4	4966.3	0.26918	0.023417	21.594
0.0006	3286.7	4889.4	0.52335	0.089095	54.377
0.00075	4148.4	4743.9	0.80906	0.22885	102.76
0.0009	3873.6	4529.9	0.99962	0.46112	154.7
0.00105	2819.1	4240.1	1	0.77953	196.85

```

fx >> |
    
```
- Workspace:**

Name	Value
c	1x1 struct
g	1x1 struct
m	1x1 struct
p	1x1 struct
s	1x1 struct
t	8x10 table
- File Explorer:** Shows the current folder containing files like '1_cadprog', 'Add-Ons', 'cb pyro.mat', 'example.mat', 'fred.mat', 'fred1.html', 'gcutter.mat', 'report.html', and 'run.mat'.

CADPROG V10, MATLAB Generic Guillotine Cutter

- HTML Format, structured
- Seamless to Microsoft Products
 - Excel
 - PowerPoint
 - Word

```

CADPROG V10
Location: file:///C:/Users/User/Documents/MATLAB/gcutter.html

CADPROG - Version 10 Engineering Ballistic Simulator

Geometry          Kinematics          Loss Factors
AHI 0.000000e+00  THET 0.000000e+00   K1 0.000000e+00
VHI 1.000000e+00      W  5.700000e-01   K2 0.000000e+00
                        SSP 6.000000e+02
                        XMAX 1.000000e+00

Time Step          Igniter
DT 1.5e-05         IM 9.368000e-06
DTPR 10            FI 1.899000e+05

