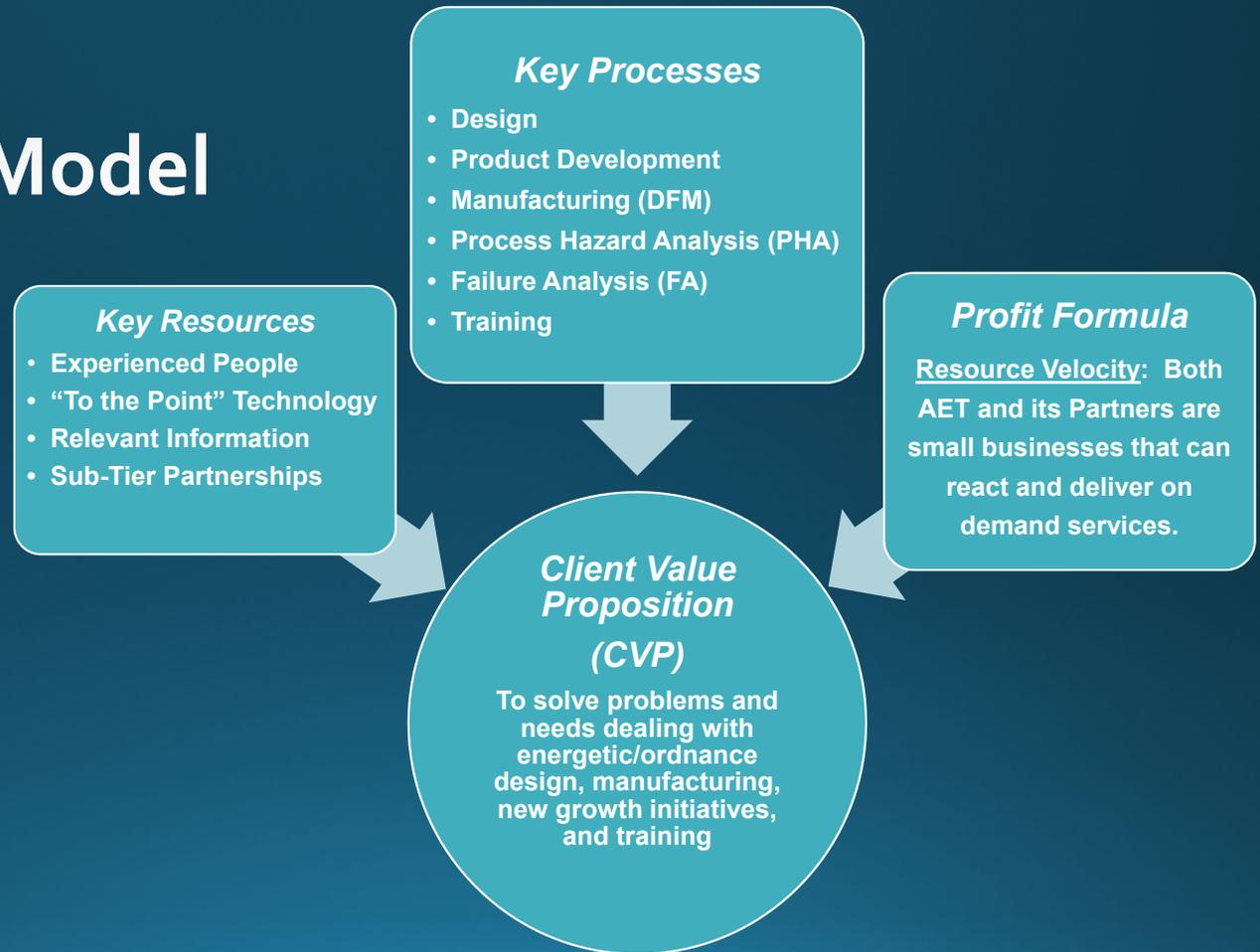


AET//Argent Energetics Technology, LLC

**Graphical User Interface (GUI)
Update to the
CADPROG Ballistic Computer Simulation Program**

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AET// Business Model



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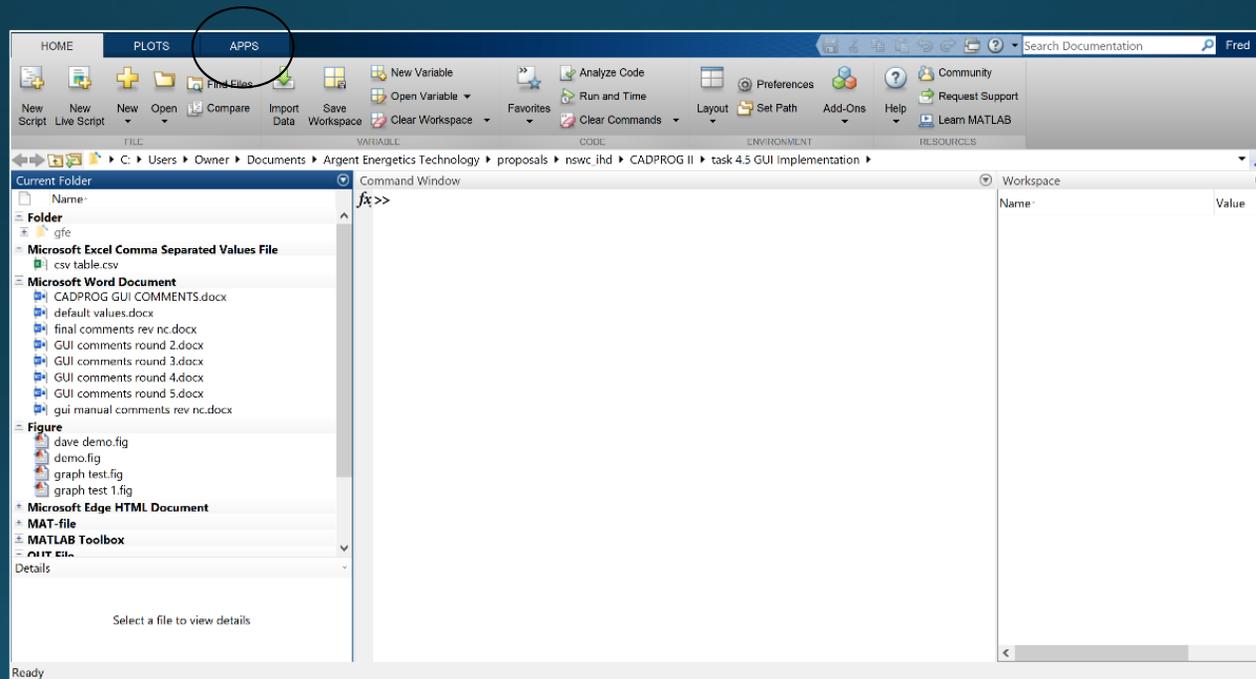
CADPROG VERSION HISTORY

- CADPROG v1-6, and v8-v9: UNIX (SGI) FORTRAN 77 Platform
- CADPROG v7: PC FORTRAN 77 Platform
- CADPROG v10: Windows, MATLAB® R2017A Platform
 - AET contract: No0174-16-P-0052
 - MATLAB® command and workspace structure, knowledge of MATLAB®
 - Presented at 2018 CAD/PAD Workshop
- CADPROG v11: Windows, MATLAB® R2018A Platform (application program interface, api)
 - AET contract: No0174-19-P-0123
 - MATLAB® GUI, little to almost no knowledge of MATLAB® required

