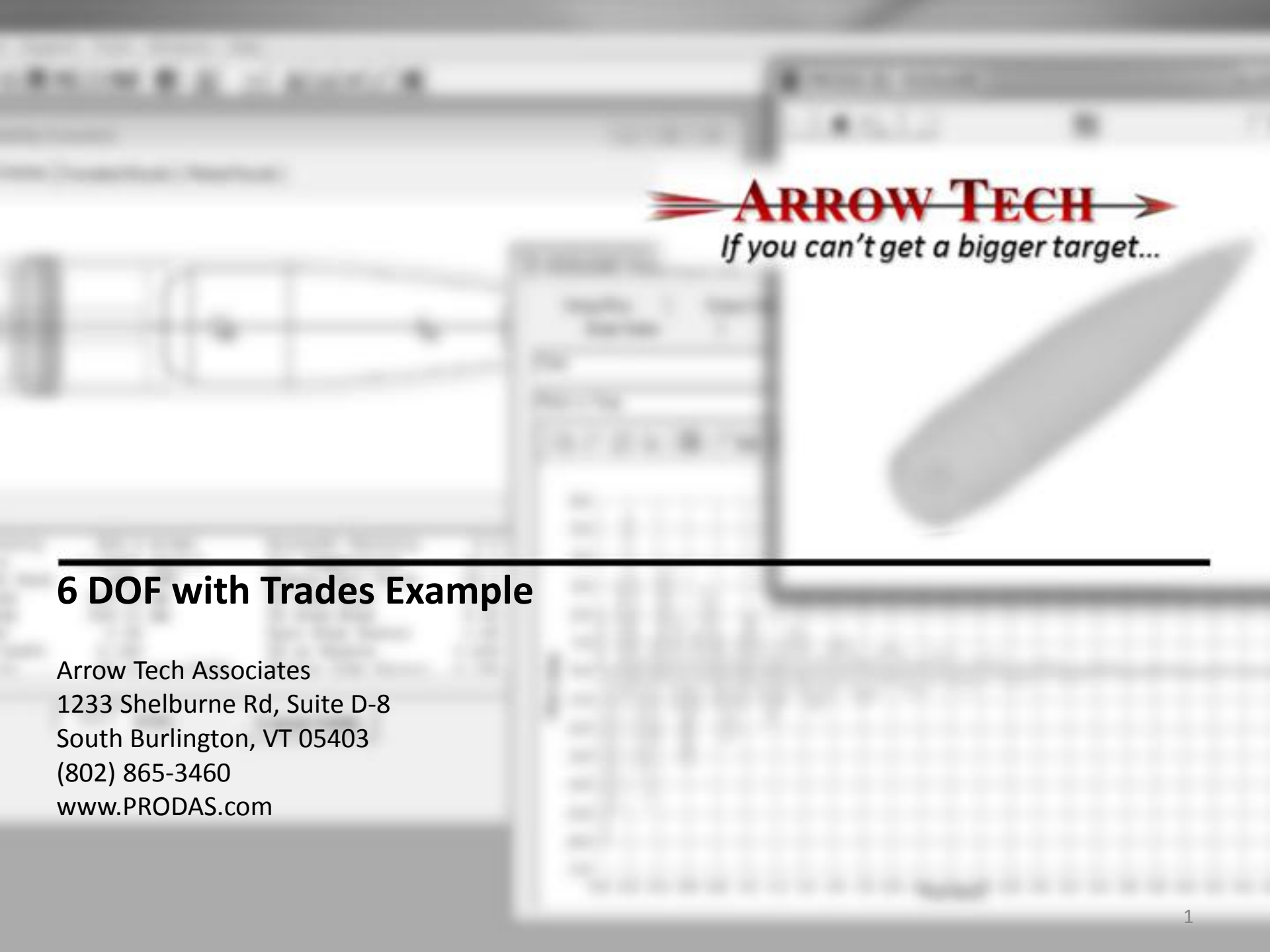


6 DOF with Trades Example

Arrow Tech Associates
1233 Shelburne Rd, Suite D-8
South Burlington, VT 05403
(802) 865-3460
www.PRODAS.com

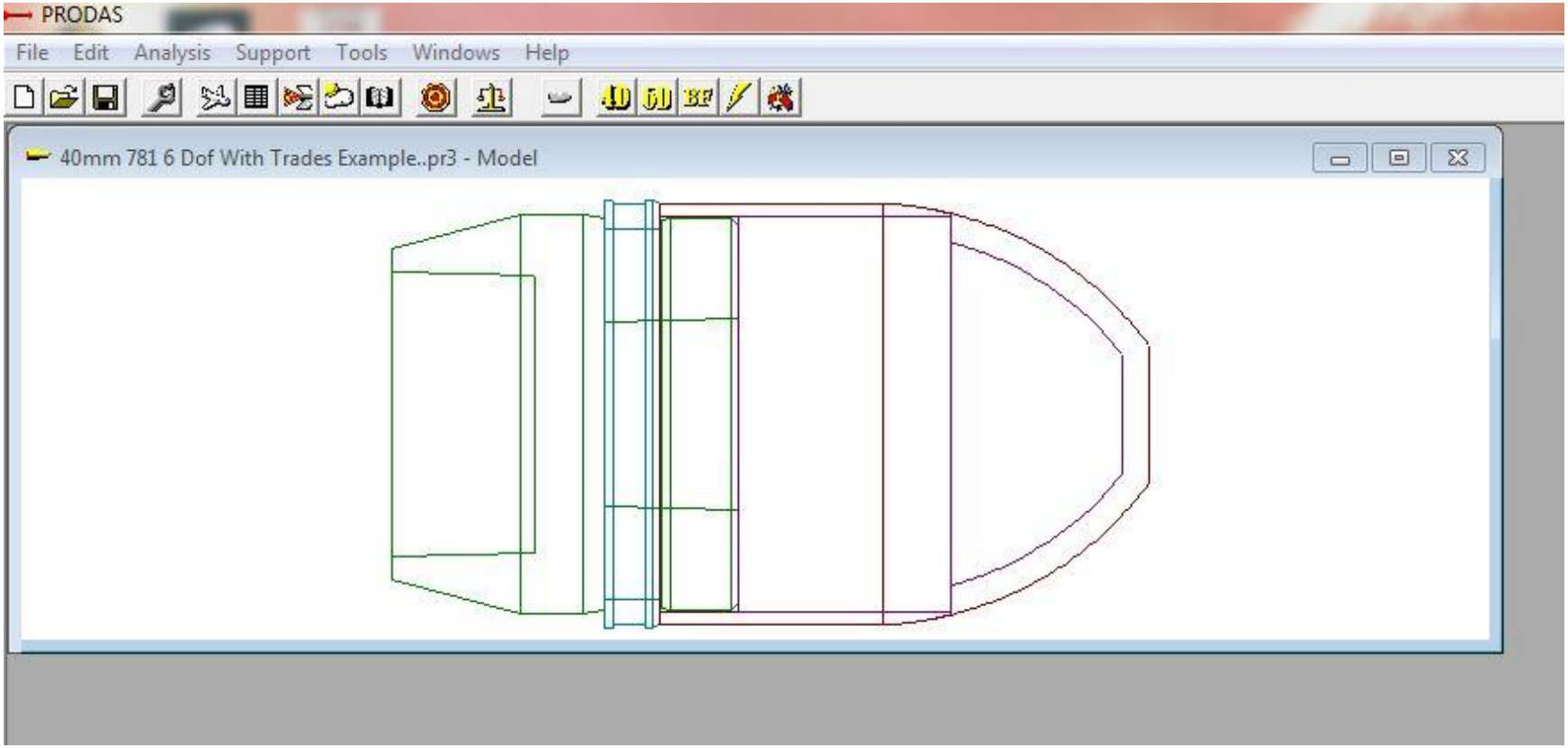
PRODAS 6 Dof with trades example

ARROW TECH
If you can't get a bigger target…

The following presentation is an example of using the 6 degree of freedom trajectory module within PRODAS with the trade study options. For this example we will run the following:

- 40mm M781 Grenade fired from a M203 Launcher
  - Study the horizontal impact patterns of projectiles fired at 3 different quadrant elevations
  - Introduce an error budget for the following initial conditions – Muzzle Velocity, Temperature, Pressure, Winds and Ammunition Dispersion
  - Verify Dispersion Performance buy firing against a 100m vertical target
  - Simulate 3000 separate 6 DOF of freedom trajectories at each Quadrant Elevation

Projectile Model



40mm M781

Projectile Data

ARROW TECH
If you can't get a bigger target...

Projectile Data

Projectile Dia.	4.054	cm
Weight	171.100	gm
Axial Inertia	393.590027	gm-cm^2
Trans Inertia	445.42001	gm-cm^2
CG (from nose)	5.02	cm

Initial Conditions

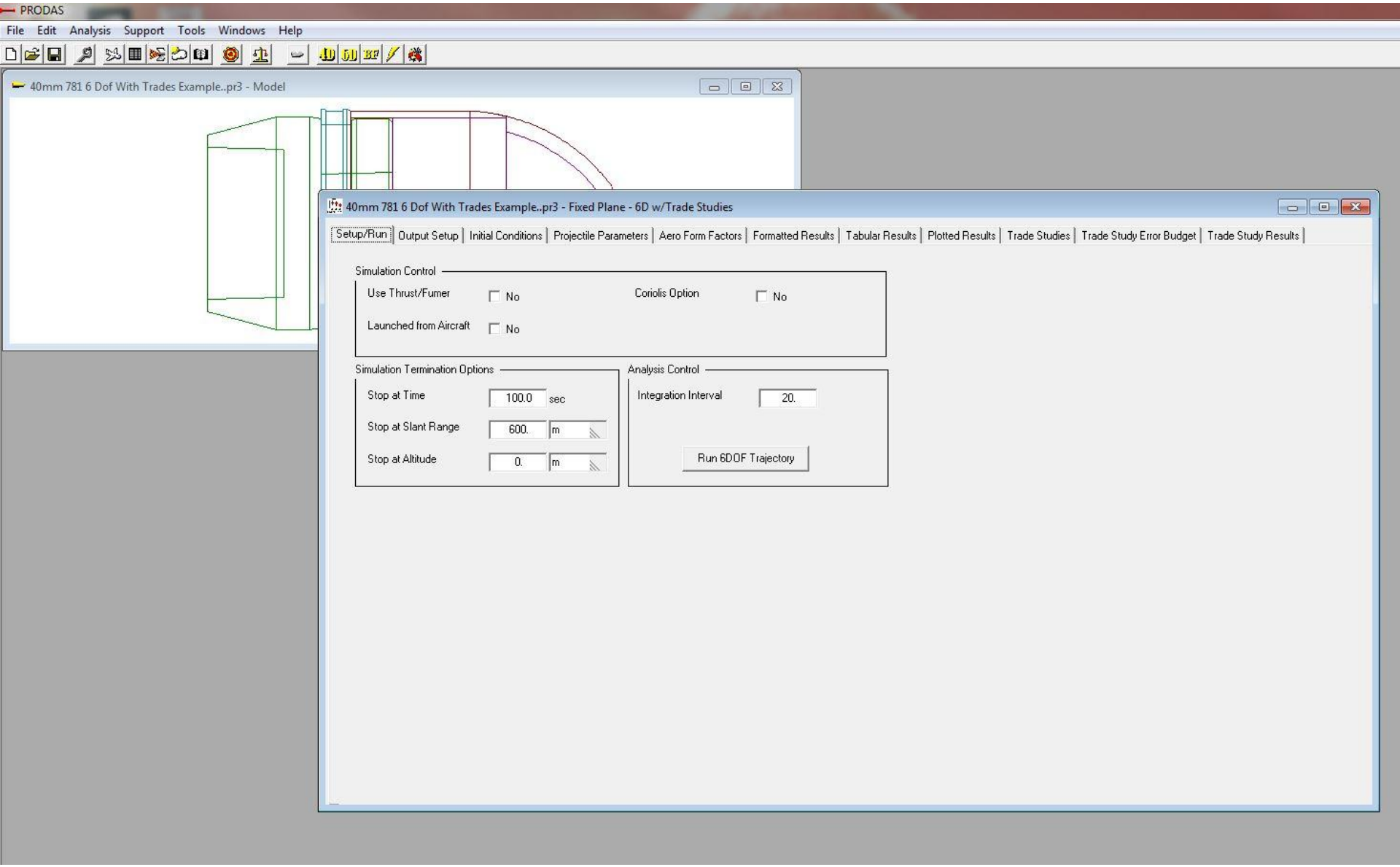
Muzzle Velocity	75.0	m/sec	Initial Pitch Angle +up	0.000	deg
Initial Spin	385.8	rad/sec	Initial Yaw Angle +rt	0.0	deg
Quadrant Elevation	28.125	deg	Initial Pitch Rate +up	30.0	rad/sec
Gun Azimuth (from N)	0.000	deg	Initial Yaw Rate +rt	30.0	rad/sec
Initial Range	0.0	m			
Initial Deflection	0.0	m			
Initial Altitude (re sl)	0.0	m			

Met Data at the Launch Location

Gun Altitude above SL	0.0	m	Density	1.2250	kg/m^3
Temperature	15.0	C	Range Wind	0.0	m/sec
Pressure	1013.2	millibars	Cross Wind	0.0	m/sec
Gravity Acceleration	9.80665	m/sec**2			

6DOF With Trades Interface

ARROW TECH
If you can't get a bigger target...



Example Details

- Error Budget for the analysis example
  - Muzzle Velocity Error – 0.8 m/s (1 std deviation)
  - Ammunition Dispersion - 0.5 mils Radial (1 std deviation)
    - An Example or test of dispersion against a vertical target will be run first to determine angular motion needed at the muzzle to generate corresponding aerodynamic jump for the example projectile.
  - Met Errors (all one standard Deviation)
    - 2 deg Celsius
    - 10 millibars
    - 2.75 m/s Cross and Head/Tail Winds
- Will be fired at 3 different quadrant elevations and 3000 trajectories at each range with the error budget super imposed.
- These errors represent error levels for the analysis example
  - User encouraged to use error levels seen in live fire testing along with specific MET errors for specific mission requirements. This is just an example and the error budget ,while trying to remain realistic is just an example and does not represent an official error budget for this system

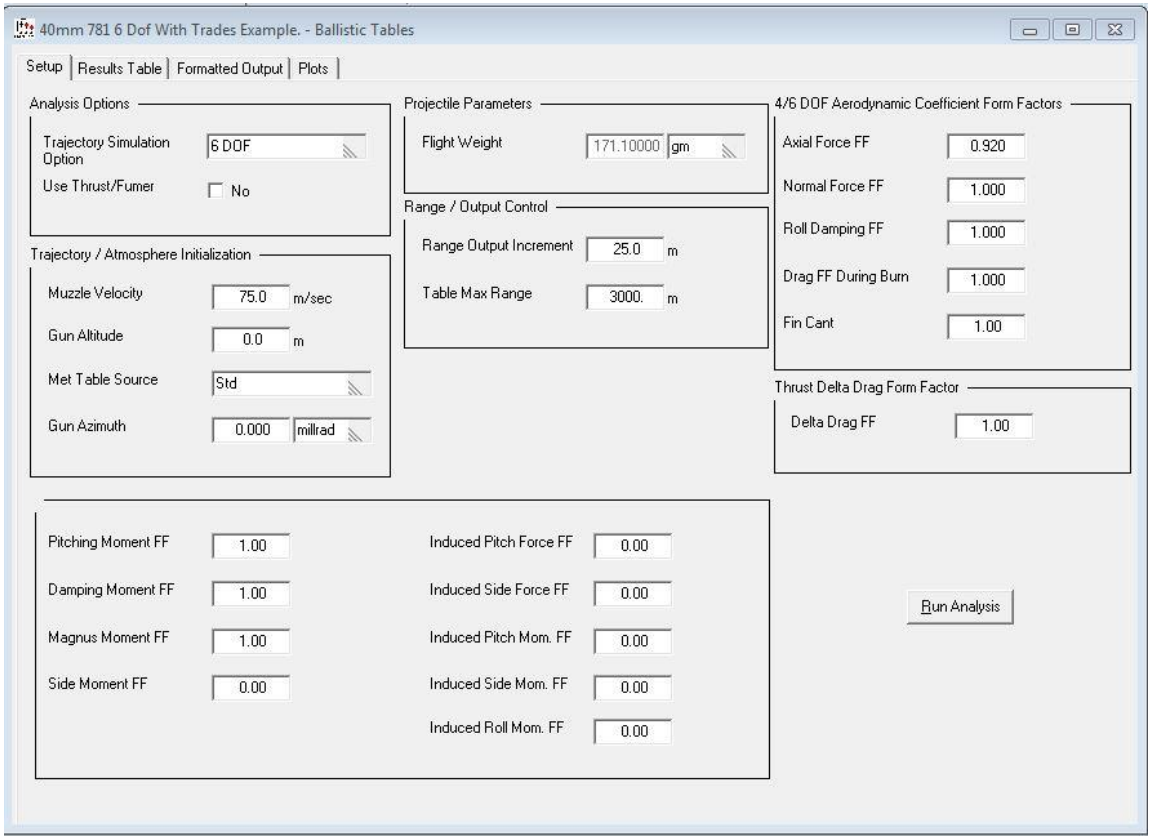
Example Details – Determining Angular Rate