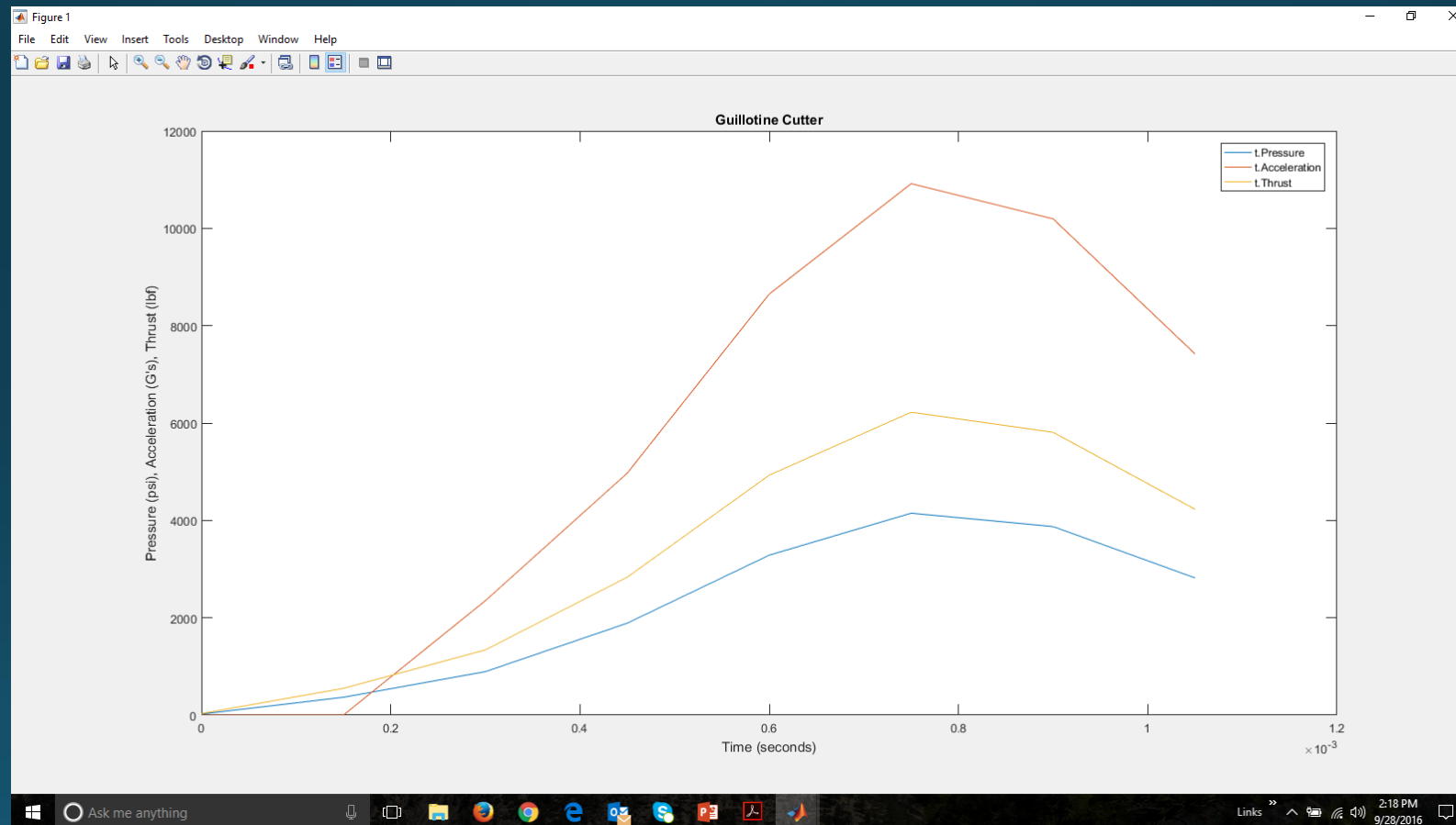
Displacement Area Tables
                        X      Area
5.000000e+00  1.500000e+00
0.000000e+00  0.000000e+00
0.000000e+00  0.000000e+00

Thermo              Burn Rate Table
CV 4.998000e+02     R      P
TV 5.000000e+03     1.500000e-01  2.500000e+01
N  4.730000e-02     2.800000e-01  1.000000e+02
NU 5.000000e+03     3.600000e-01  5.000000e+02
RHO 5.700000e-02    5.600000e-01  7.500000e+02
                        9.000000e-01  1.250000e+03
                        1.500000e+00  2.000000e+03

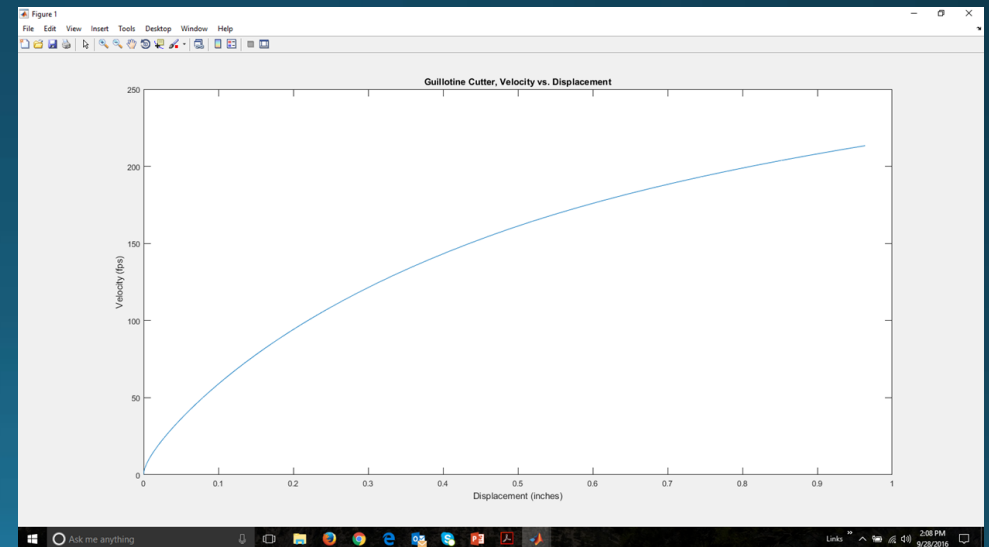
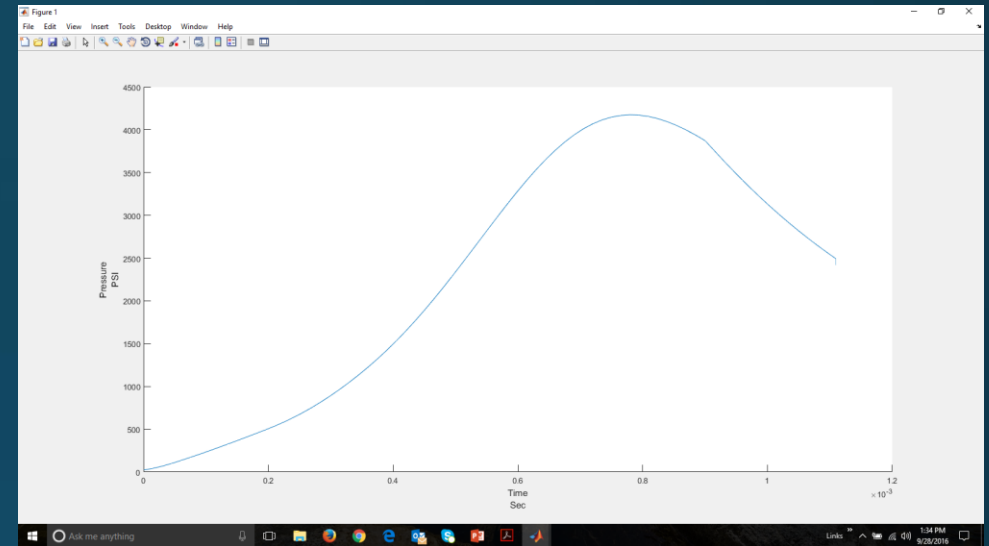
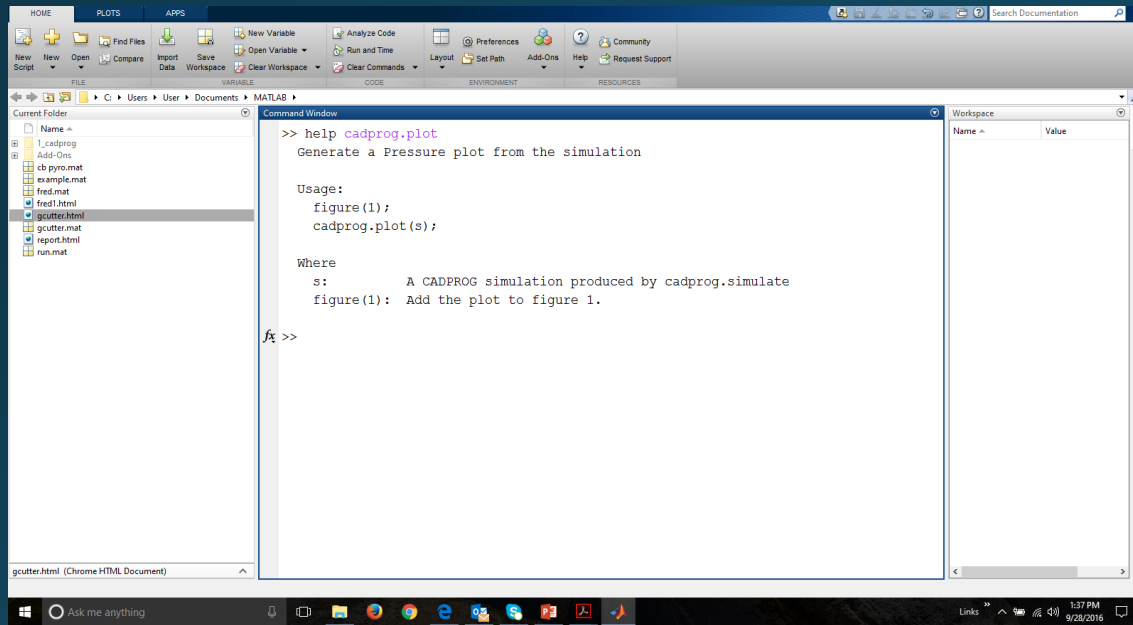
Grain 1             Computed Constants
D 0.01              GC 32.174
H 0.003             G 32.174
PD 0.0075           R 2782
A1 1.133333e+03     F 657943
A2 -3.644444e+05    GAMMA 1.26328
A3 3.555556e+07     W1 0.57
CB 9.000000e-04     PSI 0.66054
WEB 1.500000e-03    CHI 2.70386e-06
                        VCHI 0.984211
                        XMAX 1

Time  Pressure  Temperature  Fraction_Burned  Displacement  Velocity  Acceleration  Thrust  Length_Burn  Surface_Area
Sec   PSIA         K              LBS              IN             IN/SEC      G              LBS      IN           IN^2
0.0000  22           5000           0.0000           0.00           0.00        0.00           33      0.000        0.0003
0.0002  367          5000           0.0478           0.00           0.00        0.00           550     0.000        0.0002
0.0003  893          4997           0.1210           0.00           4.50        2350.62        1340    0.000        0.0002
0.0004  1889         4966           0.2692           0.02           21.59       4972.23        2834    0.000        0.0002
0.0006  3287         4889           0.5234           0.09           54.38       8649.16        4930    0.001        0.0002
0.0008  4148         4744           0.8091           0.23           102.76      10916.95       6223    0.001        0.0001
0.0009  3874         4530           0.9996           0.46           154.70      10193.69       5810    0.001        0.0001
0.0011  2819         4240           1.0000           0.78           196.85      7418.65        4229    0.002        0.0000
    
```