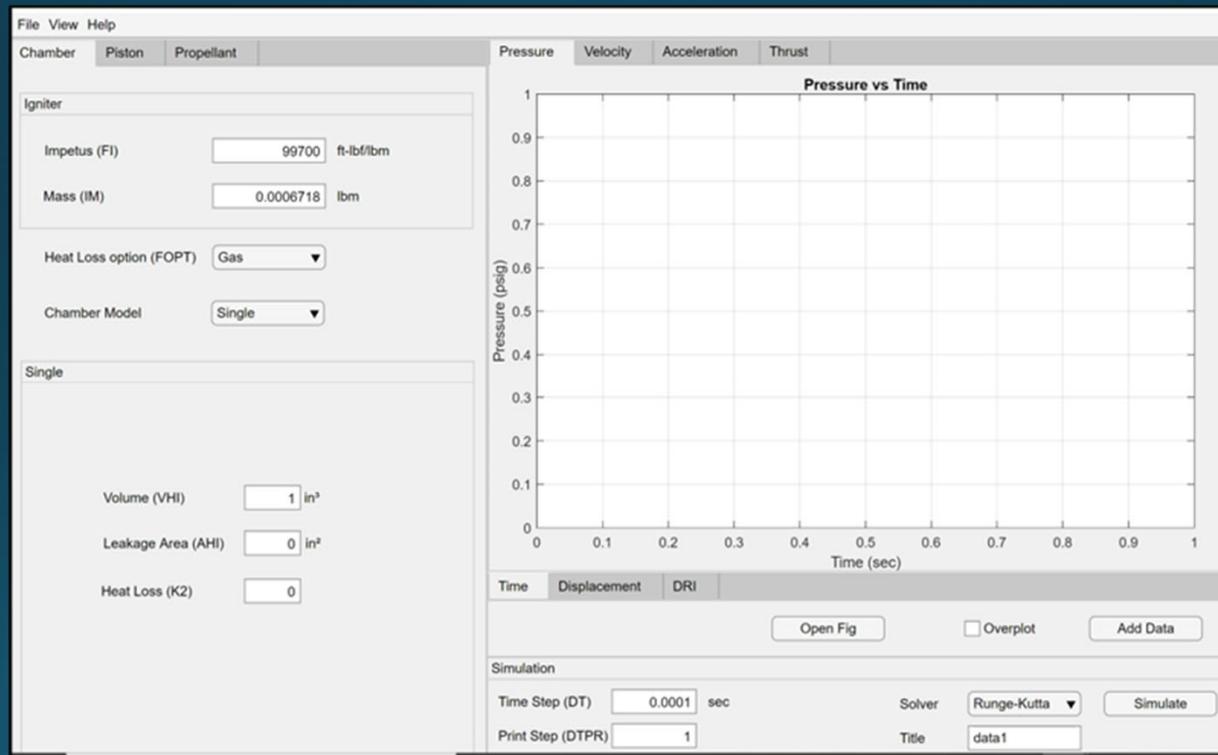
CADPROG v11, Improvements

1. Improved “User” interface, which minimizes the knowledge required of the MATLAB® command language.
2. Option for the MATLAB® embedded Ordinary Differential Equations (ODE).
 - a. The use of the MATLAB® embedded ODE will allow for the implementation of automated parametric studies for selected parameters (such as propellant charge weight(s) and dimensions and piston mass), and the detection of zero crossover for event determined termination criteria.
 - b. An expanded burn rate table, allowing the user to enter more than the current six burn rate vs. pressure data points for defining a propellant’s burn rate vs. pressure curve.

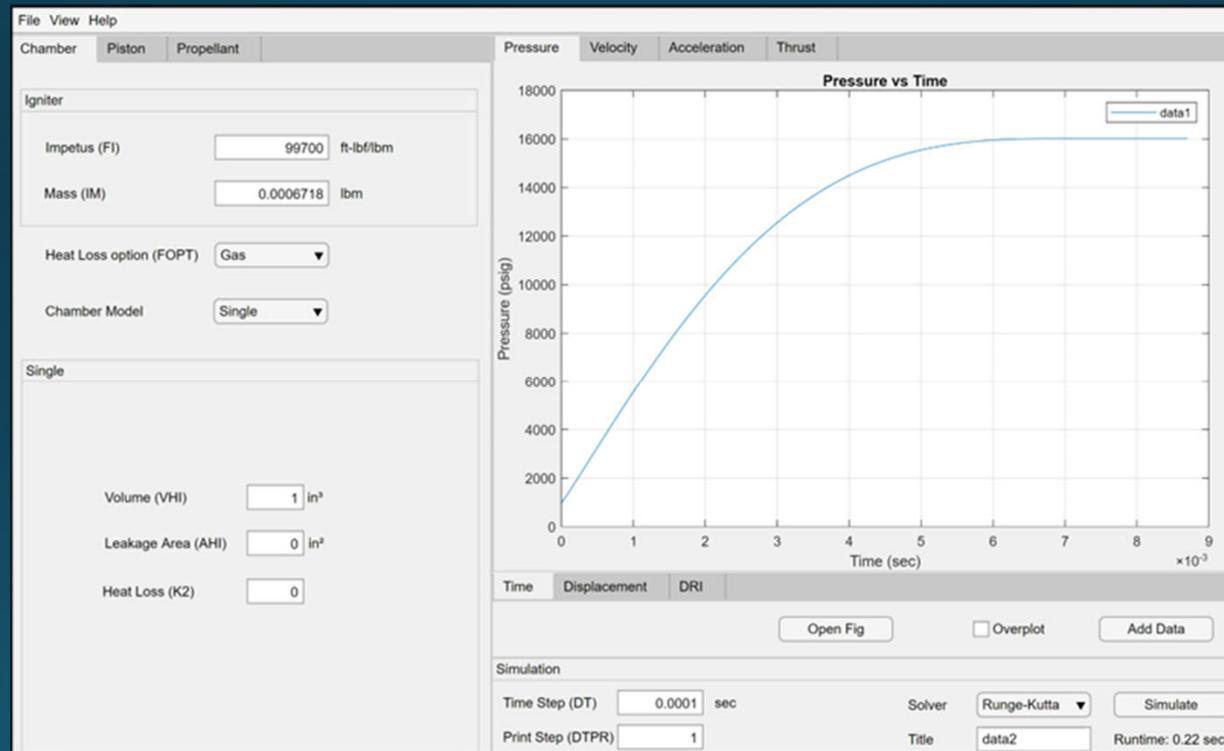
APP's Window for CADPROG v11



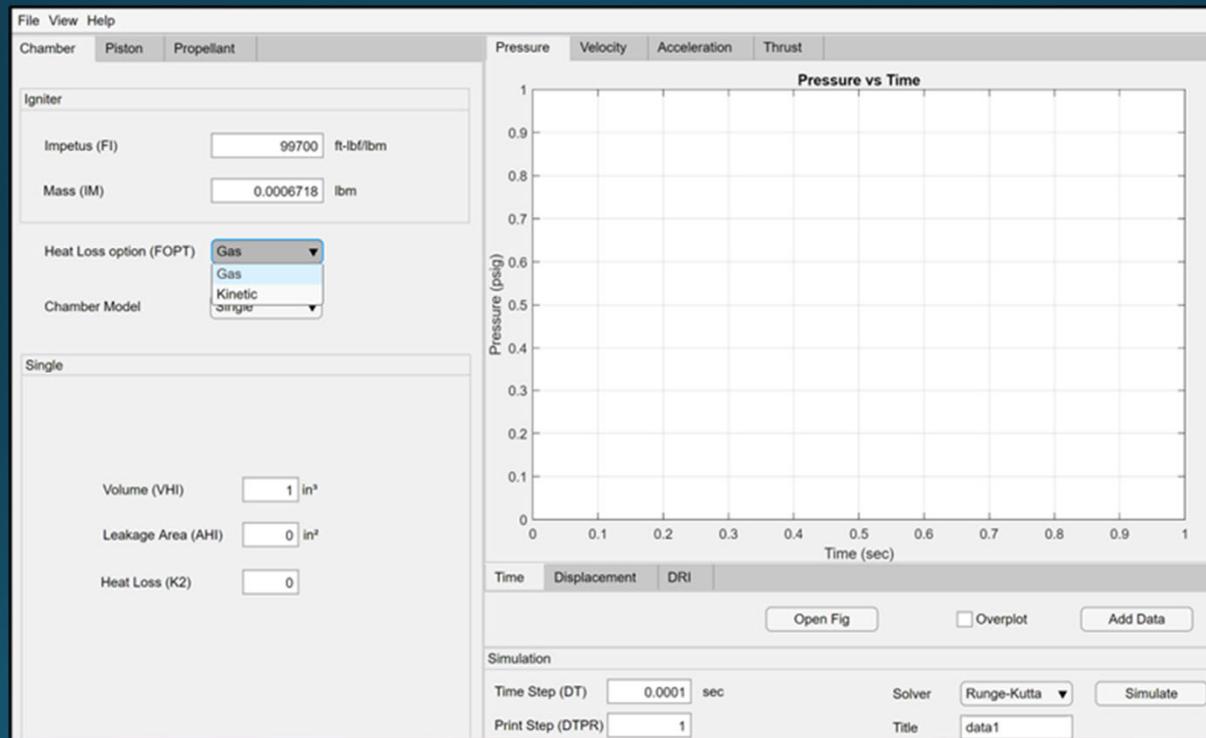
CADPROG GUI Opening Screen Shot



CADPROG GUI Default Simulation



CADPROG GUI Heat Loss Option



CADPROG GUI Dual Chamber Inputs

The screenshot displays the CADPROG GUI interface for dual chamber inputs. The interface is organized into several sections:

- Igniter Section:** Contains input fields for Impetus (FI) set to 99700 ft-lbf/lbm, Mass (IM) set to 0.0006718 lbm, Heat Loss option (FOPT) set to Gas, and Chamber Model set to High / Low.
- High / Low Section:** Features a Throat Area (AT) input field set to 0.01 in².
- Low Chamber Section:** Includes input fields for Volume (VLO) set to 0 in³, Leakage Area (ALO) set to 0 in², and Heat Loss (K3) set to 0.
- High Chamber Section:** Includes input fields for Volume (VHI) set to 1 in³, Leakage Area (AHI) set to 0 in², and Heat Loss (K2) set to 0.
- Simulation Section:** Contains input fields for Initial Temp (TLO) set to 294 K, Amb. Press. (PA) set to 14.7 psia, Time Step (DT) set to 0.0001 sec, Print Step (DTPR) set to 1, Solver set to Runge-Kutta, and Title set to data1. A Simulate button is also present.

On the right side of the GUI, there is a graph titled "Pressure vs Time". The y-axis is labeled "Pressure (psig)" and ranges from 0 to 1.0. The x-axis is labeled "Time (sec)" and ranges from 0 to 1.0. The graph area is currently empty, with a grid overlay. Below the graph, there are tabs for "Time", "Displacement", and "DRI", and buttons for "Open Fig", "Overplot", and "Add Data".

CADPROG GUI Piston Tab

The screenshot shows the CADPROG GUI Piston Tab. The interface includes a menu bar (File, View, Help) and a tabbed view with 'Chamber', 'Piston', and 'Propellant' tabs. The 'Piston' tab is active, displaying various simulation parameters:

- Friction Factor (K1): 0
- Accel Mass (W): 1 lbm
- Launch Angle (THET): 0 deg [-90,90]
- Gravity Field (GFLD): 0 G
- Release Pressure (RP): 1e+06 psia

Below these parameters is a 'Displacement Area Table (XAREA)' section with a 'Pistons' dropdown set to 1. A table is shown with the following data:

Piston X(i)	Disp (in)	Area (in ²)
1	11	1

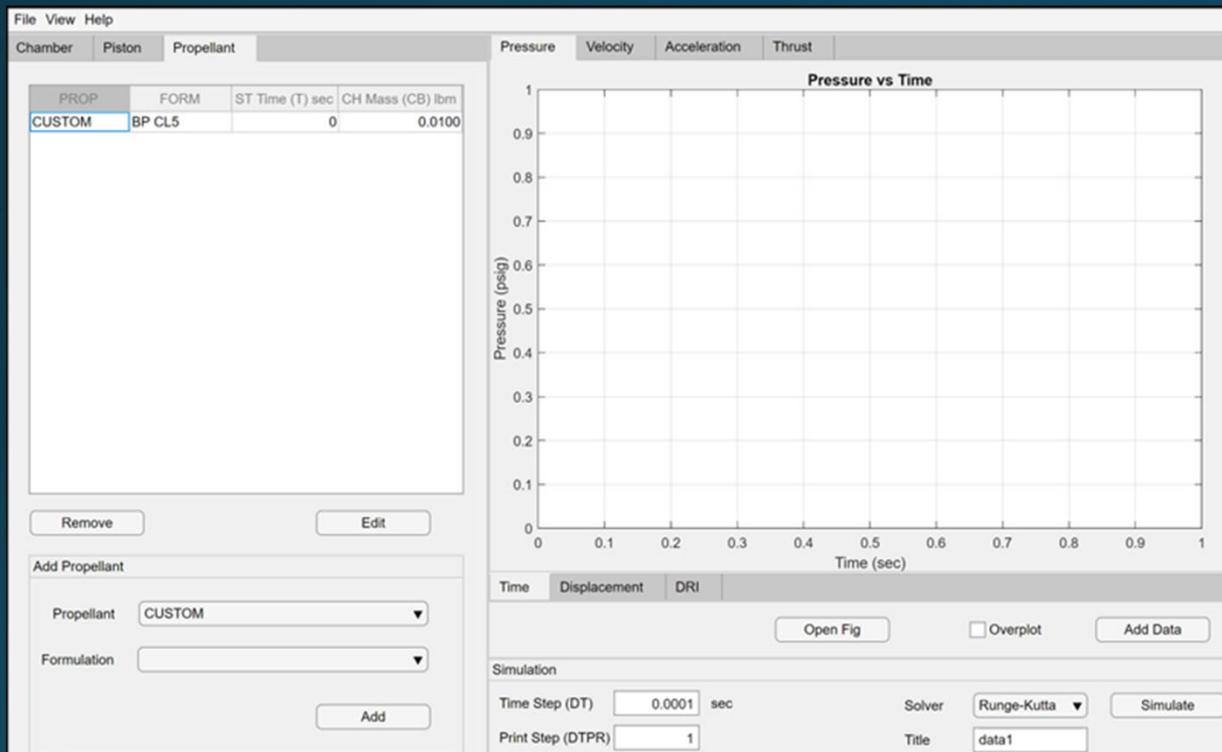
At the bottom left, 'Max Displacement (XMAX)' is set to 10 in.

The right side of the GUI features a 'Pressure vs Time' graph with 'Pressure (psig)' on the y-axis (0 to 1) and 'Time (sec)' on the x-axis (0 to 1). Below the graph are tabs for 'Time', 'Displacement', and 'DRi'. The 'Time' tab is active, showing simulation controls:

- Buttons: Open Fig, Overplot (checkbox), Add Data
- Simulation section:
 - Time Step (DT): 0.0001 sec
 - Solver: Runge-Kutta
 - Print Step (DTPR): 1
 - Title: data1
 - Simulate button