- The final assessment of the example analysis will be the pattern of the projectile on a horizontal surface. However prior to that we must determine the angular rates needed to produce the desired radial dispersion of 0.5 mils which can only be determined against a Vertical Target down range. To do this we will show examples of the following
  - Simulate firing against a vertical target
    - Stop projectile at desired range
    - Input Error Levels for angular rate at muzzle
    - Run Simulation
    - Assess results
    - Modify input error levels
- Radial Dispersion is defined as $\sigma_r = \frac{(\sigma_h - \sigma_v)}{2}$

Example Details

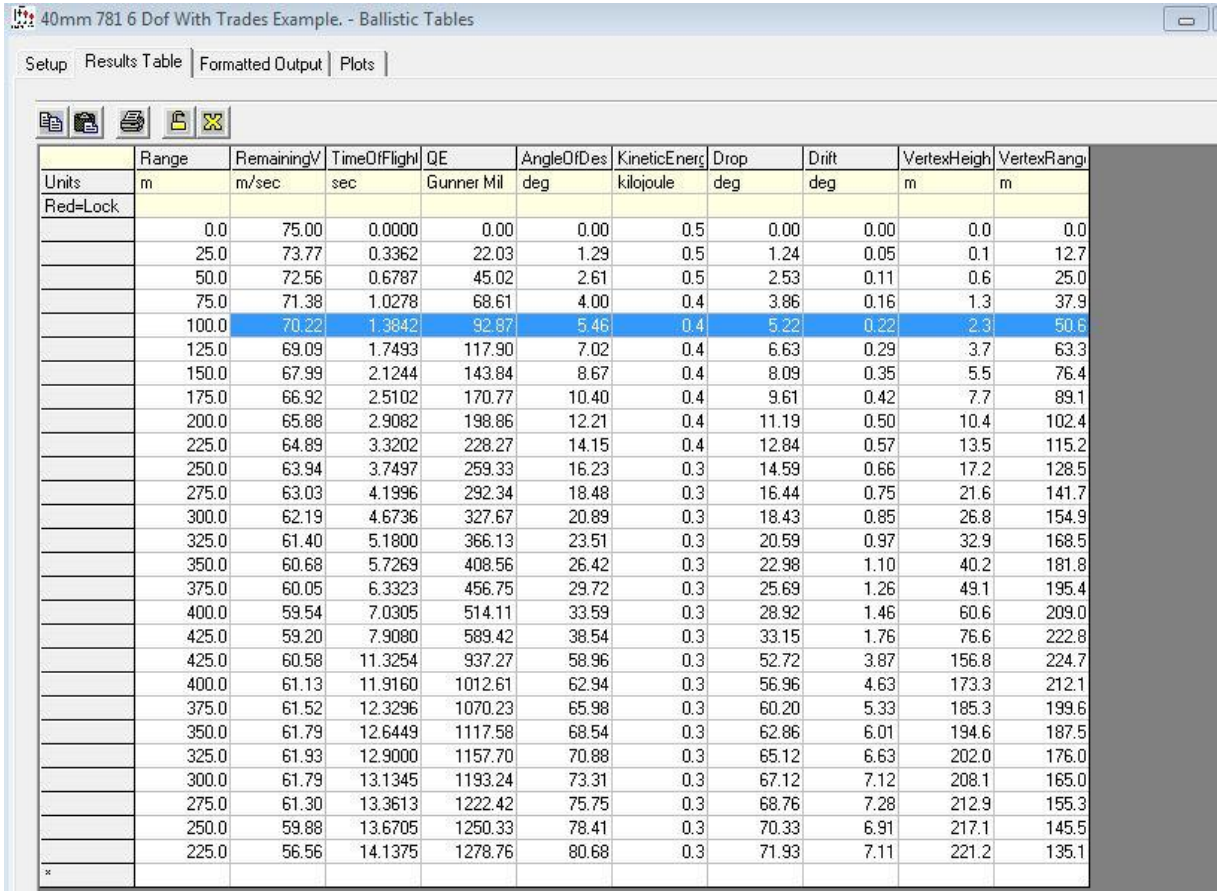
ARROW TECH
If you can't get a bigger target…

- For this part of the example we will be assessing projectile performance against a vertical target at 100m distance from the Weapon.
  - Go to the Ballistic Match Module (Analysis Pull down menu, "Firing Tables – Ballistic Tables"
  - The following Interface should appear



Example Details

- Make sure the 6 DOF trajectory option is chosen (vs 4DOF option) and run the simulation. Once complete please open up the Tabular Results interface and view the information at 100m

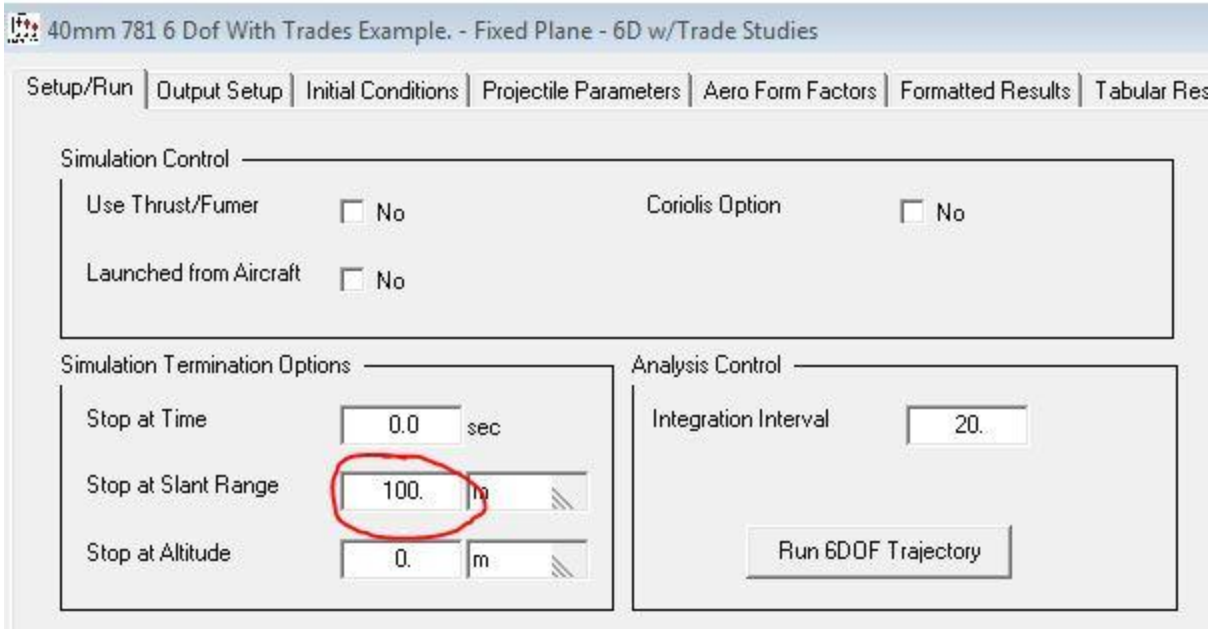

40mm 781 6 Dof With Trades Example. - Ballistic Tables

Setup | Results Table | Formatted Output | Plots

	Range	RemainingV	TimeOfFlight	QE	AngleOfDes	KineticEnerg	Drop	Drift	VertexHeigh	VertexRang
Units	m	m/sec	sec	Gunner Mil	deg	kilojoule	deg	deg	m	m
Red=Lock										
	0.0	75.00	0.0000	0.00	0.00	0.5	0.00	0.00	0.0	0.0
	25.0	73.77	0.3362	22.03	1.29	0.5	1.24	0.05	0.1	12.7
	50.0	72.56	0.6787	45.02	2.61	0.5	2.53	0.11	0.6	25.0
	75.0	71.38	1.0278	68.61	4.00	0.4	3.86	0.16	1.3	37.9
	100.0	70.22	1.3842	92.87	5.46	0.4	5.22	0.22	2.3	50.6
	125.0	69.09	1.7493	117.90	7.02	0.4	6.63	0.29	3.7	63.3
	150.0	67.99	2.1244	143.84	8.67	0.4	8.09	0.35	5.5	76.4
	175.0	66.92	2.5102	170.77	10.40	0.4	9.61	0.42	7.7	89.1
	200.0	65.88	2.9082	198.86	12.21	0.4	11.19	0.50	10.4	102.4
	225.0	64.89	3.3202	228.27	14.15	0.4	12.84	0.57	13.5	115.2
	250.0	63.94	3.7497	259.33	16.23	0.3	14.59	0.66	17.2	128.5
	275.0	63.03	4.1996	292.34	18.48	0.3	16.44	0.75	21.6	141.7
	300.0	62.19	4.6736	327.67	20.89	0.3	18.43	0.85	26.8	154.9
	325.0	61.40	5.1800	366.13	23.51	0.3	20.59	0.97	32.9	168.5
	350.0	60.68	5.7269	408.56	26.42	0.3	22.98	1.10	40.2	181.8
	375.0	60.05	6.3323	456.75	29.72	0.3	25.69	1.26	49.1	195.4
	400.0	59.54	7.0305	514.11	33.59	0.3	28.92	1.46	60.6	209.0
	425.0	59.20	7.9080	589.42	38.54	0.3	33.15	1.76	76.6	222.8
	425.0	60.58	11.3254	937.27	58.96	0.3	52.72	3.87	156.8	224.7
	400.0	61.13	11.9160	1012.61	62.94	0.3	56.96	4.63	173.3	212.1
	375.0	61.52	12.3296	1070.23	65.98	0.3	60.20	5.33	185.3	199.6
	350.0	61.79	12.6449	1117.58	68.54	0.3	62.86	6.01	194.6	187.5
	325.0	61.93	12.9000	1157.70	70.88	0.3	65.12	6.63	202.0	176.0
	300.0	61.79	13.1345	1193.24	73.31	0.3	67.12	7.12	208.1	165.0
	275.0	61.30	13.3613	1222.42	75.75	0.3	68.76	7.28	212.9	155.3
	250.0	59.88	13.6705	1250.33	78.41	0.3	70.33	6.91	217.1	145.5
	225.0	56.56	14.1375	1278.76	80.68	0.3	71.93	7.11	221.2	135.1

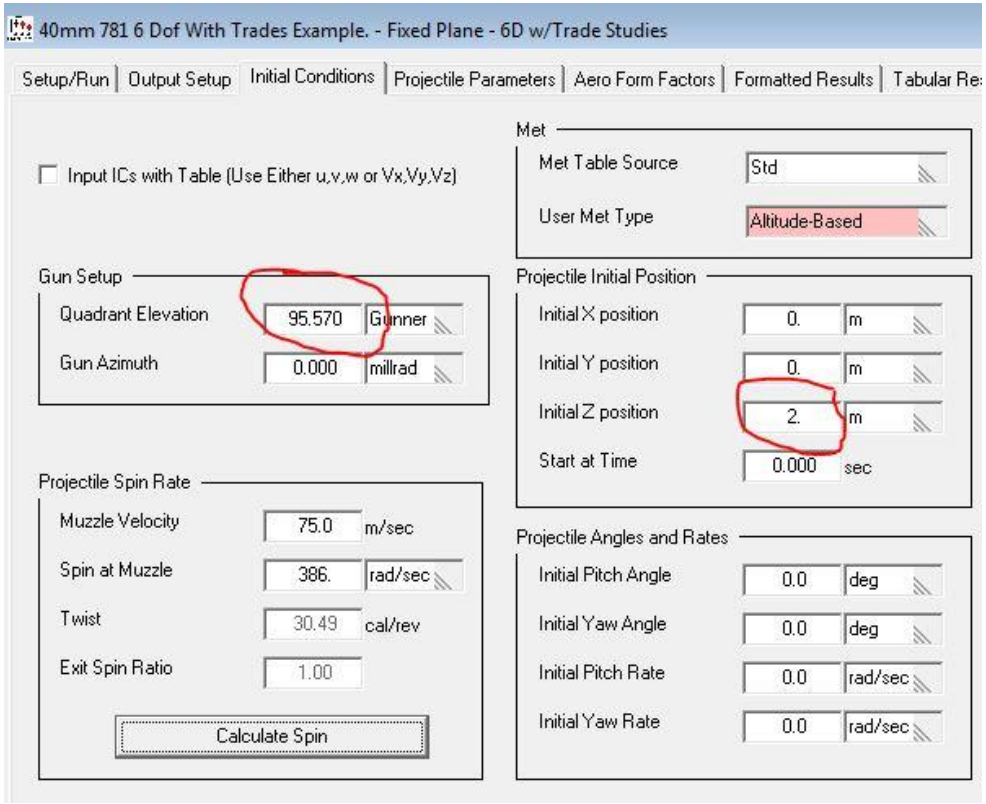
Example Details

- A QE of 92.87 mils is needed to impact at 100mm range. We will added 3 mils to this to bias the impact in altitude by 0.3 m along with raising the weapon to 2 meters altitude to ensure that all of the rounds will impact on target. Since in this part of the example we will modifying only the Angular Rates to verify the impact dispersion we now need to set up the trade analysis to stop at 100 m range
- Please open the Analysis pull down menu and go to the Trajectory submenu and choose "Fixed Plane- 6D w/ Trade Studies"
- You should see the Setup Interface appear. Notice slant range is set 100m



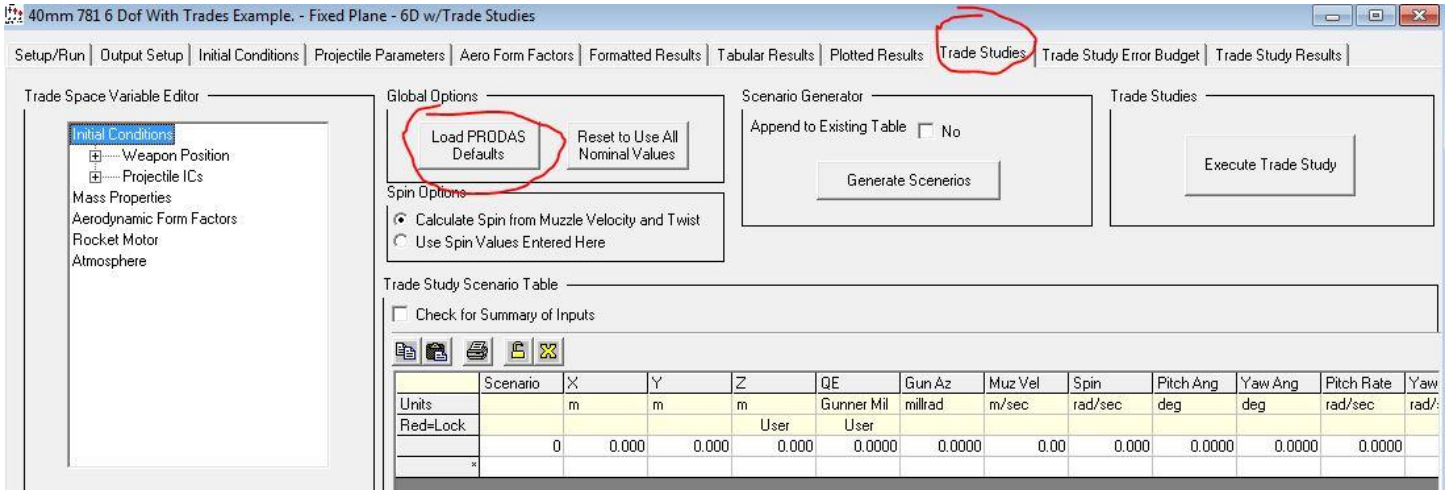
Example Details

- Next go to the Initial Conditions Interface and set the QE to 95.67 Gunner's Mils.
- Set the initial Z position to 2 m altitude (This ensures that all of the impact will be captured at 100m and not fall short)



Example Details

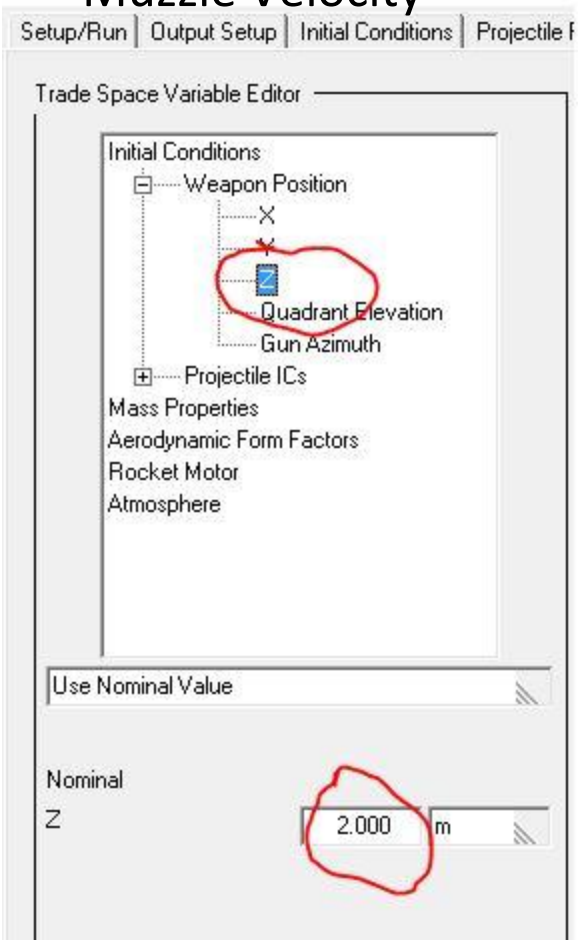
- Please save the file at this time via the File pull down menu at the top left of the PRODAS interface.
- Now please go to the trade Interface with the 6D w/Trade Studies Interface