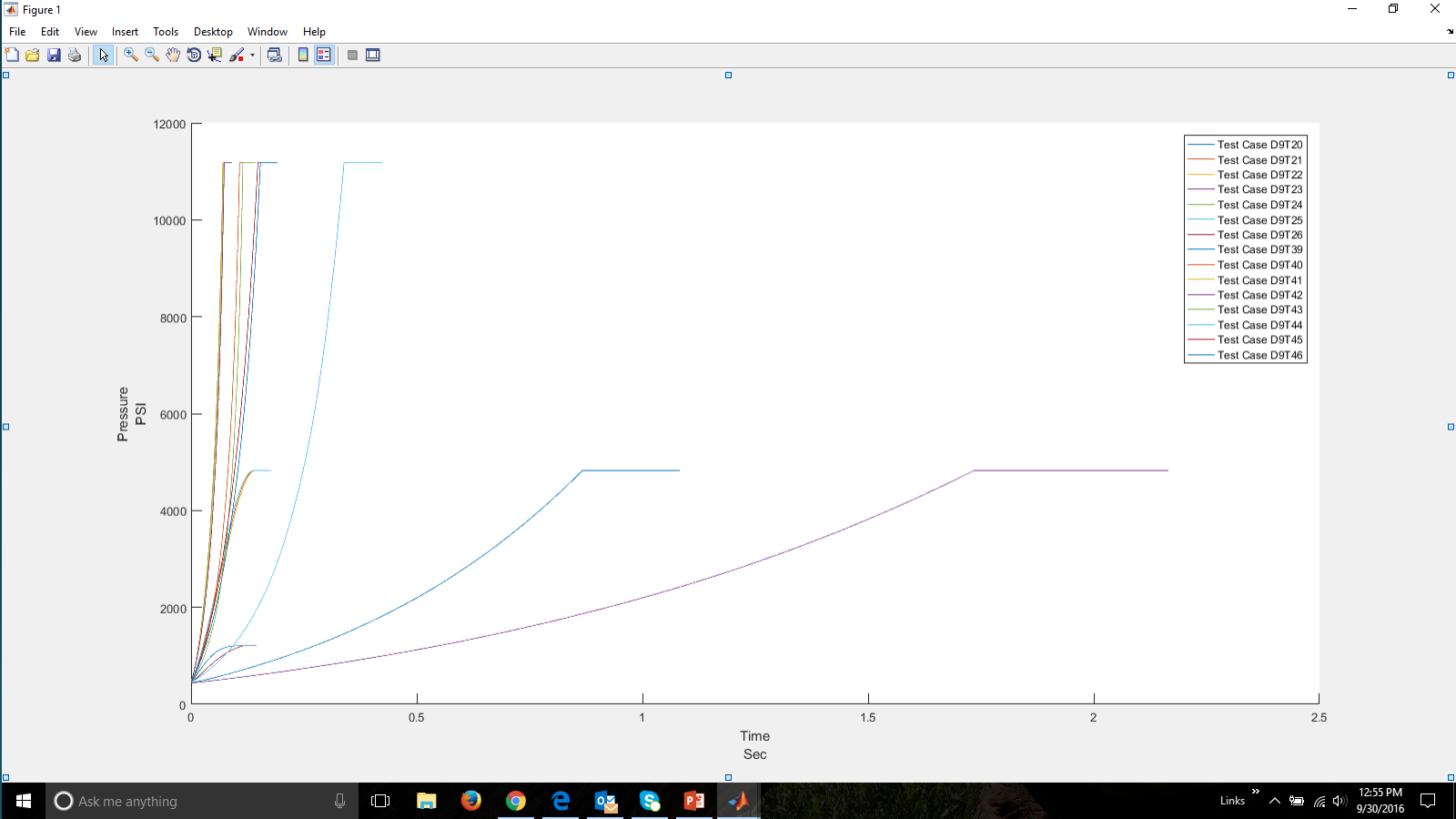
CADPROG V10, MATLAB Generic Guillotine Cutter