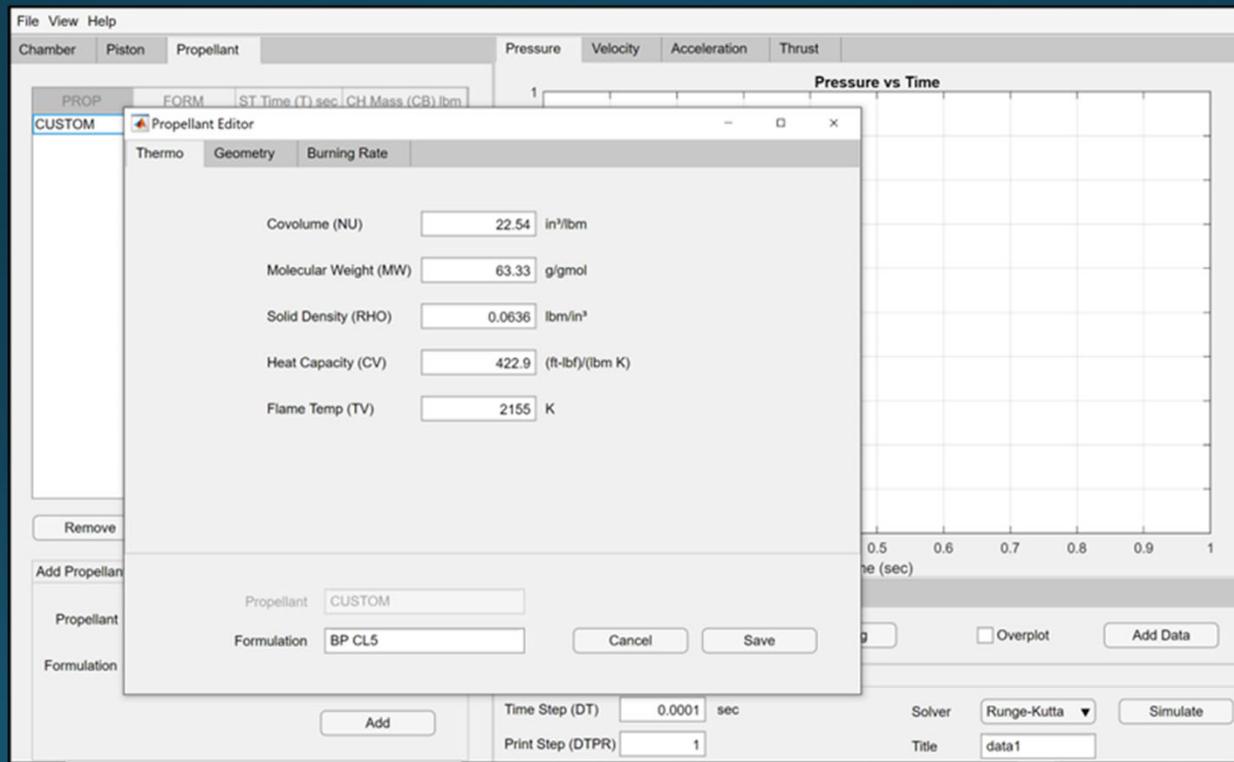
Note that XMAX must be less than the final piston displacement. Error message will be created if XMAX is greater than the displacement.

GUI Propellant Tab

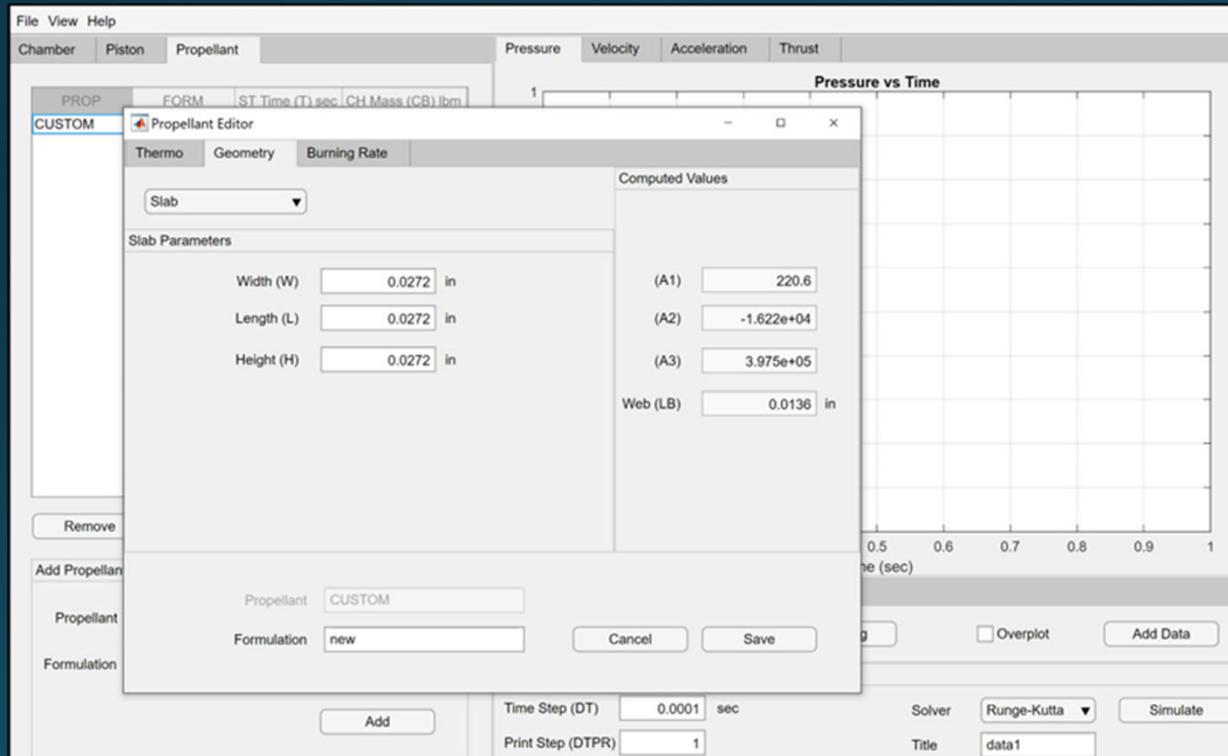


Once these buttons are activated, then the selected row can be edited or removed from the table. If the charge mass is greater than the allowed volume or if there is zero mass, an error message will be created to warn the 'user'.

GUI Propellant Editor Thermo Tab



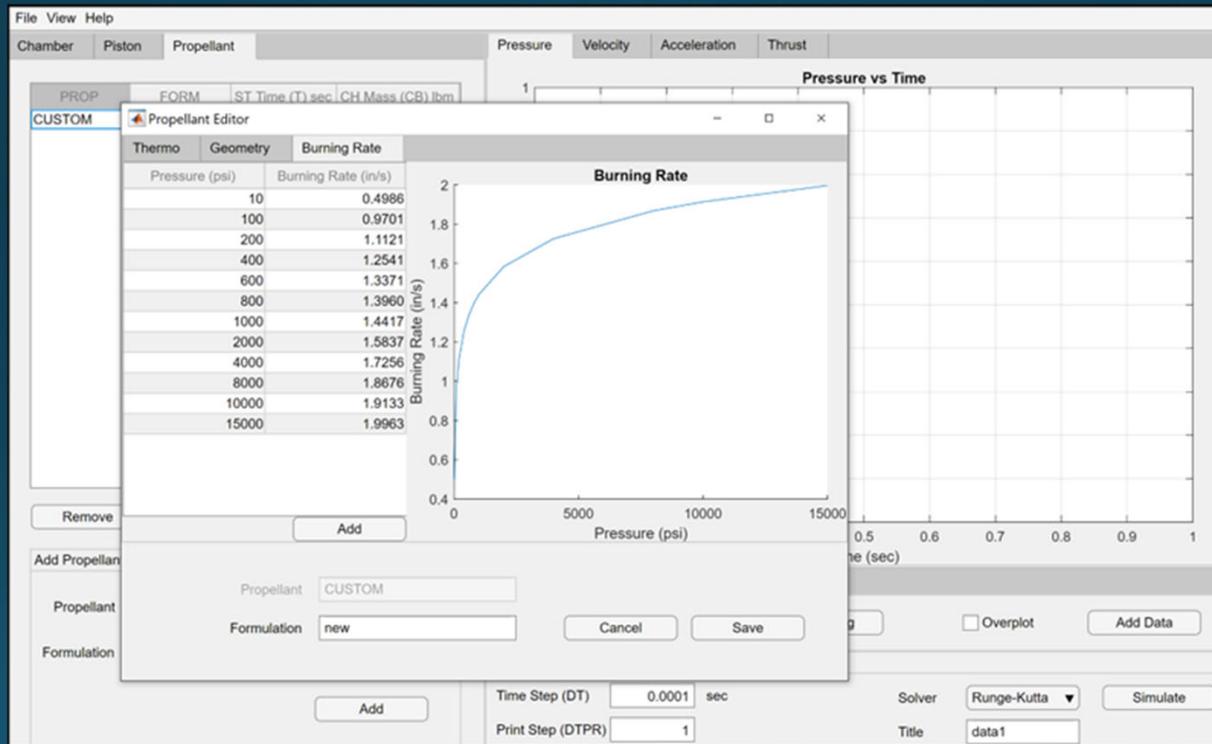
GUI Propellant Editor Geometry Tab (Model Default – Slab Pane)



Geometry pane options: slab, cylinder, sphere, and coefficient.