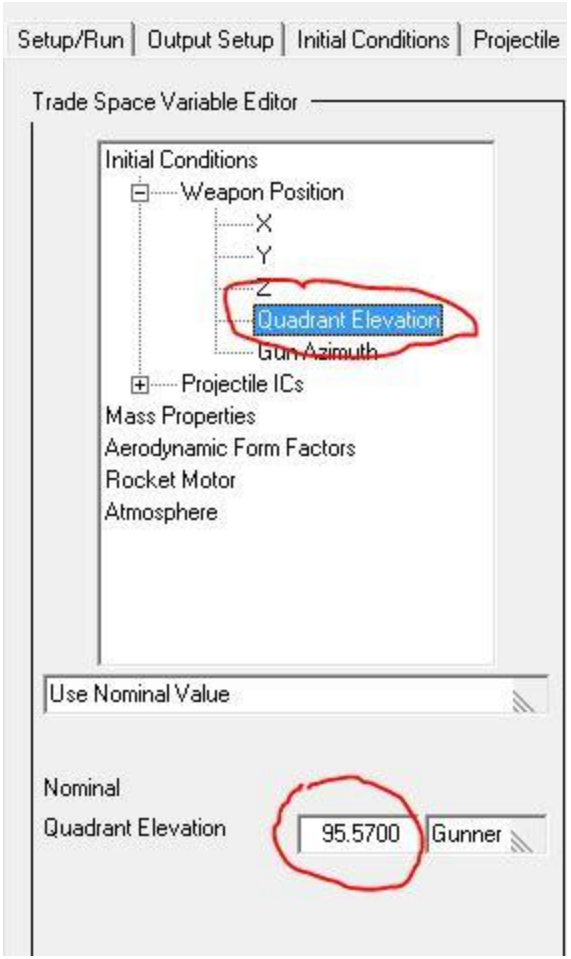


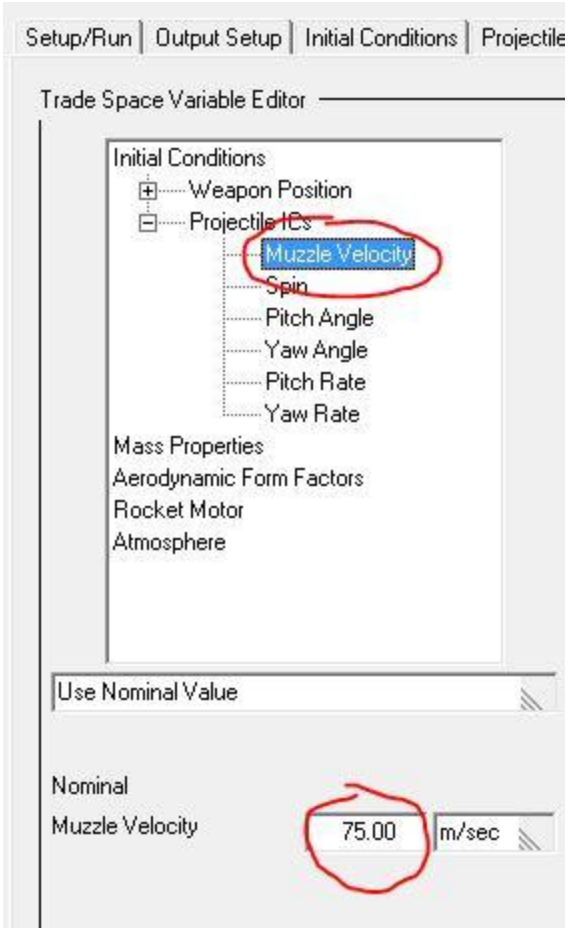
Please use the "Load PRODAS Default" command which will load the saved data from the prior input screens.

Example Details

- Using the "Trade Space Variables Editor" section please expand the input tree and verify the following values for Z position, Quadrant Elevation and Muzzle Velocity



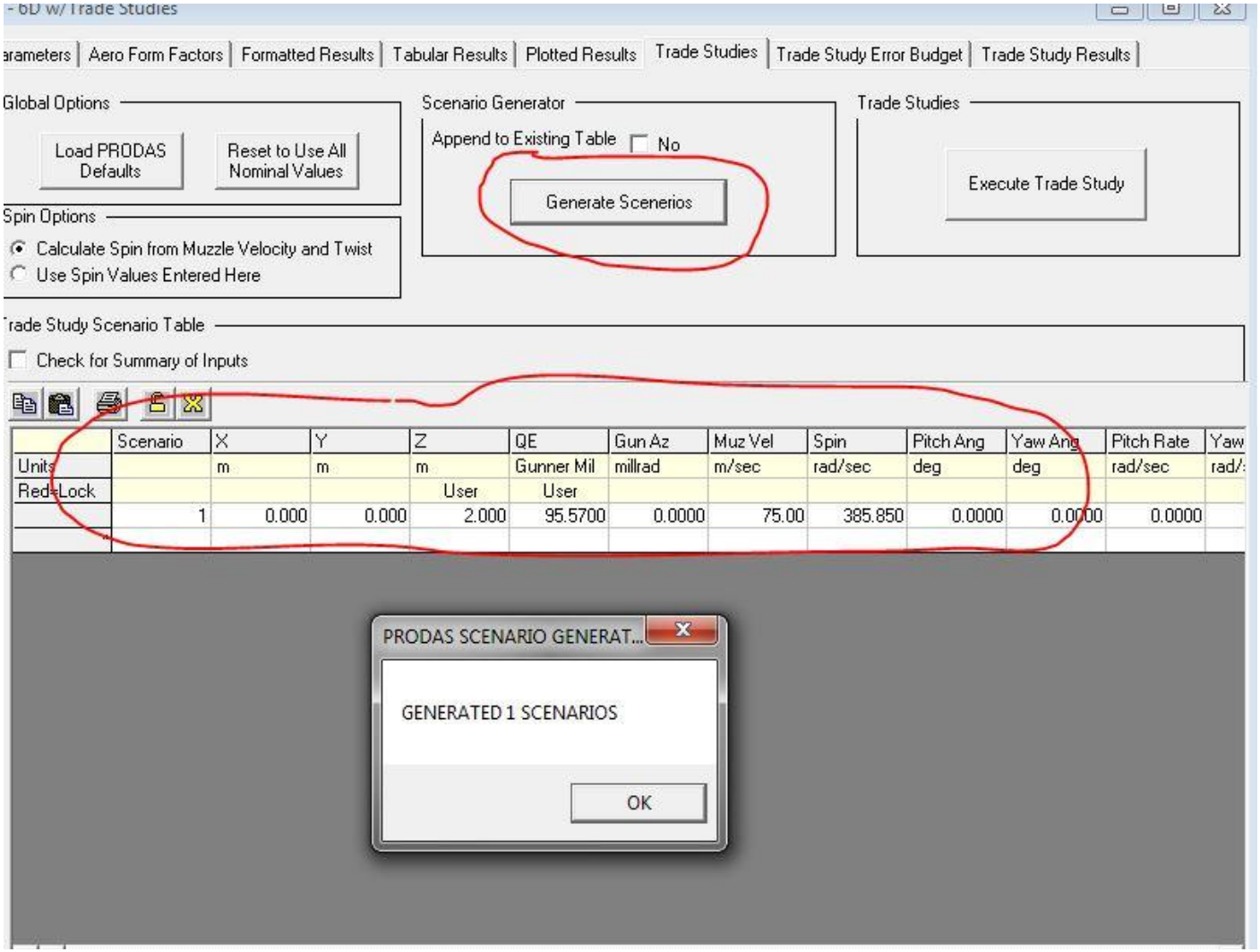




Example Details

- This data was populated by the interface itself when the "Load PRODAS Default" Command was used. The user can overide these if they choose.
- Please use the "Generate Scenarios command to populate the "Trade Study Scenario Table"
- You will now see the Trade Study Scenario Table has been populated with the Initial Conditions Saved in the file.
- This table will be used as our baseline trajectory setup to which we will add errors to.

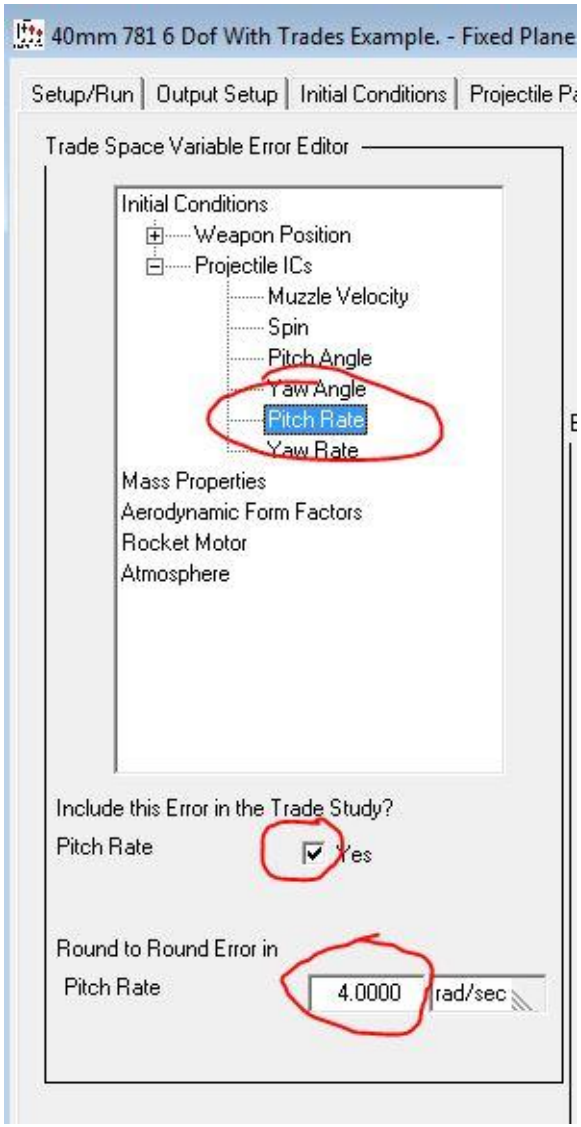
Example Details

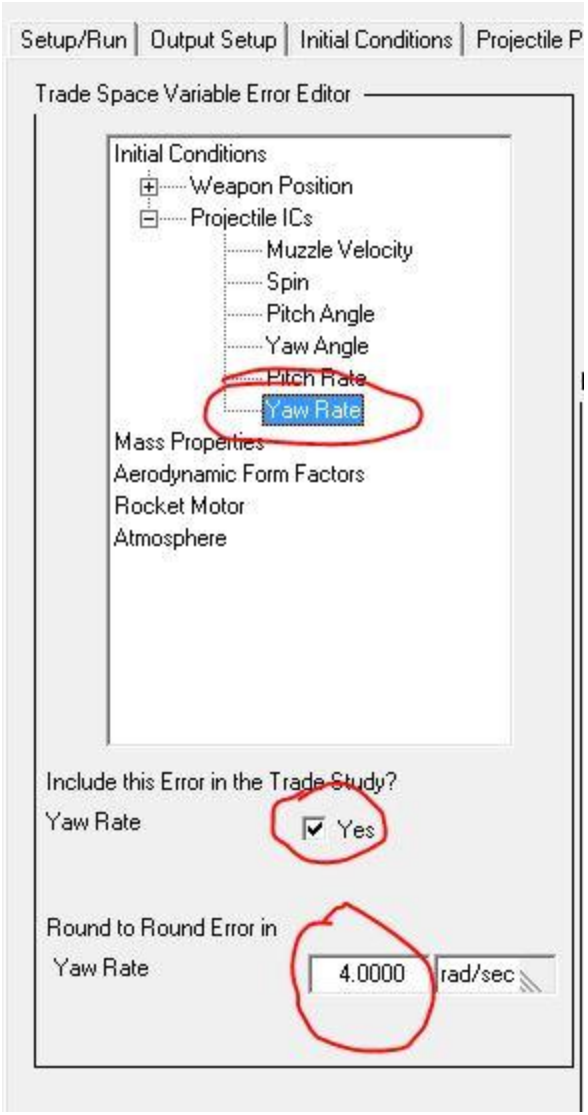


Example Details

- Now the user should go to the "Trade Study-Error Budget Interface"
  - Interface allows input of errors to the input sources available in the Trade Space Variables Error Editor
- In this case we are only interested in the angular rates at launch.
- Please expand the Initial Conditions- Projectile IC Error Tree and choose "Pitch Rate"
- Please Check the "Include this Error in the Trade Study" box and input a 4 rad/sec rate (1 std deviation) in the Pitch Rate Error level box
- Do the same for Yaw Rate
- (See next page for details)