CADPROG V10, MATLAB Generic Guillotine Cutter



CADPROG V10, MATLAB Fifteen Test Cases



CADPROG V₉ compared to V₁₀

Attribute	CADPROG Version 9	CADPROG Version 10
User Platform	UNIX (SGI)	PC, Windows
Source Language	Fortran 77	MATLAB R2016a
Input	Direct User Input, CADPROG file or ASCII (matrix)	Direct User Program Input or MATLAB file
Tabular Output	ASCII File, unstructured table	MATLAB & HTML File, structured
Graphic Output	External Display Graphics, no edit capability, with Ten Overlying Files	Embedded Plotting with Editing and Ten Overlying Files
Data Output	Pressure, Velocity, Acceleration, Thrust, Displacement, Time, DRI, Fraction Burned, & Surface Area	Pressure, Velocity, Acceleration, Thrust, Displacement, Time, DRI, Fraction Burned, & Surface Area
Program Help	External User Manual, Imbedded Error Messages	External User Manual, Imbedded Error Messages & Imbedded Help
Chambers (option)	Single or Two Chamber (High/Low)	Single or Two Chamber (High/Low)
Chamber Venting	Both Chamber Option	Both Chamber Option

CADPROG V₉ compared to V₁₀ (continued)

Attribute	CADPROG Version 9	CADPROG Version 10
Propellant Location	Single/High Chamber	Single/High Chamber
Piston	Single (multiple areas for telescoping)	Single (multiple areas for telescoping)
Telescoping	Three	Three
Number of Propellants	Three	Three
Number of Granulations	Three	Three
Time Delay	Three	Three
Release Pressure	Yes	Yes
Mass w/piston	Yes	Yes
Angle of Launch	Yes	Yes

CADPROG V10, Conclusions

- AET progressing on Version 10 of CADPROG using MATLAB
- Version 10 will provide:
 - Same ballistic analysis capabilities as Version 9.
 - Combine ballistic modeler's computational scheme with graphical display of output data on PCs within a single program.
 - Speed up the CAD design process.
 - Allow more design options to be investigated.
 - Simplify troubleshooting and failure analysis of existing designs.
 - More user friendly than Fortran command line program running under UNIX.
- Contract work in progress, estimate completion: March 2017.
- A version of CADPROG that runs on a PC will be made available to CAD/PAD contractors who make a request in writing to cadpad@navy.mil