Note that for geometry selection of Coefficient, the 'user' may directly input the web or allow CADPROG to calculate the web by leaving the input window equal to zero (0).

GUI Propellant Editor Burning Rate Pane



GUI Formulation Drop Down Menu

The screenshot shows a software interface for propellant formulation and simulation. The main window is titled "File View Help" and has tabs for "Chamber", "Piston", and "Propellant". The "Propellant" tab is active, displaying a table with columns: PROP, FORM, ST Time (T) sec, and CH Mass (CB) lbm. The table contains one row: CUSTOM, BP CL5, 0, 0.0100.

Below the table is a "Remove" button and an "Add Propellant" section. The "Add Propellant" section has a "Propellant" dropdown menu and a "Formulation" dropdown menu. The "Formulation" dropdown menu is open, showing a list of options: British G12, British G20, British G40, COM_FFFFG, COM_FFFG, MIL Class 1, MIL Class 2, MIL Class 3, MIL Class 4, MIL Class 5, MIL Class 6, MIL Class 7, and MIL Class 8. The "British G12" option is selected.

Below the "Formulation" dropdown menu is an "Add" button.

On the right side of the interface, there are tabs for "Pressure", "Velocity", "Acceleration", and "Thrust". The "Pressure" tab is active, displaying a graph titled "Pressure vs Time". The graph has a y-axis labeled "Pressure (psig)" ranging from 0 to 1.0 and an x-axis labeled "Time (sec)" ranging from 0 to 1.0. The graph area is currently empty.

Below the graph are tabs for "Time", "Displacement", and "DRI". The "Time" tab is active. There are buttons for "Open Fig", "Overplot", and "Add Data".

At the bottom, there is a "Simulation" section with the following controls:

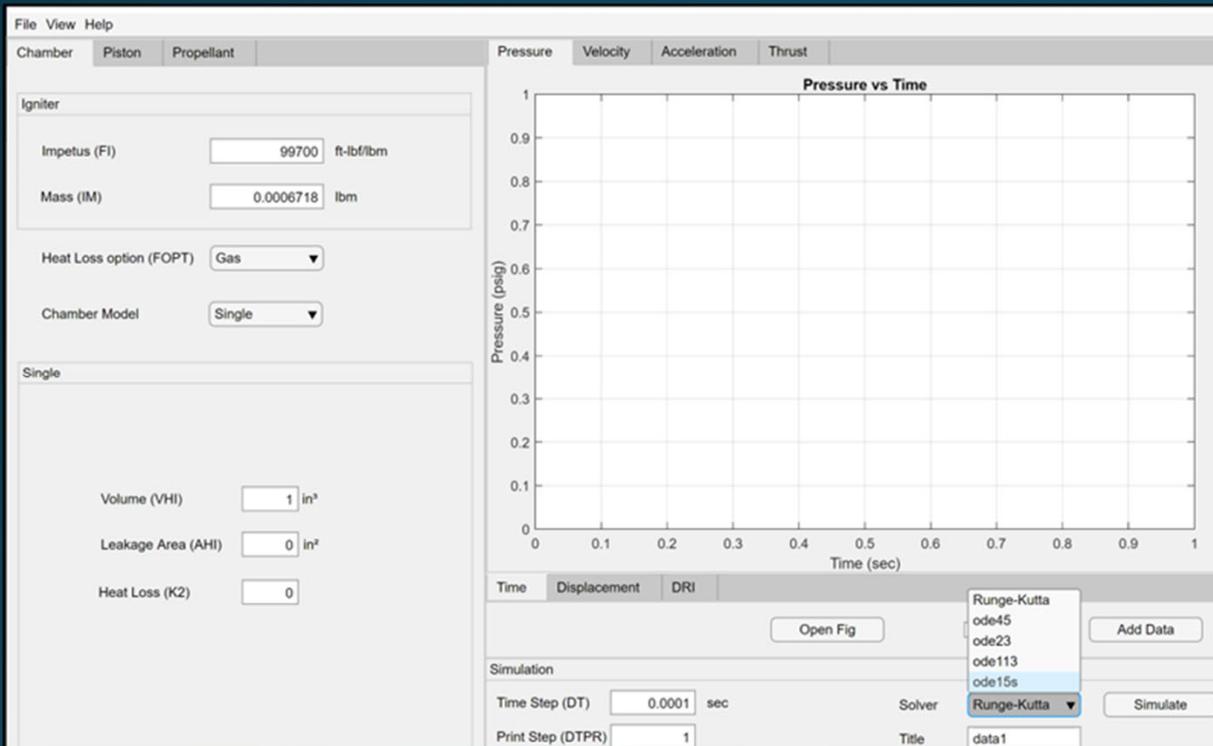
- Time Step (DT): 0.0001 sec
- Solver: Runge-Kutta
- Print Step (DTPR): 1
- Title: data1
- Buttons: Simulate

Opened Propellant.xlsx in Excel "Administer Access Only"

The screenshot shows the Microsoft Excel interface with the following data in the spreadsheet:

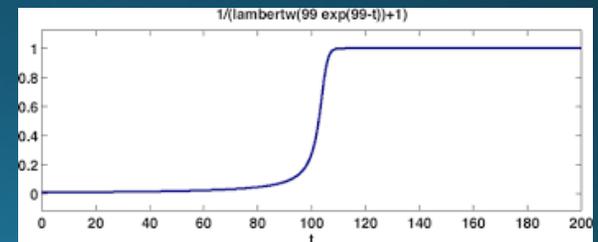
Propellant	Formulation	NU	MW	RHO	CV	TV	XBURNRATE	D	PD	L	NPF	ENDS
Black Powder	British G12	22.5	63.33	0.0636	422.93	2155	burnrate_bp					
Black Powder	British G20	22.5	63.33	0.0636	422.93	2155	burnrate_bp					
Black Powder	British G40	22.5	63.33	0.0636	422.93	2155	burnrate_bp					
Black Powder	COM_FFG	22.5	62.40	0.0772	375.00	2038	burnrate_bp					
Black Powder	COM_FFFG	22.5	62.40	0.0772	375.00	2038	burnrate_bp					
Black Powder	COM_FFFFG	22.5	62.40	0.0772	375.00	2038	burnrate_bp					
Black Powder	MIL Class 1	22.5	63.33	0.0636	422.93	2155	burnrate_bp					
Black Powder	MIL Class 2	22.5	63.33	0.0636	422.93	2155	burnrate_bp					
Black Powder	MIL Class 3	22.5	63.33	0.0636	422.93	2155	burnrate_bp					
Black Powder	MIL Class 4	22.5	63.33	0.0636	422.93	2155	burnrate_bp					
Black Powder	MIL Class 5	22.5	63.33	0.0636	422.93	2155	burnrate_bp					
Black Powder	MIL Class 6	22.5	63.33	0.0636	422.93	2155	burnrate_bp					
Black Powder	MIL Class 7	22.5	63.33	0.0636	422.93	2155	burnrate_bp					
Black Powder	MIL Class 8	22.5	63.33	0.0636	422.93	2155	burnrate_bp					
DS	F1 COPE0S0	28.1	21.14	0.0570	499.80	2432	burnrate_F1	0.325	0.000	0.670	0	0
DS	F1 COPE1S0	28.1	21.14	0.0570	499.80	2432	burnrate_F1	0.325	0.000	0.670	0	1