Example Details

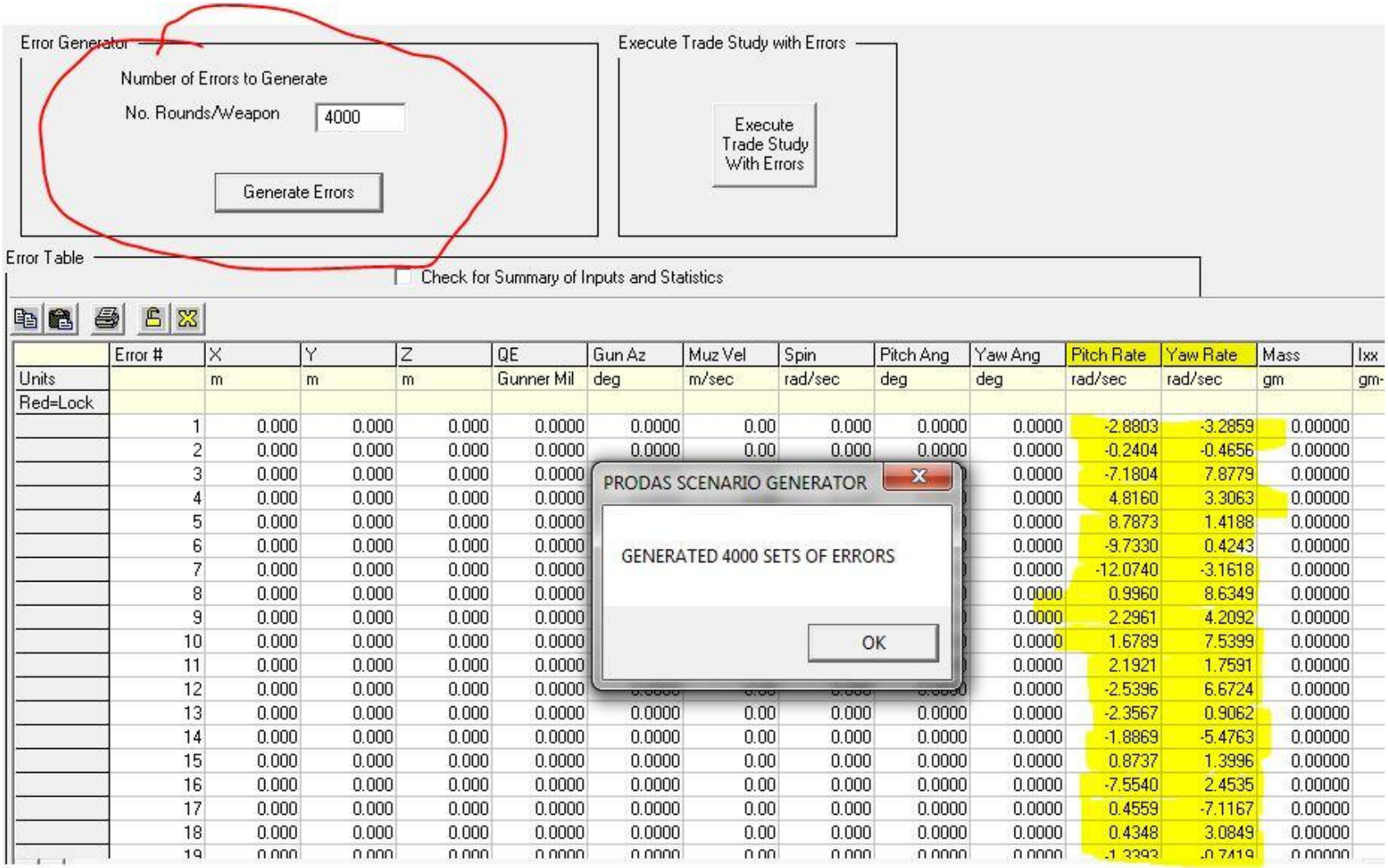




Example Details

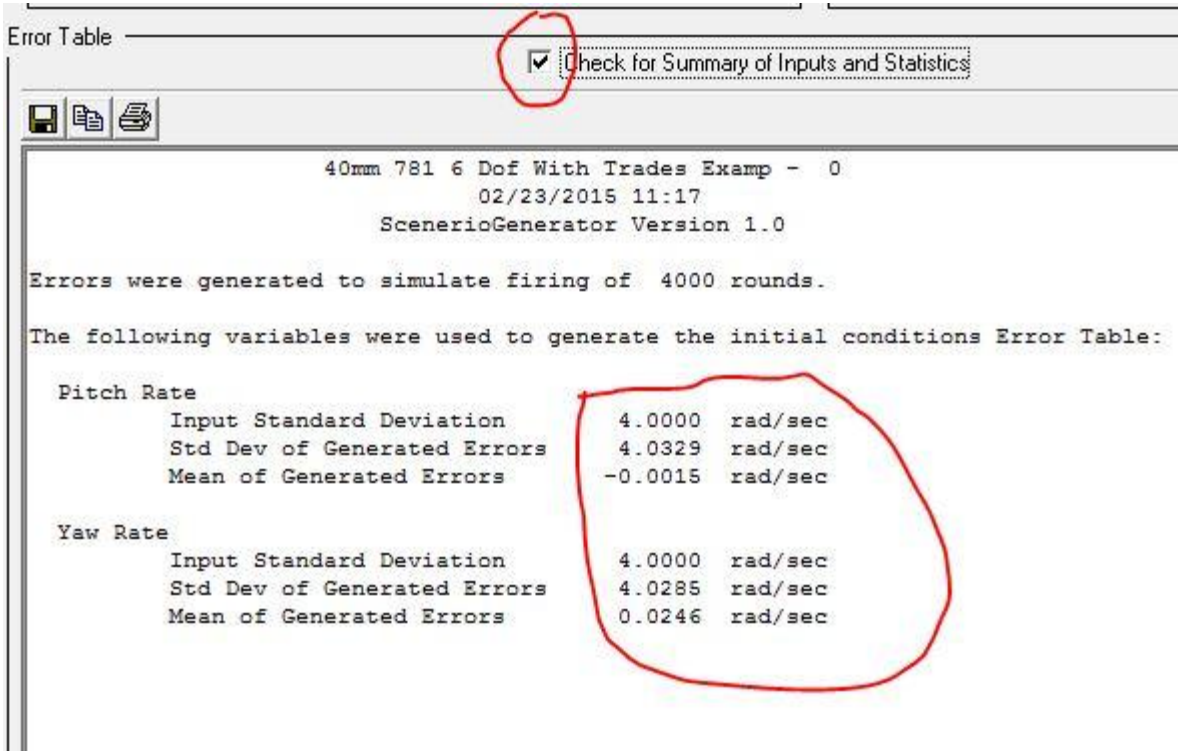
- Please go to the Error Generator section and modify the Number of Errors input to 4000 (This just gives us a lot of errors to minimize random number generator noise)
- Hit the Generate Errors command and you will see the Error Table Populate itself.
- Notice the only errors input to the table are the initial Pitch and Yaw rates at launch.
- If you check the "Check for Input summary and statistics" you will notice the output in the windows summarizes the errors generated for this run

Example Details



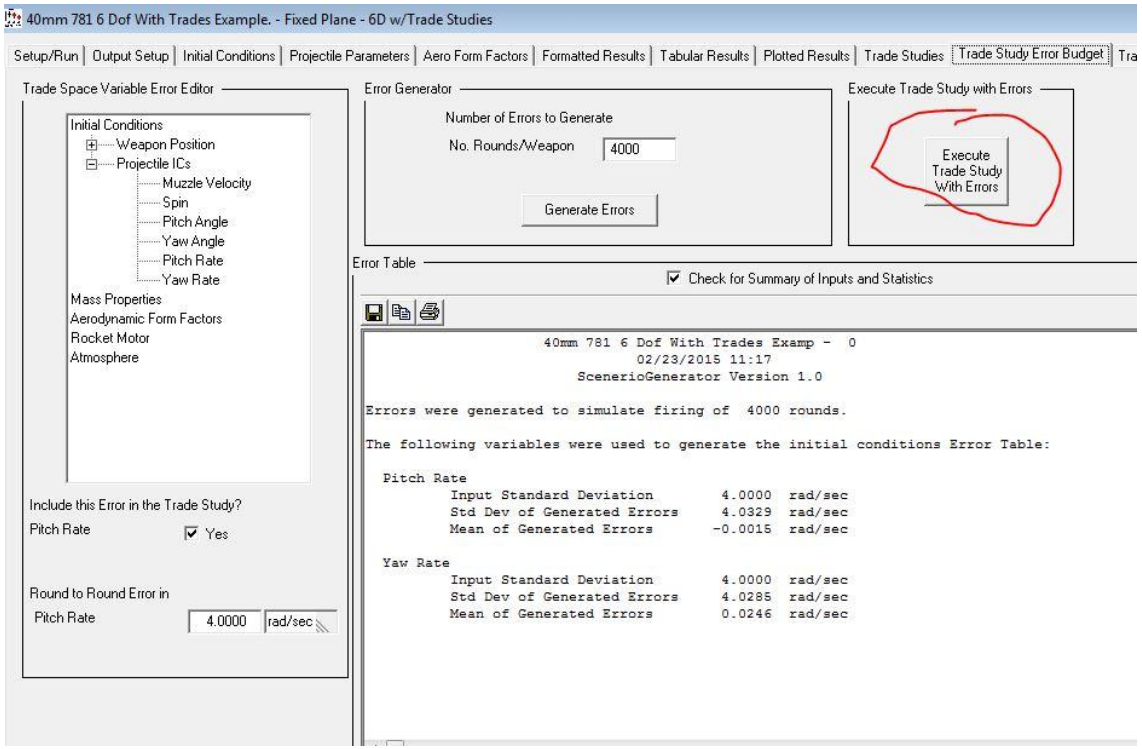
	Error #	X	Y	Z	QE	Gun Az	Muz Vel	Spin	Pitch Ang	Yaw Ang	Pitch Rate	Yaw Rate	Mass	Ixx
Units		m	m	m	Gunner Mil	deg	m/sec	rad/sec	deg	deg	rad/sec	rad/sec	gm	gm-
Red=Lock														
	1	0.000	0.000	0.000	0.0000	0.0000	0.00	0.000	0.0000	0.0000	-2.8803	-3.2859	0.00000	
	2	0.000	0.000	0.000	0.0000	0.0000	0.00	0.000	0.0000	0.0000	-0.2404	-0.4656	0.00000	
	3	0.000	0.000	0.000	0.0000					0.0000	-7.1804	7.8779	0.00000	
	4	0.000	0.000	0.000	0.0000					0.0000	4.8160	3.3063	0.00000	
	5	0.000	0.000	0.000	0.0000					0.0000	8.7873	1.4188	0.00000	
	6	0.000	0.000	0.000	0.0000					0.0000	-9.7330	0.4243	0.00000	
	7	0.000	0.000	0.000	0.0000					0.0000	-12.0740	-3.1618	0.00000	
	8	0.000	0.000	0.000	0.0000					0.0000	0.9960	8.6349	0.00000	
	9	0.000	0.000	0.000	0.0000					0.0000	2.2961	4.2092	0.00000	
	10	0.000	0.000	0.000	0.0000					0.0000	1.6789	7.5399	0.00000	
	11	0.000	0.000	0.000	0.0000					0.0000	2.1921	1.7591	0.00000	
	12	0.000	0.000	0.000	0.0000					0.0000	-2.5396	6.6724	0.00000	
	13	0.000	0.000	0.000	0.0000	0.0000	0.00	0.000	0.0000	0.0000	-2.3567	0.9062	0.00000	
	14	0.000	0.000	0.000	0.0000	0.0000	0.00	0.000	0.0000	0.0000	-1.8869	-5.4763	0.00000	
	15	0.000	0.000	0.000	0.0000	0.0000	0.00	0.000	0.0000	0.0000	0.8737	1.3996	0.00000	
	16	0.000	0.000	0.000	0.0000	0.0000	0.00	0.000	0.0000	0.0000	-7.5540	2.4535	0.00000	
	17	0.000	0.000	0.000	0.0000	0.0000	0.00	0.000	0.0000	0.0000	0.4559	-7.1167	0.00000	
	18	0.000	0.000	0.000	0.0000	0.0000	0.00	0.000	0.0000	0.0000	0.4348	3.0849	0.00000	
	19	0.000	0.000	0.000	0.0000	0.0000	0.00	0.000	0.0000	0.0000	-1.3393	-0.7419	0.00000	

Example Details



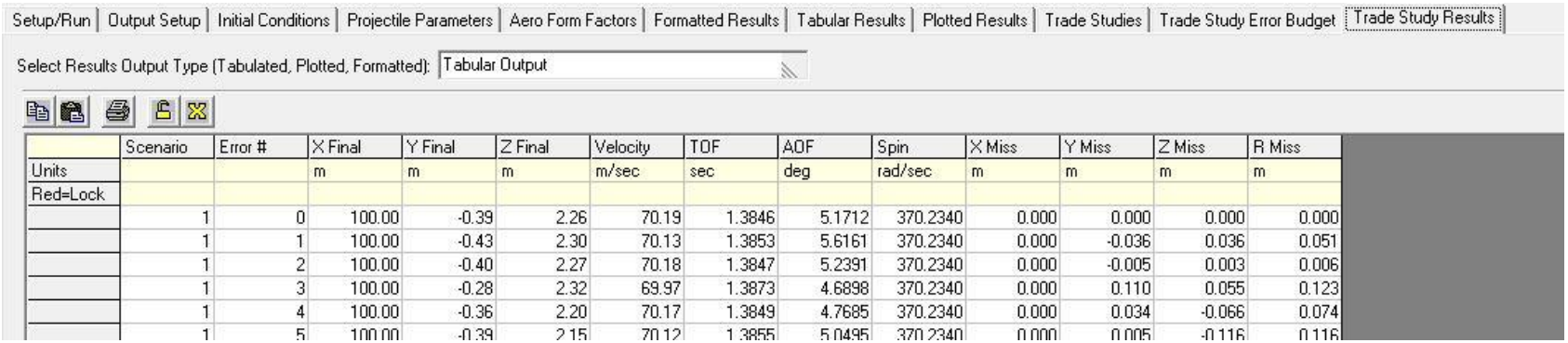
Example Details

- Now that we have generated our baseline Trade Study and the Trade Study Errors please use the "Execute Trade Study With Errors" command within the "Trade Study Error Budget Interface" window
- Wait for the analysis to finish – you may get some VB script warnings about how long the analysis is taking –ignore these.



Example Details

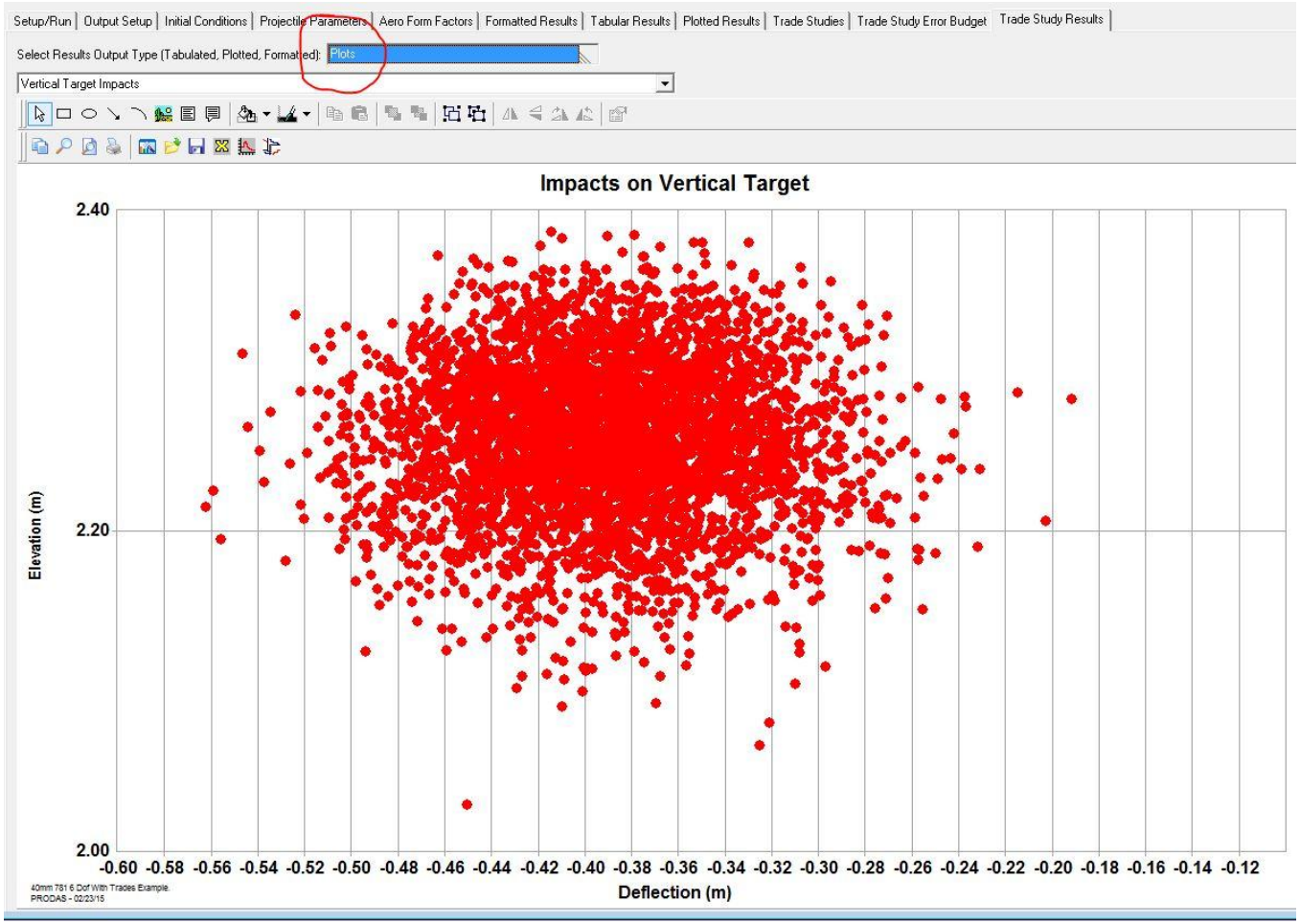
- Once the anlysis is complete we can take a look at the output in the "Trade Study Results interface. The first set of results are in tabular form and show the impact points relative to the nominal trajectory
  - Note the 1st Scenario Number 0 represent the nominal flight of the prjectile without any error



	Scenario	Error #	X Final	Y Final	Z Final	Velocity	TOF	AOF	Spin	X Miss	Y Miss	Z Miss	R Miss
Units			m	m	m	m/sec	sec	deg	rad/sec	m	m	m	m
Red=Lock													
	1	0	100.00	-0.39	2.26	70.19	1.3846	5.1712	370.2340	0.000	0.000	0.000	0.000
	1	1	100.00	-0.43	2.30	70.13	1.3853	5.6161	370.2340	0.000	-0.036	0.036	0.051
	1	2	100.00	-0.40	2.27	70.18	1.3847	5.2391	370.2340	0.000	-0.005	0.003	0.006
	1	3	100.00	-0.28	2.32	69.97	1.3873	4.6898	370.2340	0.000	0.110	0.055	0.123
	1	4	100.00	-0.36	2.20	70.17	1.3849	4.7685	370.2340	0.000	0.034	-0.066	0.074
	1	5	100.00	-0.39	2.15	70.12	1.3855	5.0495	370.2340	0.000	0.005	-0.116	0.116

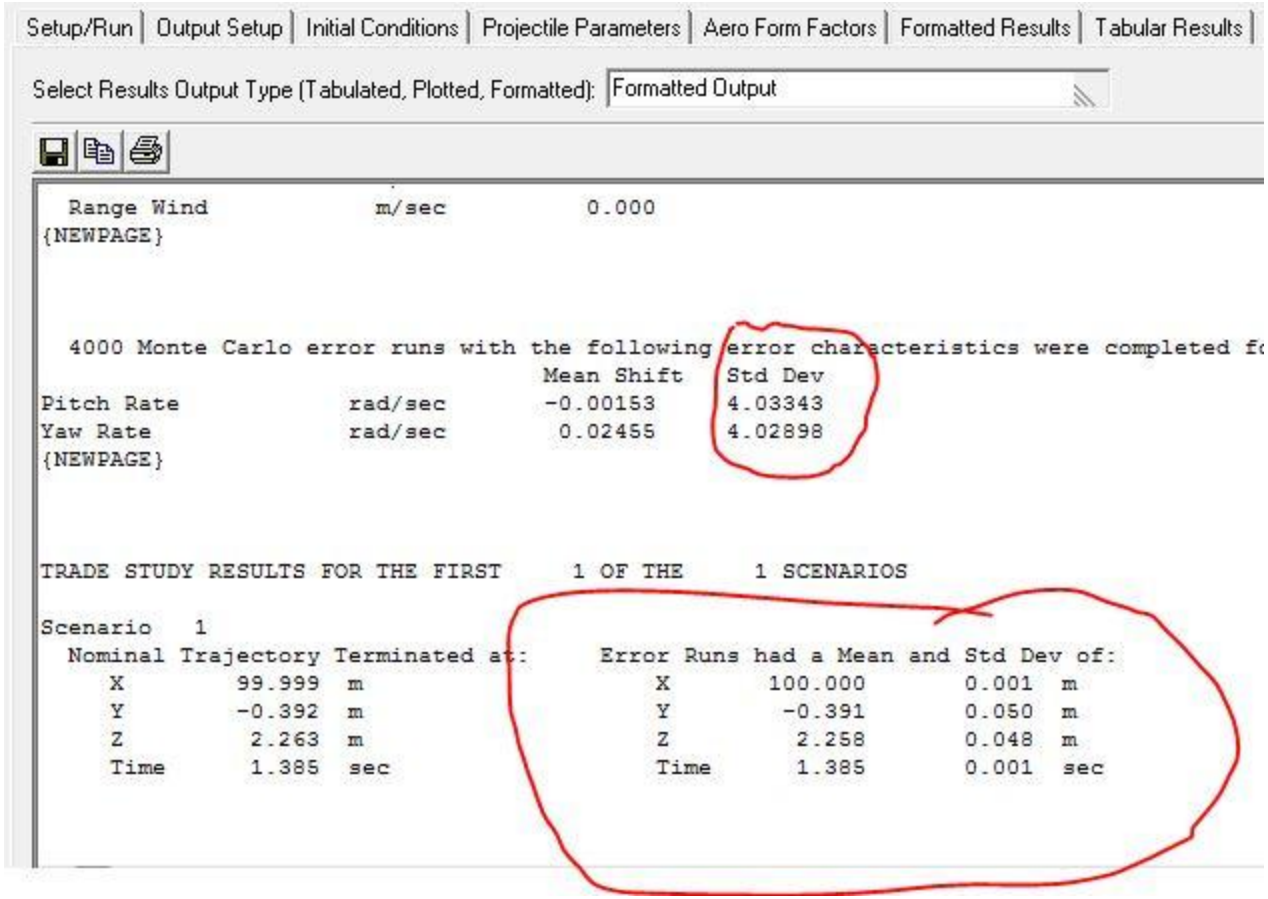
Example Details

- The next set of outputs are the plotted outputs. N this case we are interested in the Vertical Target Impacts so please select that plot.