GUI Solver Drop Down Menu

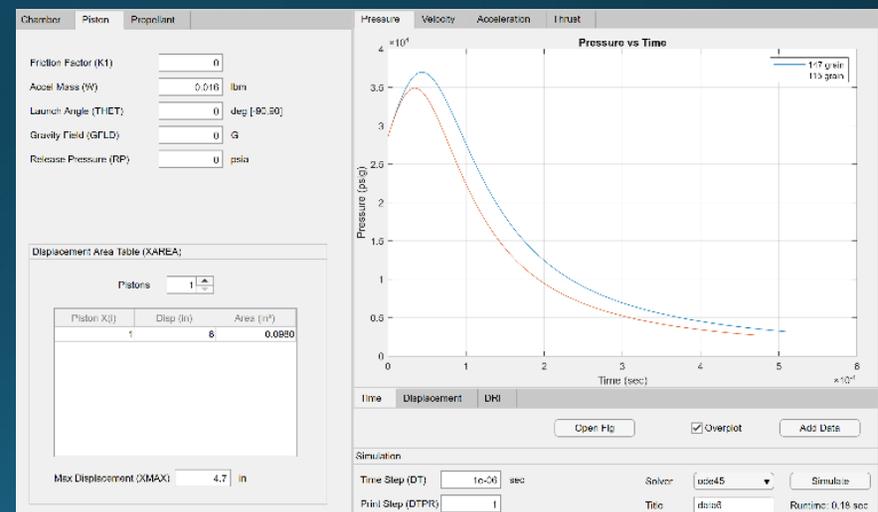
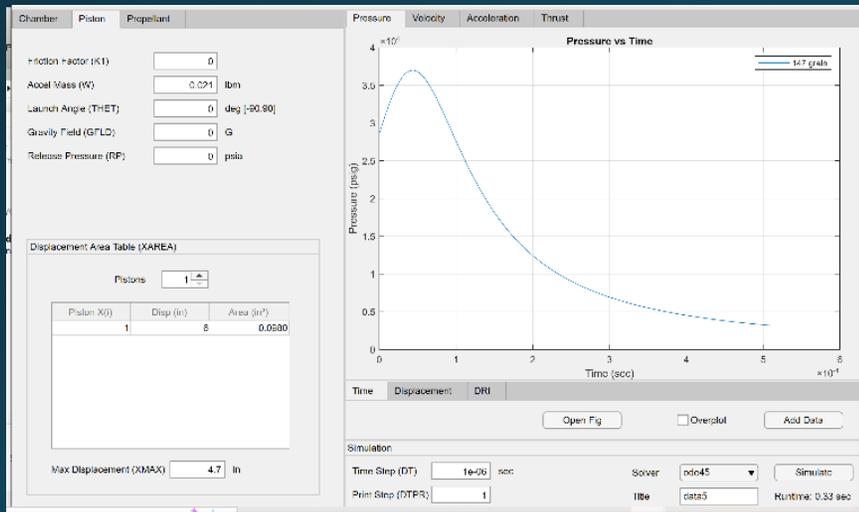


MATLAB® Solver	Problem Type	Accuracy
ode23	Non-Stiff	Low to Moderate
ode45	Non-Stiff	Medium
ode113	Stiff	Low to High
ode15s	Stiff	Low to Medium

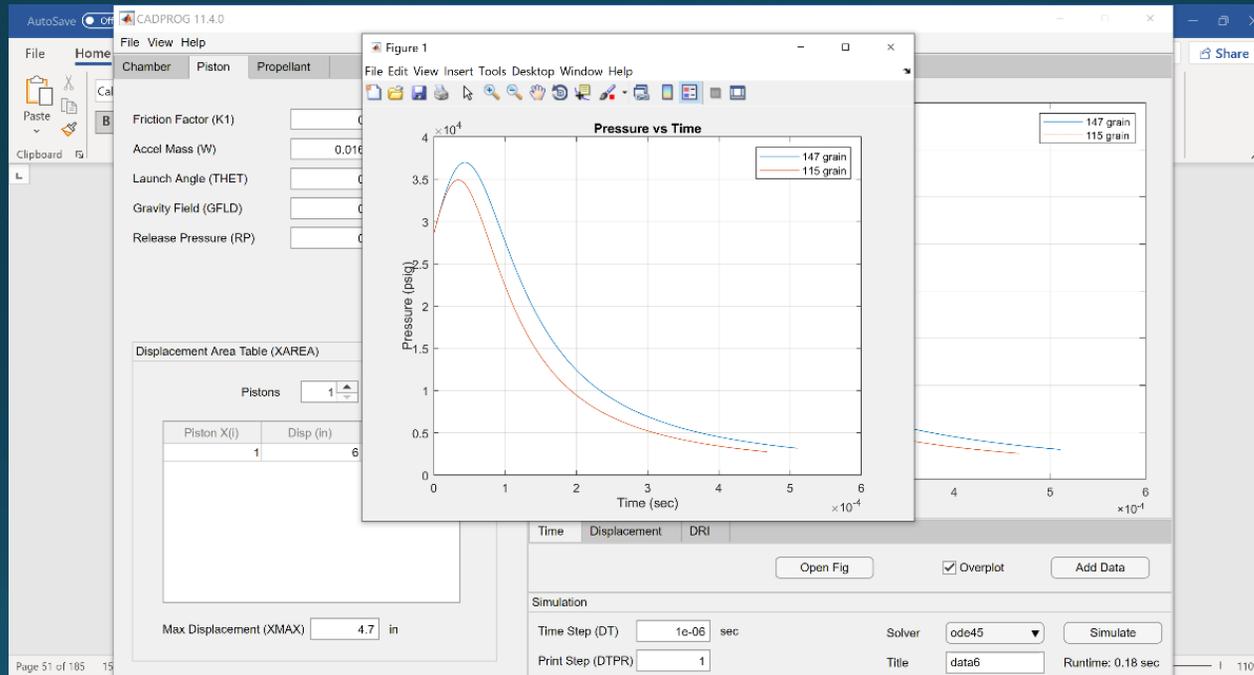
An ordinary differential equation problem is stiff if the solution being sought is varying slowly, but there are nearby solutions that vary rapidly.



Interior Ballistic Simulation



Edit Graph "Open Figure"



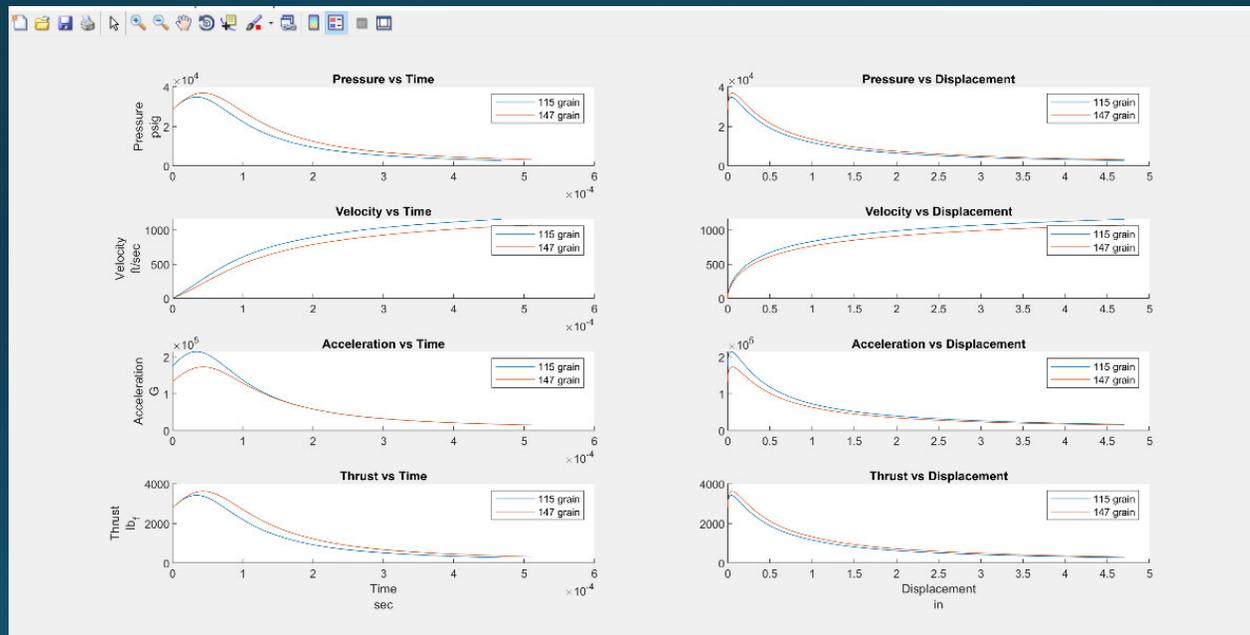
GUI View Drop Down Menu

The screenshot displays the CADPROG 11.4.0 software interface. The 'View' menu is open, showing options: HTML Report, Excel Table, and All Figures (highlighted). The main window is divided into several sections:

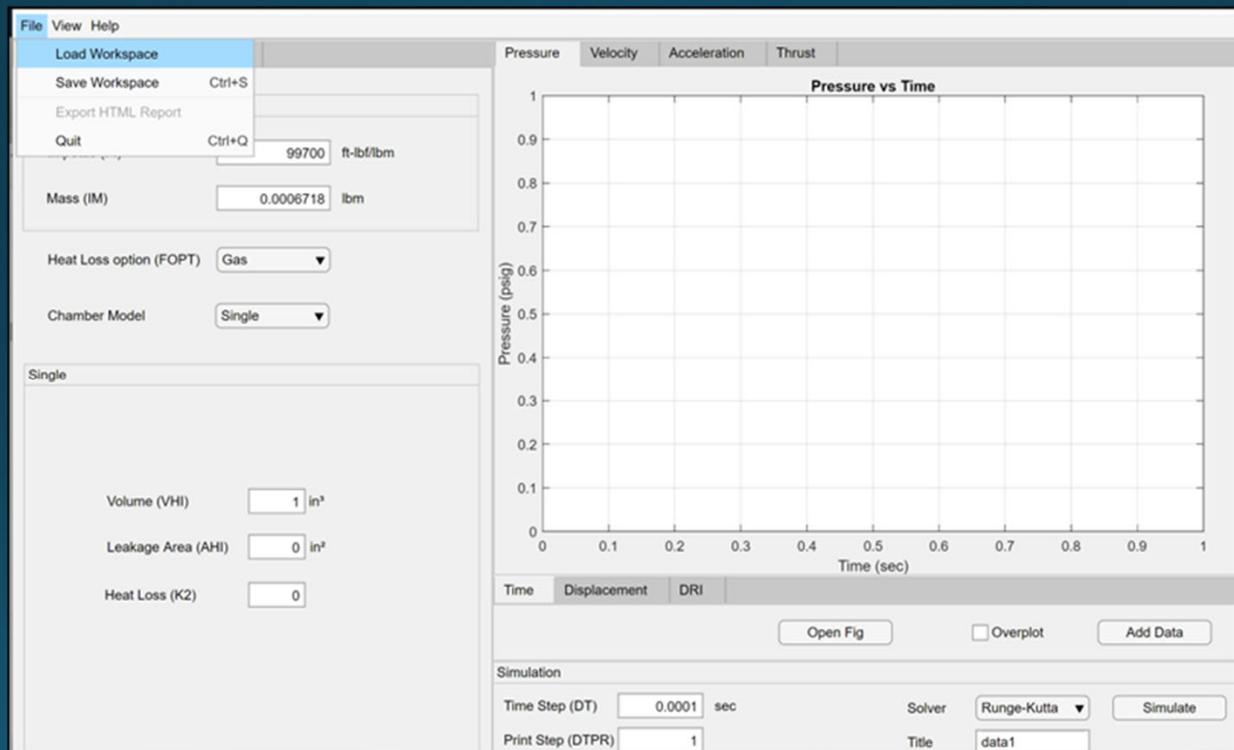
- Parameters:** Includes input fields for Friction (0), Accel Mass (0.016 lbm), Launch Angle (0 deg [-90,90]), Gravity Field (0 G), and Release Pressure (0 psia).
- Displacement Area Table (XAREA):** A table with columns for Piston X(i), Disp (in), and Area (in²). The table contains one row:

Piston X(i)	Disp (in)	Area (in²)
1	6	0.0980
- Max Displacement (XMAX):** Set to 4.7 in.
- Pressure vs Time Graph:** A line graph showing Pressure (psig) on the y-axis (scaled by 10⁴) versus Time (sec) on the x-axis (scaled by 10⁻⁴). Two curves are plotted: 147 grain (blue) and 115 grain (orange). Both curves show a peak pressure around 0.5 x 10⁻⁴ seconds, with the 147 grain curve reaching a higher peak (~3.7 x 10⁴ psig) than the 115 grain curve (~3.5 x 10⁴ psig). Both curves then decay over time.
- Simulation Controls:** Includes buttons for 'Open Fig', 'Overplot' (checked), and 'Add Data'. Simulation parameters include Time Step (DT) of 1e-06 sec, Solver set to 'ode45', and Title 'data6'. The runtime is 0.18 sec.

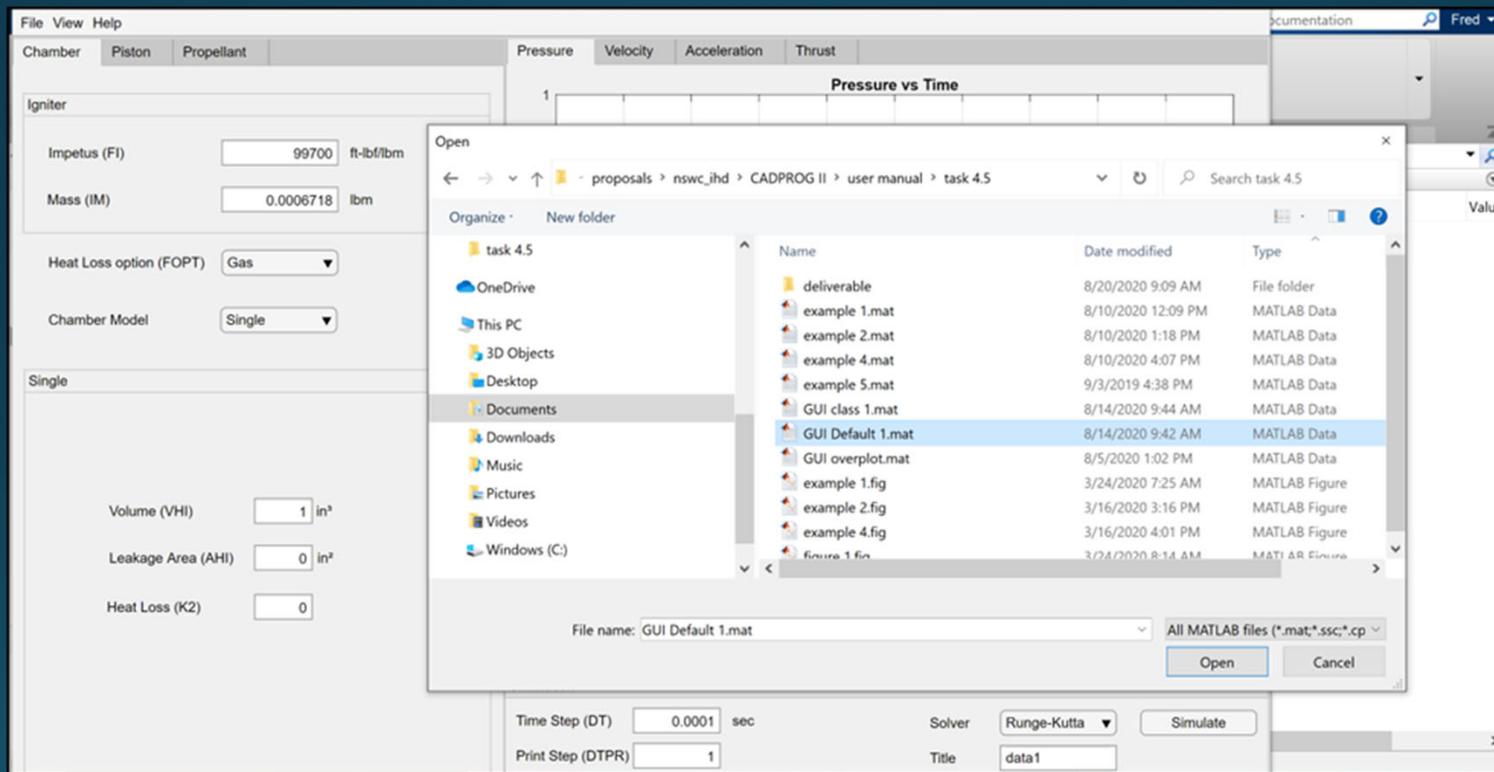
All Figures



File Tab: Load and Save Workspace

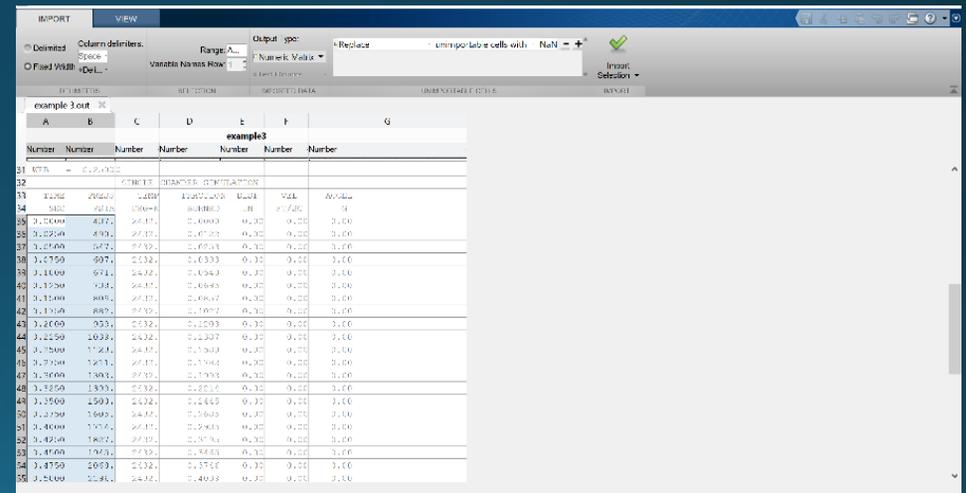
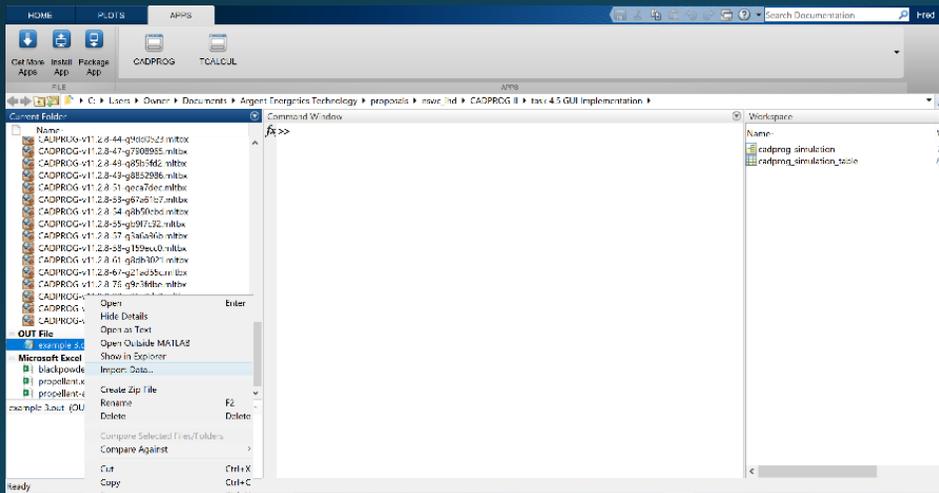


Load Simulation through Explorer



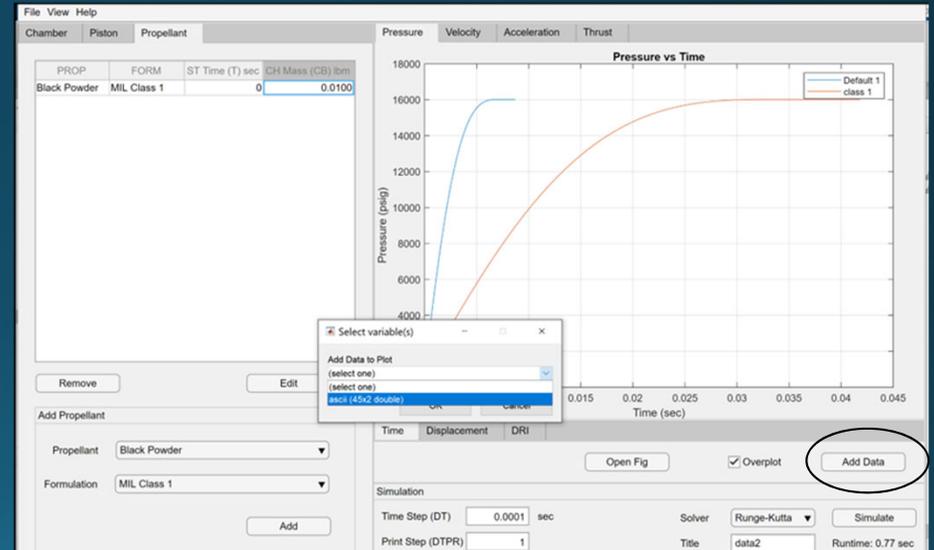
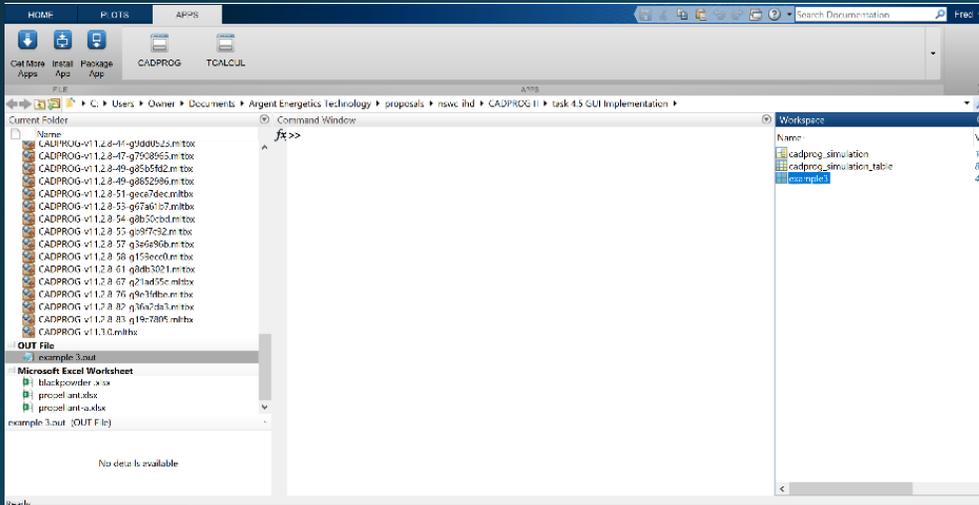
Import Data

You are correct these operations are MATLAB® command intensive!
Even worse these operations are outside the GUI.



Import Data, continued

Back to the GUI, YEAH!



Help Tab

The screenshot displays a software interface for a simulation. On the left, there are input fields for 'Igniter' parameters: Impetus (FI) set to 99700 ft-lb/lbm, Mass (IM) set to 0.0006718 lbm, Heat Loss option (FOPT) set to Gas, and Chamber Model set to Single. Below this, under 'Single', are fields for Volume (VHI) set to 1 in³, Leakage Area (AHI) set to 0 in², and Heat Loss (K2) set to 0. On the right, a graph titled 'Pressure vs Time' shows Pressure (psig) on the y-axis (0 to 1) and Time (sec) on the x-axis (0 to 1). The graph is currently empty. Below the graph are tabs for 'Time', 'Displacement', and 'DRI', with 'Time' selected. There are buttons for 'Open Fig', 'Overplot', and 'Add Data'. At the bottom, the 'Simulation' section includes 'Time Step (DT)' set to 0.0001 sec, 'Print Step (DTPR)' set to 1, 'Solver' set to Runge-Kutta, and a 'Simulate' button. The 'Title' field contains 'data1'.

Final Statement

The CADPROG v11 modeler is the property
of the U.S. Navy.