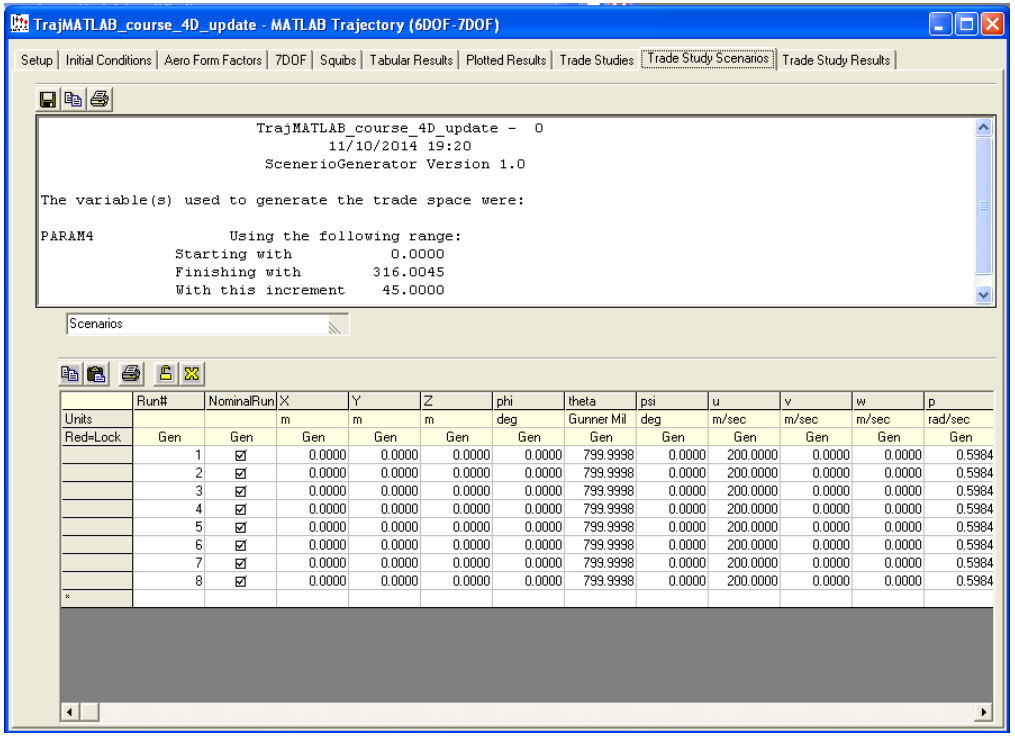
Example Details

- The final option for output is the "Formatted Output" which gives our input summary and impact statistics so the we verify the dispersion performance at the angular rate errors input.



Trade Study Scenarios Tab

- Text Window shows results of generating an error table or generating scenarios.
- List box to select one of three tables to display
- Scenarios Table
  - Table of IC's to be used in the simulation
  - Each row is a run
- Error Level Table
  - Summary table of all errors and trade space variables that generated the scenarios
- Errors Table
  - Table of error deltas based on the error definitions

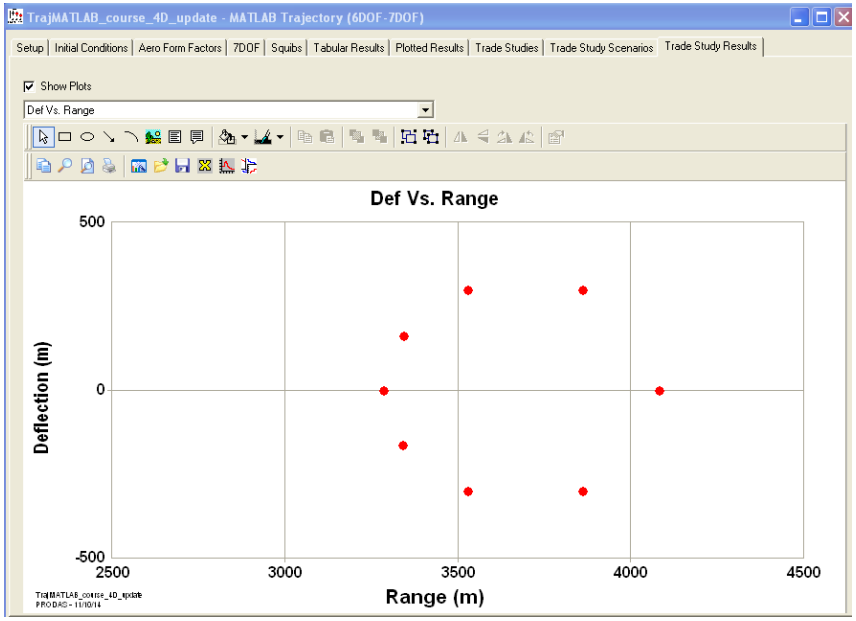


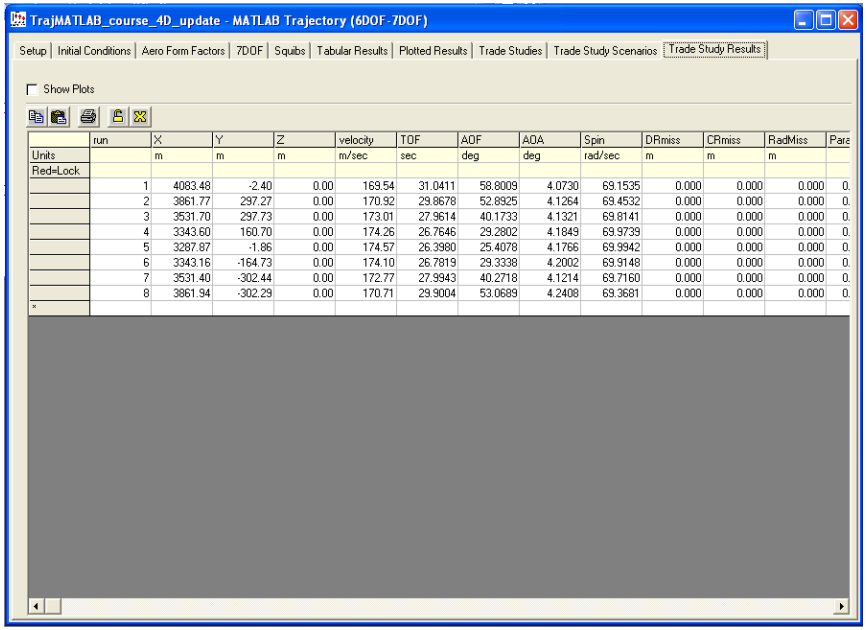
	Run#	NominalRun	X	Y	Z	phi	theta	psi	u	v	w	p
Units			m	m	m	deg	Gunner Mil	deg	m/sec	m/sec	m/sec	rad/sec
Red=Lock	Gen	Gen	Gen	Gen	Gen	Gen	Gen	Gen	Gen	Gen	Gen	Gen
	1	☑	0.0000	0.0000	0.0000	0.0000	799.9998	0.0000	200.0000	0.0000	0.0000	0.5984
	2	☑	0.0000	0.0000	0.0000	0.0000	799.9998	0.0000	200.0000	0.0000	0.0000	0.5984
	3	☑	0.0000	0.0000	0.0000	0.0000	799.9998	0.0000	200.0000	0.0000	0.0000	0.5984
	4	☑	0.0000	0.0000	0.0000	0.0000	799.9998	0.0000	200.0000	0.0000	0.0000	0.5984
	5	☑	0.0000	0.0000	0.0000	0.0000	799.9998	0.0000	200.0000	0.0000	0.0000	0.5984
	6	☑	0.0000	0.0000	0.0000	0.0000	799.9998	0.0000	200.0000	0.0000	0.0000	0.5984
	7	☑	0.0000	0.0000	0.0000	0.0000	799.9998	0.0000	200.0000	0.0000	0.0000	0.5984
	8	☑	0.0000	0.0000	0.0000	0.0000	799.9998	0.0000	200.0000	0.0000	0.0000	0.5984
*												

Trade Study Results

ARROW TECH
If you can't get a bigger target...

- Summary data brought back to PRODAS when a trade studies run is complete
- One row for each run





	run	X	Y	Z	velocity	TOF	AOF	AOA	Spin	DRmiss	CRmiss	RadMiss	Para
Units		m	m	m	m/sec	sec	deg	deg	rad/sec	m	m	m	
Red=Lock													
	1	4083.48	-2.40	0.00	169.54	31.0411	58.8009	4.0730	69.1535	0.000	0.000	0.000	0.
	2	3861.77	297.27	0.00	170.92	29.8678	52.8925	4.1264	69.4532	0.000	0.000	0.000	0.
	3	3531.70	297.73	0.00	173.01	27.9614	40.1733	4.1321	69.8141	0.000	0.000	0.000	0.
	4	3343.60	160.70	0.00	174.26	26.7646	29.2802	4.1849	69.9739	0.000	0.000	0.000	0.
	5	3287.87	-1.86	0.00	174.57	26.3980	25.4078	4.1766	69.9942	0.000	0.000	0.000	0.
	6	3343.16	-164.73	0.00	174.10	26.7819	29.3338	4.2002	69.9148	0.000	0.000	0.000	0.
	7	3531.40	-302.44	0.00	172.77	27.9943	40.2718	4.1214	69.7160	0.000	0.000	0.000	0.
	8	3861.94	-302.29	0.00	170.71	29.9004	53.0689	4.2408	69.3681	0.000	0.000	0.000	0.

Example Details

- From the Results we can see that our standard deviation in Y is .050 m or 0.5 mils and our standard deviation in Z is 0.048m or .48 mils which is ~ 0.49 mils Radial Dispersion. Please increase the initial std deviation in Pitch Rate to 4.3 rad/sec in the "Trade Study-Error Budget Interface". This will result in a std deviation I impact in Z of .050m which equates to 0.5 mils dispersion and the desired radial ammunition dispersion of 0.5 mils

$$\sigma_r = \frac{(\sigma_h - \sigma_v)}{2}$$

Example Details

ARROW TECH
If you can't get a bigger target…

4000 Monte Carlo error runs with the following error characteristics were completed for each scenario.

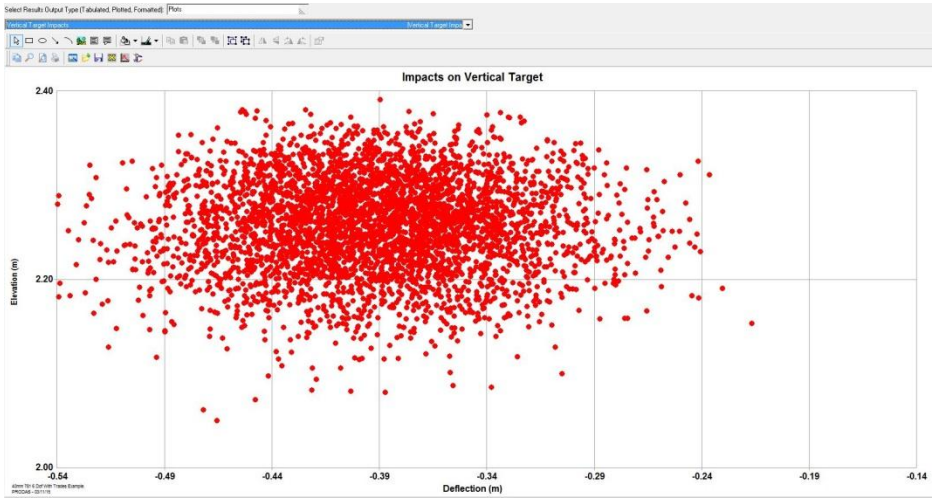
		Mean Shift	Std Dev
Pitch Rate	rad/sec	0.05779	4.21041
Yaw Rate	rad/sec	-0.06350	4.03027

{NEWPAGE}

TRADE STUDY RESULTS FOR THE FIRST 1 OF THE 1 SCENARIOS

Scenario 1

Nominal Trajectory Terminated at:			Error Runs had a Mean and Std Dev of:			
X	99.999	m	X	100.000	0.001	m
Y	-0.392	m	Y	-0.392	0.050	m
Z	2.263	m	Z	2.257	0.050	m
Time	1.385	sec	Time	1.385	0.001	sec

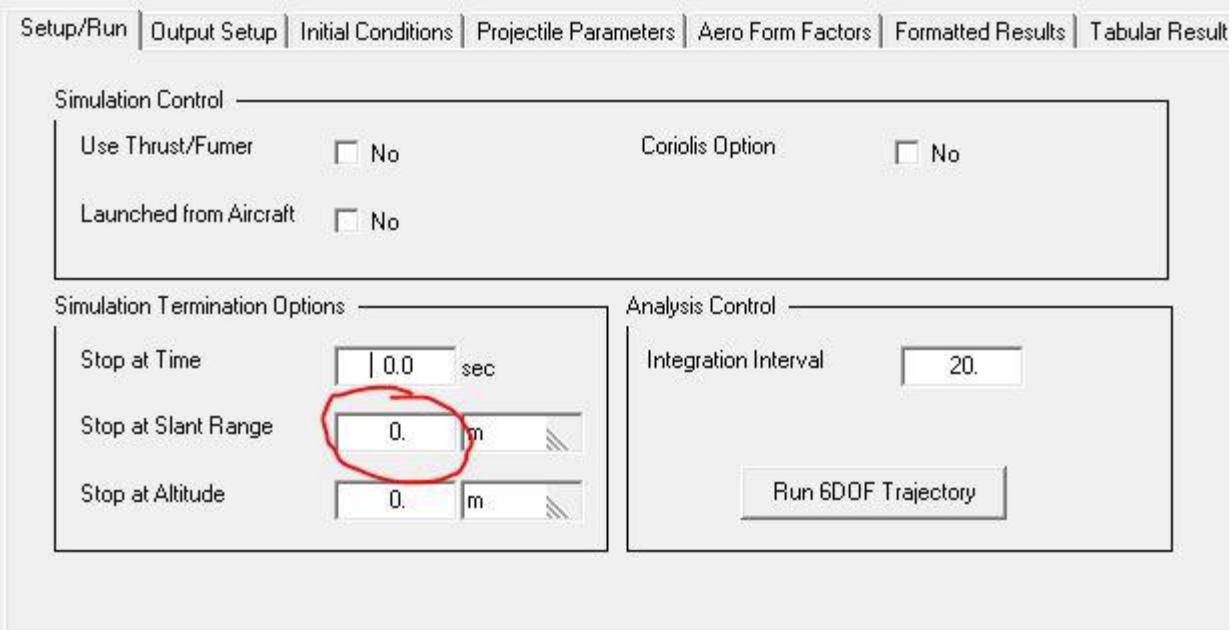


Initializing full error budget

- Now that we have verified the ammunition dispersion against a vertical target performance we can now add the other error contributions and now evaluate against a horizontal or ground impact scenario.
- Error Budget for the analysis example
  - Muzzle Velocity Error – 0.8 m/s (1 std deviation)
  - Ammunition Dispersion - 0.5 mils Radial (1 std deviation)
    - An Example or test of dispersion against a vertical target will be run first to determine angular motion needed at the muzzle to generate corresponding aerodynamic jump for the example projectile.
  - Met Errors (all one standard Deviation)
    - 2 deg Celsius
    - 10 millibars
    - 2.75 m/s Cross and Head/Tail Winds
    - Will be fired at 3 different quadrant elevations and 1000 trajectories at each range with the error budget super imposed.

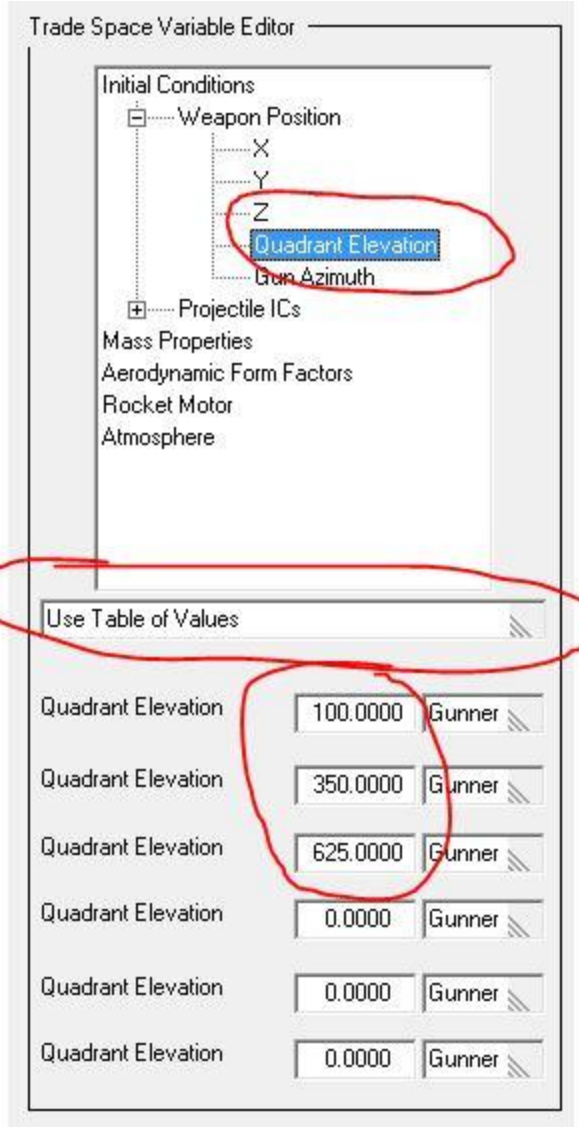
Example Details

- Since we are now interested in evaluating the ground impact patterns at 3 different Quadrant Elevations we need to modify the simulation termination options within the Setup interface window. Please modify the slant range input from 100 to 0. This ensures that the rounds will fly to ground impact regardless of the input QE.

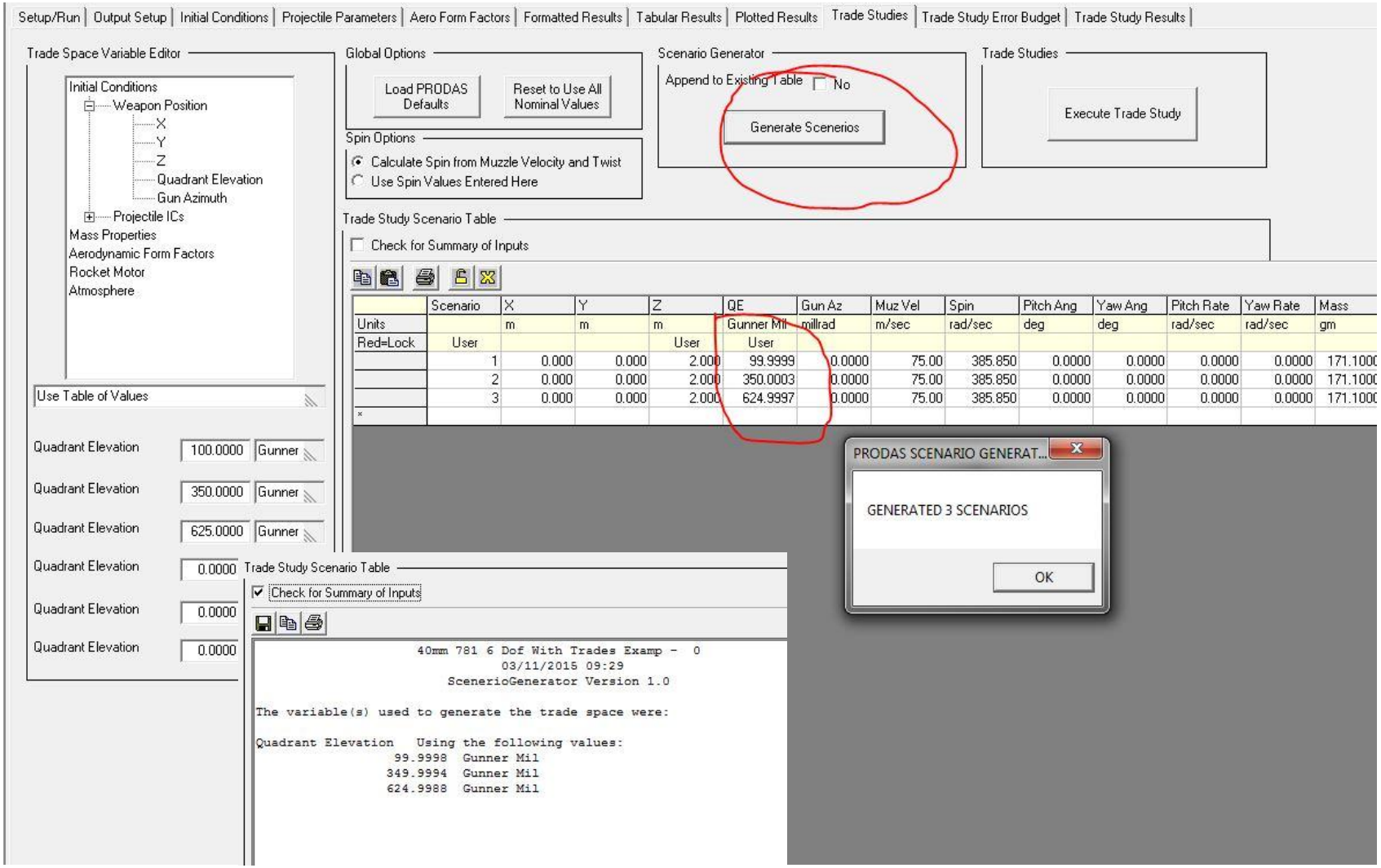


Example Details

- The next step is to add the 3 QE's desired to the Trade Study Scenario Tables found under the Trade Study Interface tab. To do this please open the "Trade Study" interface tab and go to the "Trade Space Variable Editor" and open the Weapon Position input tree and highlight Quadrant Elevation.
- There is a pull down menu midway in the interface which allow you to choose the input method. These include "Nominal" (value saved with the file) "Range and Increment" (Allows user to set the initial QE and then add incremantal adjustments) or "Table of Values". Please choose this last option and input the values shown to the right.
- Please use the Generate Scenarios Command to repopulate the Trade Study Scenario Tables

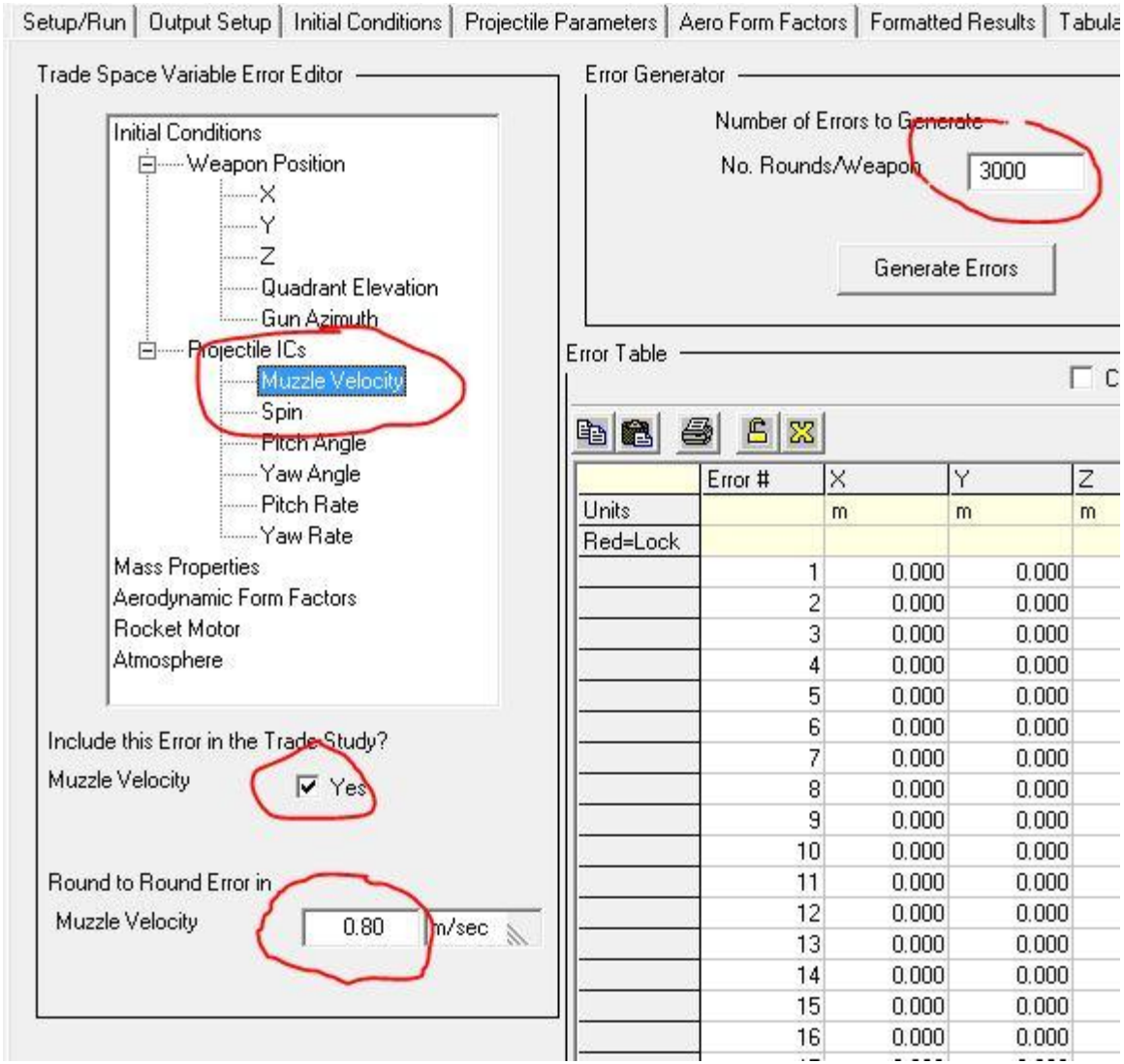


Example Details



Example Details

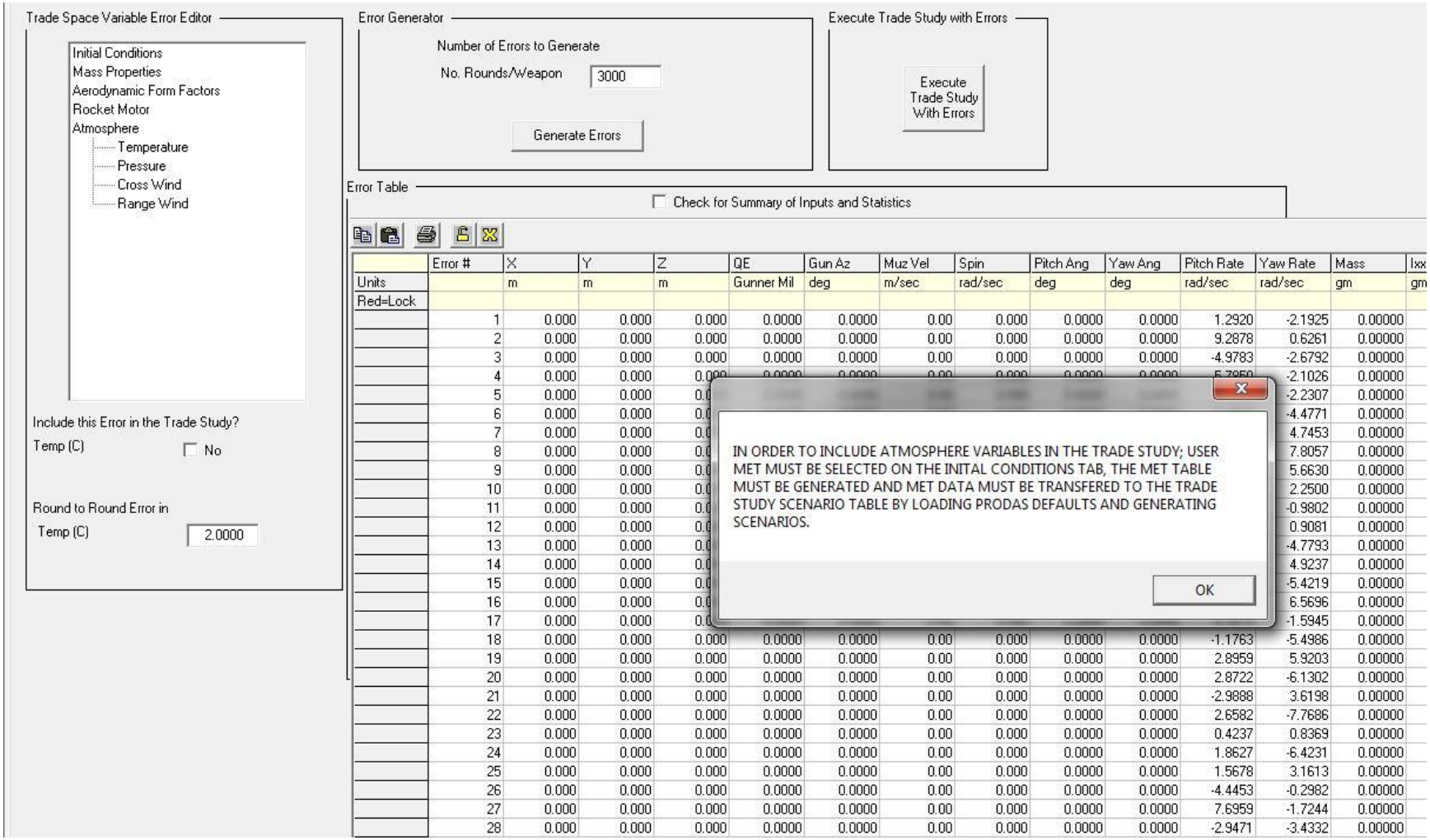
- From the newly generated "Trade Study Scenario Tables" we can now see the added Quandrant Elevations along with the initial Z of the weapon and Muzzle Velocity we would like to use.
- At this point we should now go to the Trade Study Error Budget interface and go to the Trade Space Variable Error Editor and expand the Initial Conditions, Projectile IC's tree and select the Muzzle Velocity Input and add the 0.8 m/s error. Also modify the number of errors to 3000 instead of 4000 (Total number of trajectories is 10000 per study. When these are combined with the 3 Scenarios this will generate 9000 trajectories.



Example Details

- To utilize and input MET errors the user has to do 3 things. The first is to input the actual MET errors using the Trade Study Error Budget interface and Trade Space Variable Error Editor and expand the Atmosphere Error Tree. When the user selects Temp a pop up window will appear explaining the next two steps the user will need to do to get these errors in to the Trade Study. (see next Page)

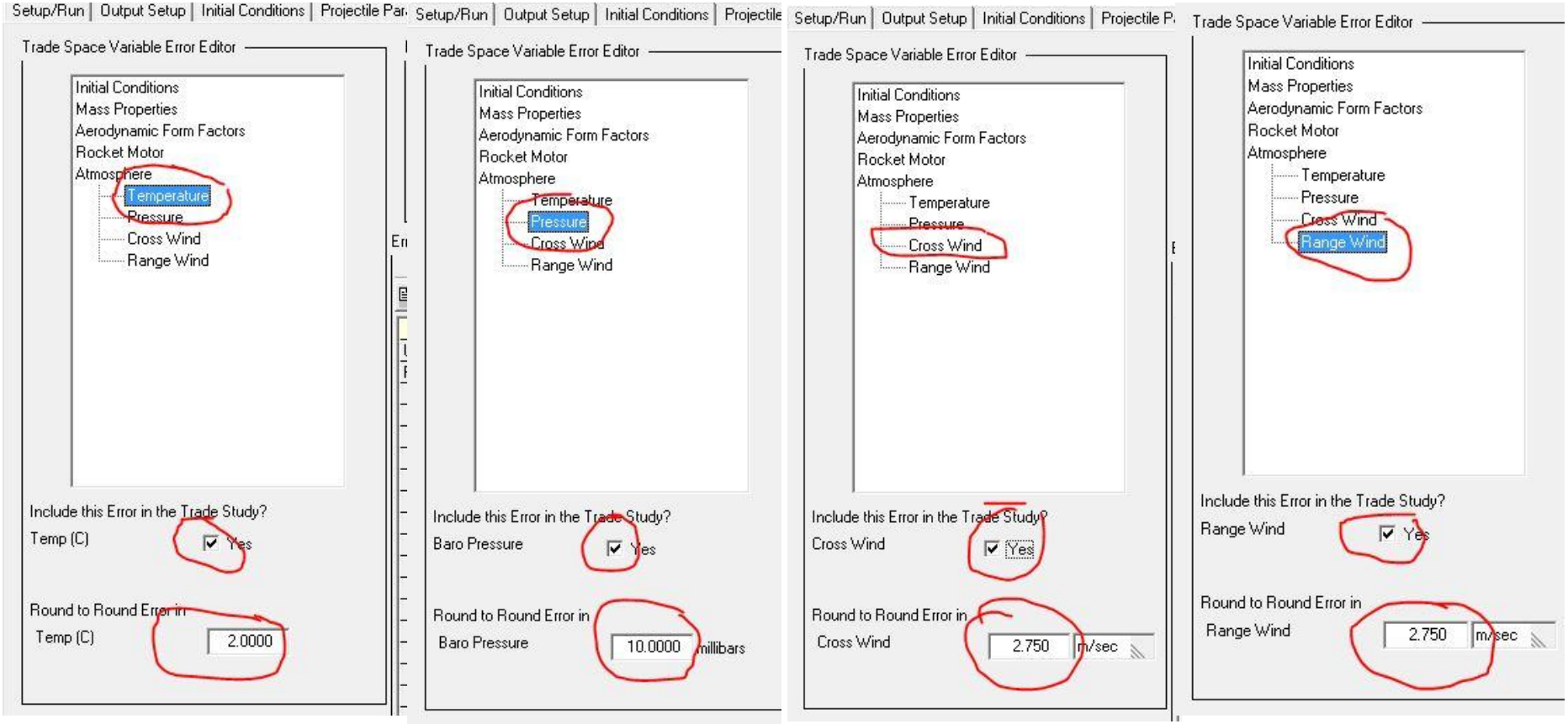
Example Details



	Error #	X	Y	Z	QE	Gun Az	Muz Vel	Spin	Pitch Ang	Yaw Ang	Pitch Rate	Yaw Rate	Mass	Ixx
Units		m	m	m	Gunner Mil	deg	m/sec	rad/sec	deg	deg	rad/sec	rad/sec	gm	gm
Red=Lock														
	1	0.000	0.000	0.000	0.0000	0.0000	0.00	0.000	0.0000	0.0000	1.2920	-2.1925	0.00000	
	2	0.000	0.000	0.000	0.0000	0.0000	0.00	0.000	0.0000	0.0000	9.2878	0.6261	0.00000	
	3	0.000	0.000	0.000	0.0000	0.0000	0.00	0.000	0.0000	0.0000	-4.9783	-2.6792	0.00000	
	4	0.000	0.000	0.000	0.0000	0.0000	0.00	0.000	0.0000	0.0000	5.7850	-2.1026	0.00000	
	5	0.000	0.000	0.000	0.0000	0.0000	0.00	0.000	0.0000	0.0000	1.2920	-2.2307	0.00000	
	6	0.000	0.000	0.000	0.0000	0.0000	0.00	0.000	0.0000	0.0000	9.2878	-4.4771	0.00000	
	7	0.000	0.000	0.000	0.0000	0.0000	0.00	0.000	0.0000	0.0000	-4.9783	4.7453	0.00000	
	8	0.000	0.000	0.000	0.0000	0.0000	0.00	0.000	0.0000	0.0000	5.7850	7.8057	0.00000	
	9	0.000	0.000	0.000	0.0000	0.0000	0.00	0.000	0.0000	0.0000	1.2920	5.6630	0.00000	
	10	0.000	0.000	0.000	0.0000	0.0000	0.00	0.000	0.0000	0.0000	9.2878	2.2500	0.00000	
	11	0.000	0.000	0.000	0.0000	0.0000	0.00	0.000	0.0000	0.0000	-4.9783	-0.9802	0.00000	
	12	0.000	0.000	0.000	0.0000	0.0000	0.00	0.000	0.0000	0.0000	5.7850	0.9081	0.00000	
	13	0.000	0.000	0.000	0.0000	0.0000	0.00	0.000	0.0000	0.0000	1.2920	-4.7793	0.00000	
	14	0.000	0.000	0.000	0.0000	0.0000	0.00	0.000	0.0000	0.0000	9.2878	4.9237	0.00000	
	15	0.000	0.000	0.000	0.0000	0.0000	0.00	0.000	0.0000	0.0000	-4.9783	-5.4219	0.00000	
	16	0.000	0.000	0.000	0.0000	0.0000	0.00	0.000	0.0000	0.0000	5.7850	6.5696	0.00000	
	17	0.000	0.000	0.000	0.0000	0.0000	0.00	0.000	0.0000	0.0000	1.2920	-1.5945	0.00000	
	18	0.000	0.000	0.000	0.0000	0.0000	0.00	0.000	0.0000	0.0000	-1.1763	-5.4986	0.00000	
	19	0.000	0.000	0.000	0.0000	0.0000	0.00	0.000	0.0000	0.0000	2.8959	5.9203	0.00000	
	20	0.000	0.000	0.000	0.0000	0.0000	0.00	0.000	0.0000	0.0000	2.8722	-6.1302	0.00000	
	21	0.000	0.000	0.000	0.0000	0.0000	0.00	0.000	0.0000	0.0000	-2.9888	3.6198	0.00000	
	22	0.000	0.000	0.000	0.0000	0.0000	0.00	0.000	0.0000	0.0000	2.6582	-7.7686	0.00000	
	23	0.000	0.000	0.000	0.0000	0.0000	0.00	0.000	0.0000	0.0000	0.4237	0.8369	0.00000	
	24	0.000	0.000	0.000	0.0000	0.0000	0.00	0.000	0.0000	0.0000	1.8627	-6.4231	0.00000	
	25	0.000	0.000	0.000	0.0000	0.0000	0.00	0.000	0.0000	0.0000	1.5678	3.1613	0.00000	
	26	0.000	0.000	0.000	0.0000	0.0000	0.00	0.000	0.0000	0.0000	-4.4453	-0.2982	0.00000	
	27	0.000	0.000	0.000	0.0000	0.0000	0.00	0.000	0.0000	0.0000	7.6959	-1.7244	0.00000	
	28	0.000	0.000	0.000	0.0000	0.0000	0.00	0.000	0.0000	0.0000	-2.9471	-3.4332	0.00000	

Example Details

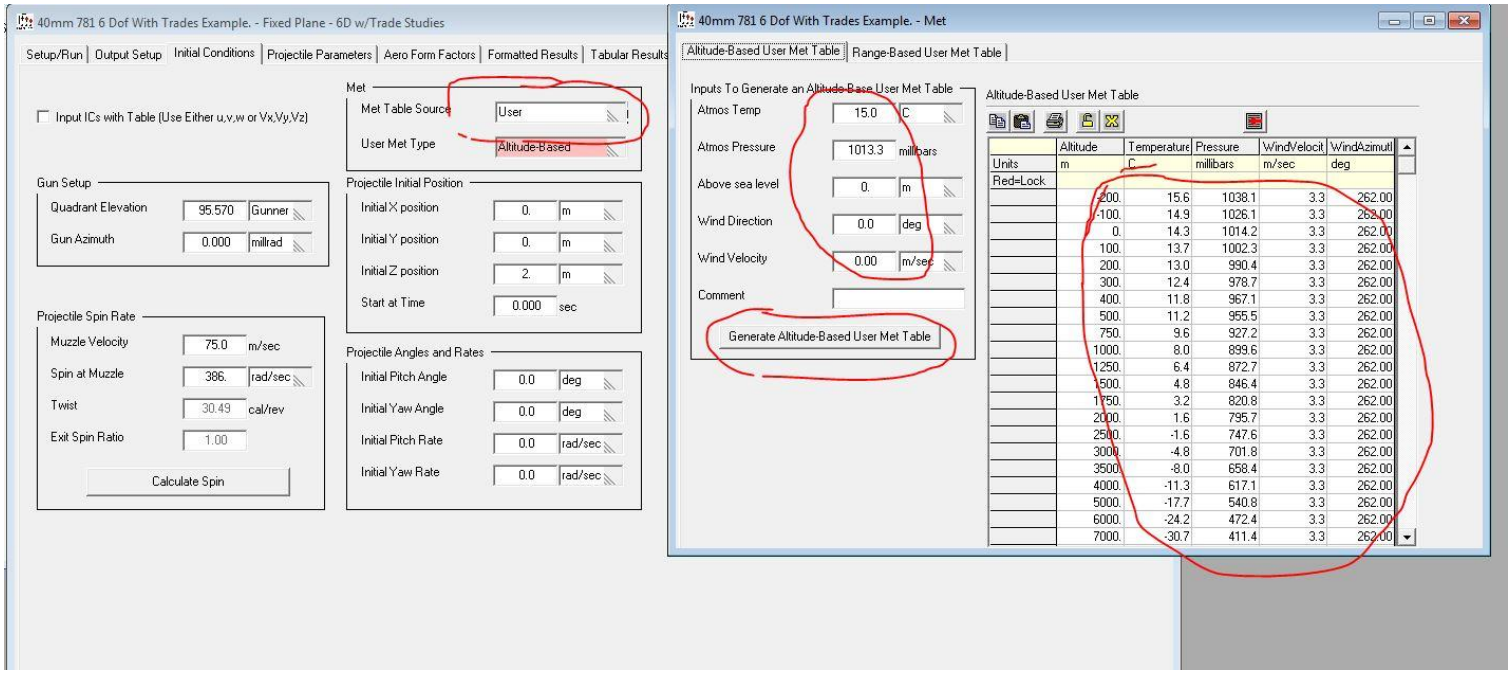
- Please Insert the Temp, Pressure and Wind Errors maing sure the Include Error box is checked for each



Example Details

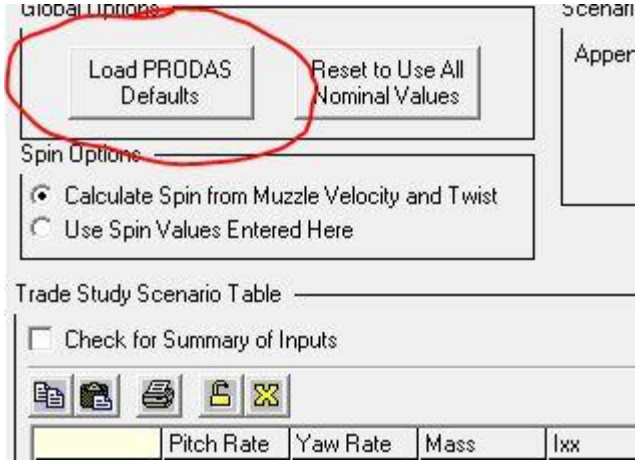
ARROW TECH
If you can't get a bigger target…

- Prior to generating Errors please do the following
  - Go the Initial Conditions interface tab and set the MET source to User
  - Please open the MET Table Genarator (Found under "Support" pull down menu "Met" and generate a std day atmosphere with Sea Leval Temp set to 15C and Pressure set to 1013.25 and hit the generate MET command. This will populate the table.
  - Please Save the PRODAS Model at this point



Example Detail

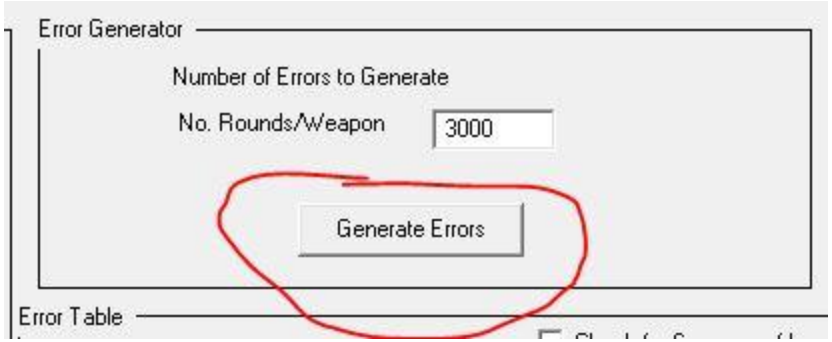
- Please return to the Trade Study Interface and use the "Load PRODAS Defaults Command.
  - This loads up the saved User MET Table that the errors produced and in the Trade Study Error Budget/Error Table will be applied.



  - Regenerate Scenario Table Also (Ensures all of the PRODAS Defaults are loaded)

- Please return to the Trade Study Error Budget interface and use the Generate Errors Command to repopulate the table with the new Muzzle Velocity and Atmospheric Errors Input Previously.

- These error will now appear in the Table and Summary Input for the Table



	Muz Vel	Spin	Pitch Ang	Yaw Ang	Pitch Rate	Yaw Rate	Mas
	m/sec	rad/sec	deg	deg	rad/sec	rad/sec	gm
)	-0.06	0.000	0.0000	0.0000	1.3317	4.7474	
)	-0.95	0.000	0.0000	0.0000	1.4583	-8.5974	
)	-1.00	0.000	0.0000	0.0000	-9.4828	10.2070	
)	0.22	0.000	0.0000	0.0000	6.9210	-3.1288	
)	-0.74	0.000	0.0000	0.0000	-0.7988	1.3505	
)	0.47	0.000	0.0000	0.0000	1.3090	1.8594	

ir	Temp (C)	Pressure	Cross Wind	Range Winc
		millibars	m/sec	m/sec
00	2.1844	13.1624	10.040	0.546
00	-4.0400	-11.7291	2.132	-0.475
00	4.0815	-0.5093	-2.269	3.755
00	-2.6737	-6.3032	4.612	-1.330
00	-2.1496	7.9107	-1.879	0.659
00	-1.4807	-18.6557	-1.671	1.817
00	2.6368	19.6137	2.717	-2.526
00	0.7940	-15.4604	-1.916	-1.794
00	-3.1636	-3.6488	2.036	0.921

Example Details

- ## Summary of Inputs

40mm 781 6 Dof With Trades Examp - 0

03/11/2015 10:16

ScenerioGenerator Version 1.0

Errors were generated to simulate firing of 3000 rounds.

The following variables were used to generate the initial conditions Error Table:

Muzzle Velocity

Input Standard Deviation	0.8000	m/sec
Std Dev of Generated Errors	0.8166	m/sec
Mean of Generated Errors	0.0117	m/sec

Pitch Rate

Input Standard Deviation	4.3000	rad/sec
Std Dev of Generated Errors	4.3045	rad/sec
Mean of Generated Errors	-0.0520	rad/sec

Yaw Rate

Input Standard Deviation	4.0000	rad/sec
Std Dev of Generated Errors	3.9172	rad/sec
Mean of Generated Errors	0.0654	rad/sec

Temp (deg C)

Input Standard Deviation	2.0000	
Std Dev of Generated Errors	1.9690	
Mean of Generated Errors	-0.0378	

Baro Pressure

Input Standard Deviation	10.0000	millibars
Std Dev of Generated Errors	9.9646	millibars
Mean of Generated Errors	0.0149	millibars

Cross Wind

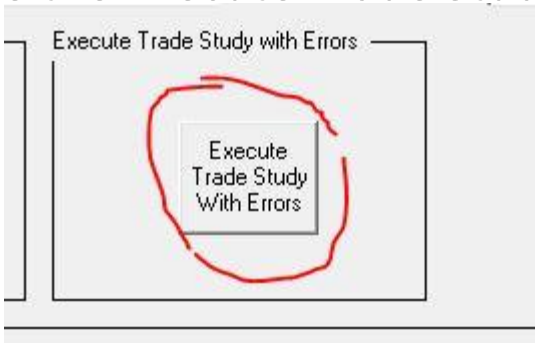
Input Standard Deviation	2.7500	m/sec
Std Dev of Generated Errors	2.8143	m/sec
Mean of Generated Errors	-0.0347	m/sec

Range Wind

Input Standard Deviation	2.7500	m/sec
Std Dev of Generated Errors	2.7088	m/sec
Mean of Generated Errors	-0.0706	m/sec

Example Details

- At this point we have done the following:
  - Set up 3 Quadrant Elevations to simulate the input Errors and loaded in the baseline Muzzle Velocity and Atmosphere
  - Verified the Ammunition Dispersion input
  - Generated 3000 initial 1 standard devaition launch errors which will be used for the execution of the analysis which include
    - 1 std deviation in Muzzle Velocity of 0.8 M/s
    - Radial dispersion of 0.5 mils (1 std deviation)
    - Temperature std deviation of 2 deg C
    - Pressure std deviation of 10 millibars
    - 2.75 m/s of Cross and Range winds
- We are now ready to execute the study so please go the Trade Study Error Budget interface and use the Execute Trade Study with Errors command

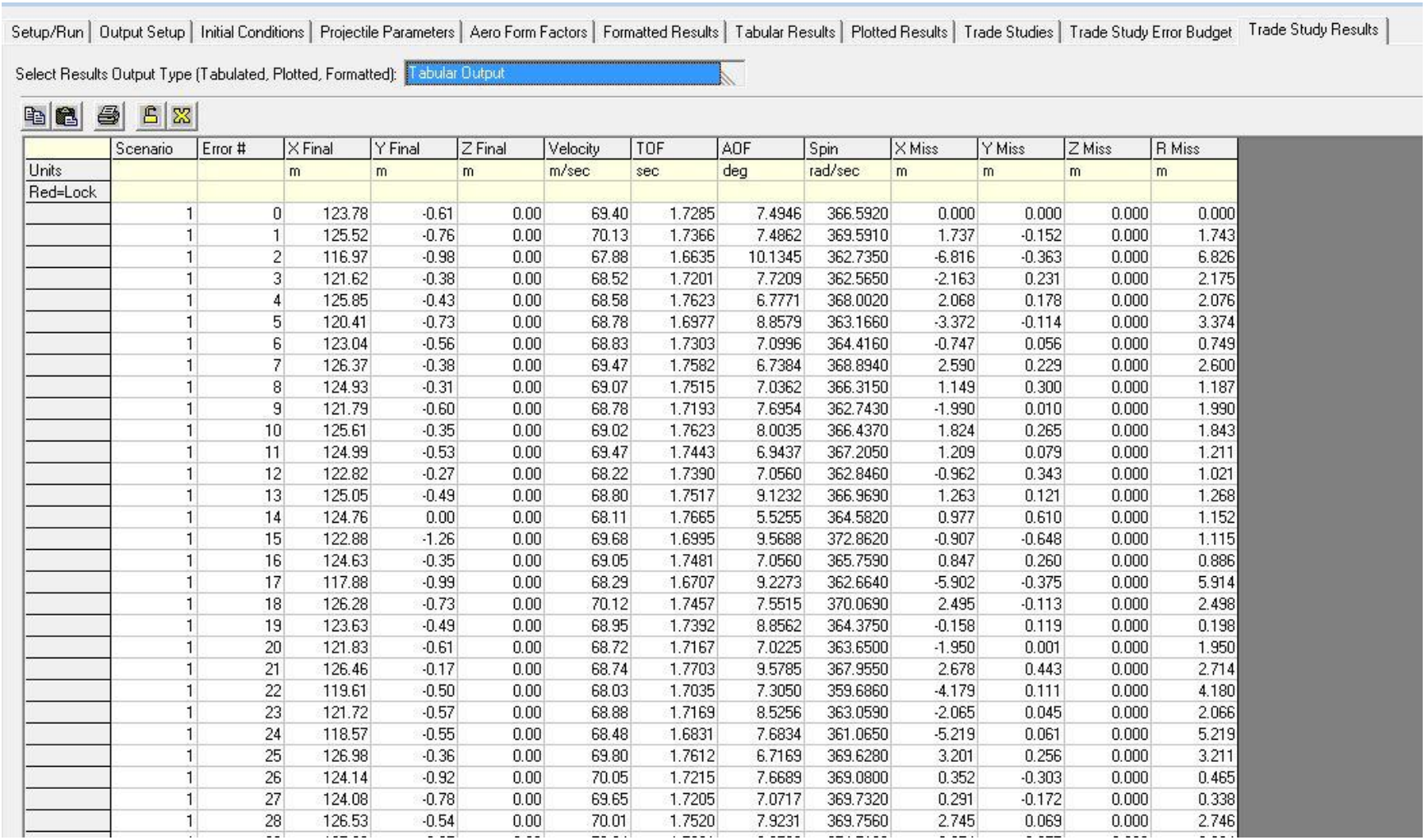


Results

- Once the analysis has been completed please go to the "Trade Study Results" interface where we can see the tabular output, the plotted output and the summary formatted output
  - Tabular Output summarizes the impacts and miss distance per error and scenario
  - The Plotted Output show the ground impact patterns for each scenario with input error budget (Please choose Ground Impact vs Vertical Impact)
  - Summary of Formatted output summarizes all fo the inputs used ans then shows the average impact and std devaition of the impacts due to the input error budgets

Tabular Output

ARROW TECH
If you can't get a bigger target…

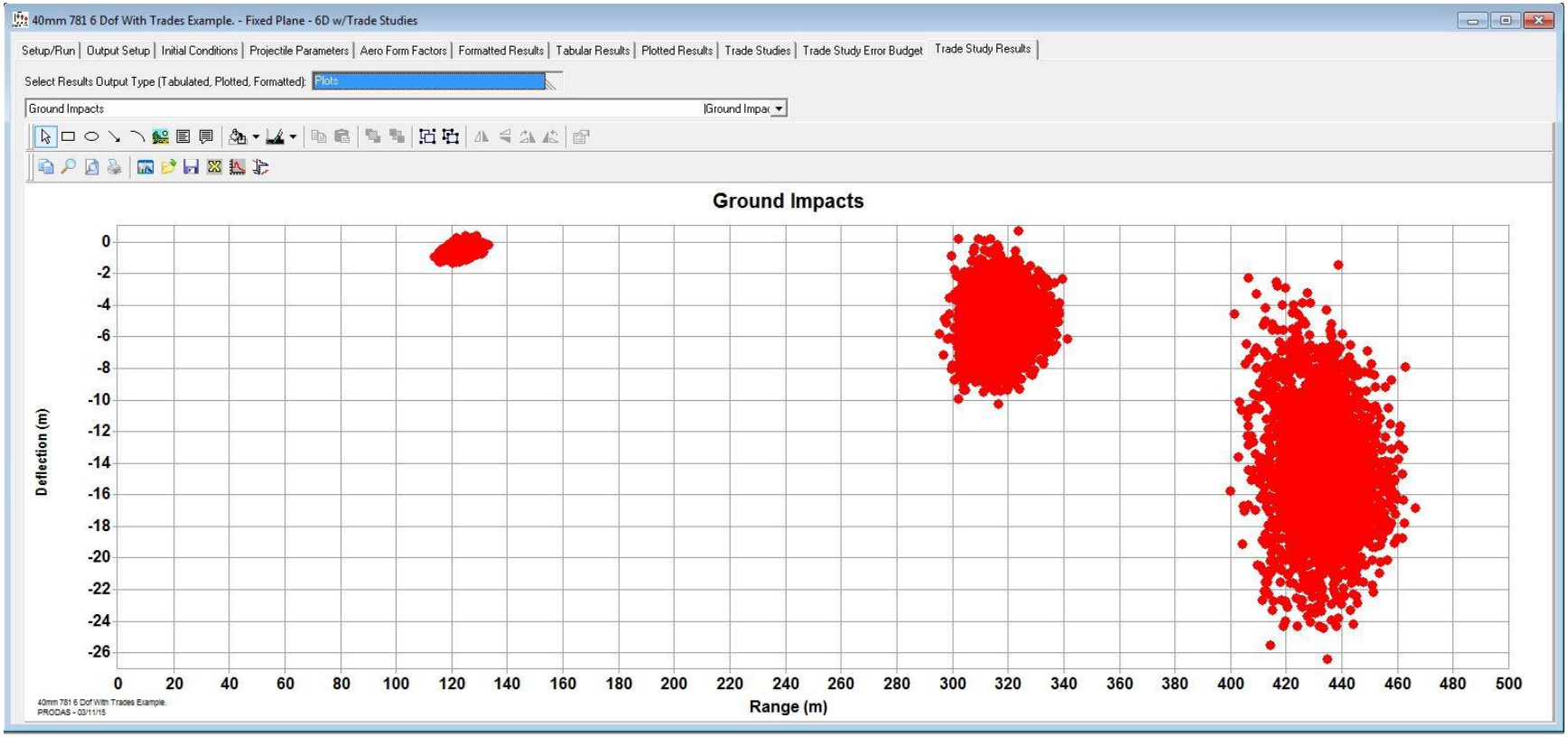


Setup/Run | Output Setup | Initial Conditions | Projectile Parameters | Aero Form Factors | Formatted Results | Tabular Results | Plotted Results | Trade Studies | Trade Study Error Budget | Trade Study Results

Select Results Output Type (Tabulated, Plotted, Formatted): Tabular Output

	Scenario	Error #	X Final	Y Final	Z Final	Velocity	TOF	AOF	Spin	X Miss	Y Miss	Z Miss	R Miss
Units			m	m	m	m/sec	sec	deg	rad/sec	m	m	m	m
Red=Lock													
	1	0	123.78	-0.61	0.00	69.40	1.7285	7.4946	366.5920	0.000	0.000	0.000	0.000
	1	1	125.52	-0.76	0.00	70.13	1.7366	7.4862	369.5910	1.737	-0.152	0.000	1.743
	1	2	116.97	-0.98	0.00	67.88	1.6635	10.1345	362.7350	-6.816	-0.363	0.000	6.826
	1	3	121.62	-0.38	0.00	68.52	1.7201	7.7209	362.5650	-2.163	0.231	0.000	2.175
	1	4	125.85	-0.43	0.00	68.58	1.7623	6.7771	368.0020	2.068	0.178	0.000	2.076
	1	5	120.41	-0.73	0.00	68.78	1.6977	8.8579	363.1660	-3.372	-0.114	0.000	3.374
	1	6	123.04	-0.56	0.00	68.83	1.7303	7.0996	364.4160	-0.747	0.056	0.000	0.749
	1	7	126.37	-0.38	0.00	69.47	1.7582	6.7384	368.8940	2.590	0.229	0.000	2.600
	1	8	124.93	-0.31	0.00	69.07	1.7515	7.0362	366.3150	1.149	0.300	0.000	1.187
	1	9	121.79	-0.60	0.00	68.78	1.7193	7.6954	362.7430	-1.990	0.010	0.000	1.990
	1	10	125.61	-0.35	0.00	69.02	1.7623	8.0035	366.4370	1.824	0.265	0.000	1.843
	1	11	124.99	-0.53	0.00	69.47	1.7443	6.9437	367.2050	1.209	0.079	0.000	1.211
	1	12	122.82	-0.27	0.00	68.22	1.7390	7.0560	362.8460	-0.962	0.343	0.000	1.021
	1	13	125.05	-0.49	0.00	68.80	1.7517	9.1232	366.9690	1.263	0.121	0.000	1.268
	1	14	124.76	0.00	0.00	68.11	1.7665	5.5255	364.5820	0.977	0.610	0.000	1.152
	1	15	122.88	-1.26	0.00	69.68	1.6995	9.5688	372.8620	-0.907	-0.648	0.000	1.115
	1	16	124.63	-0.35	0.00	69.05	1.7481	7.0560	365.7590	0.847	0.260	0.000	0.886
	1	17	117.88	-0.99	0.00	68.29	1.6707	9.2273	362.6640	-5.902	-0.375	0.000	5.914
	1	18	126.28	-0.73	0.00	70.12	1.7457	7.5515	370.0690	2.495	-0.113	0.000	2.498
	1	19	123.63	-0.49	0.00	68.95	1.7392	8.8562	364.3750	-0.158	0.119	0.000	0.198
	1	20	121.83	-0.61	0.00	68.72	1.7167	7.0225	363.6500	-1.950	0.001	0.000	1.950
	1	21	126.46	-0.17	0.00	68.74	1.7703	9.5785	367.9550	2.678	0.443	0.000	2.714
	1	22	119.61	-0.50	0.00	68.03	1.7035	7.3050	359.6860	-4.179	0.111	0.000	4.180
	1	23	121.72	-0.57	0.00	68.88	1.7169	8.5256	363.0590	-2.065	0.045	0.000	2.066
	1	24	118.57	-0.55	0.00	68.48	1.6831	7.6834	361.0650	-5.219	0.061	0.000	5.219
	1	25	126.98	-0.36	0.00	69.80	1.7612	6.7169	369.6280	3.201	0.256	0.000	3.211
	1	26	124.14	-0.92	0.00	70.05	1.7215	7.6689	369.0800	0.352	-0.303	0.000	0.465
	1	27	124.08	-0.78	0.00	69.65	1.7205	7.0717	369.7320	0.291	-0.172	0.000	0.338
	1	28	126.53	-0.54	0.00	70.01	1.7520	7.9231	369.7560	2.745	0.069	0.000	2.746

Plotted Output



Formatted Summary

ARROW TECH
If you can't get a bigger target…

Select Results Output Type (Tabulated, Plotted, Formatted): Formatted Output

{LANDSCAPE}

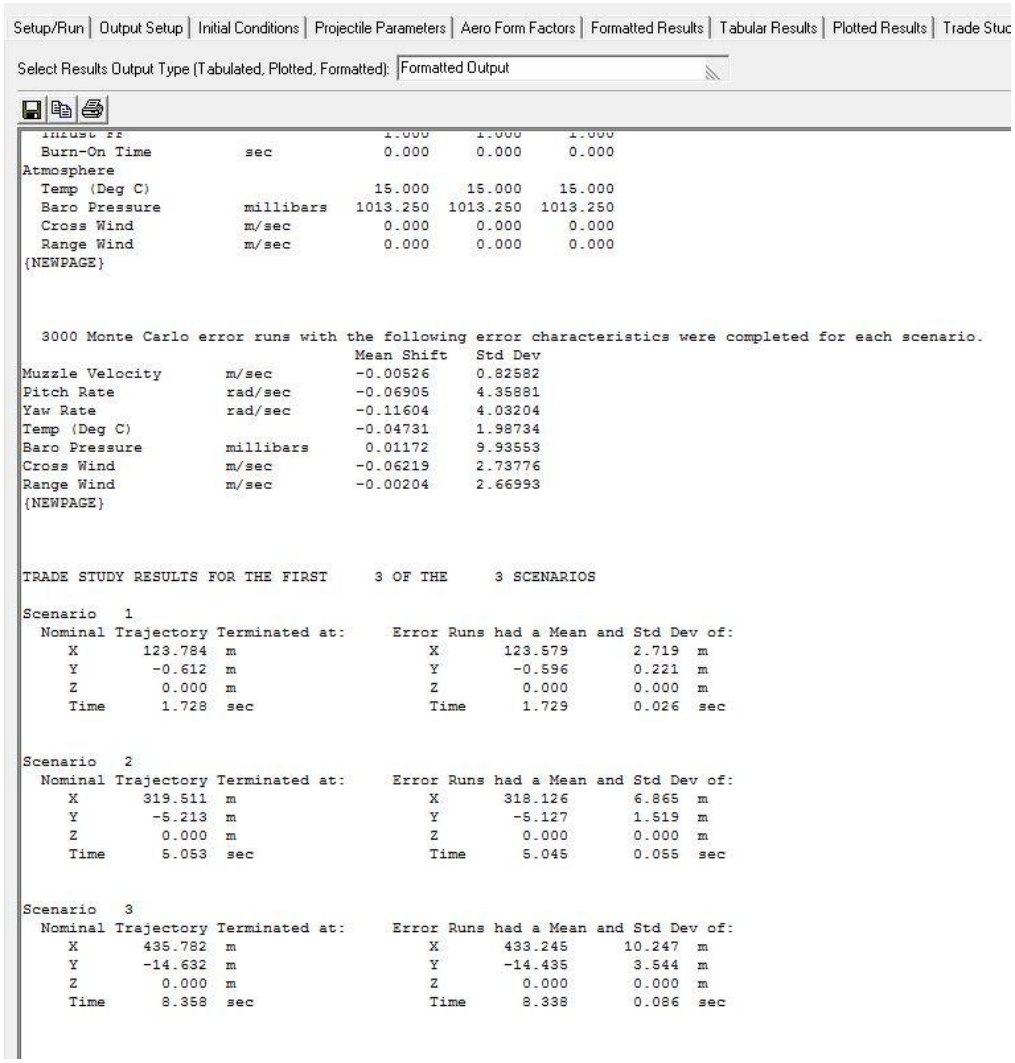
40mm 781 6 Dof With Trades Examp - 0
03/11/2015 10:48
Traj20006D_wTrades Version 3.1.0

A trade study has been completed with 3 scenarios. The following inputs were used for the first 3 of the 3 scenarios.

Parameter	Units	Scen 1	Scen 2	Scen 3
Weapon Position				
X	m	0.000	0.000	0.000
Y	m	0.000	0.000	0.000
Z	m	2.000	2.000	2.000
Quadrant Elevation	Gunner Mil	100.000	350.000	624.999
Azimuth	deg	0.000	0.000	0.000
Projectile ICs				
Muzzle Velocity	m/sec	75.000	75.000	75.000
Spin	rad/sec	385.850	385.850	385.850
Pitch Angle	deg	0.000	0.000	0.000
Yaw Angle	deg	0.000	0.000	0.000
Pitch Rate	rad/sec	0.000	0.000	0.000
Yaw Rate	rad/sec	0.000	0.000	0.000
Mass Properties				
Mass	gm	171.100	171.100	171.100
Azial Inertia	gm-cm^2	393.590	393.590	393.590
Transverse Inertia	gm-cm^2	445.420	445.420	445.420
CG Location	cm	5.023	5.023	5.023
Aerodynamic Form Factors				
Axial Force FF		0.920	0.920	0.920
Normal Force FF		1.000	1.000	1.000
Spin Decay FF		1.000	1.000	1.000
Pitching Moment FF		1.000	1.000	1.000
Damping Moment FF		1.000	1.000	1.000
Magnus Moment FF		1.000	1.000	1.000
Side Moment FF		0.000	0.000	0.000
Trim Angle (Deg)		0.000	0.000	0.000
Trim Orientation	deg	0.000	0.000	0.000
Fin Cant (Deg)		1.000	1.000	1.000
Rocket Motor				
Thrust FF		1.000	1.000	1.000
Burn-On Time	sec	0.000	0.000	0.000
Atmosphere				
Temp (Deg C)		15.000	15.000	15.000
Baro Pressure	millibars	1013.250	1013.250	1013.250
Cross Wind	m/sec	0.000	0.000	0.000
Range Wind	m/sec	0.000	0.000	0.000

{NEWPAGE}

Formatted Summary pt2



Setup/Run | Output Setup | Initial Conditions | Projectile Parameters | Aero Form Factors | Formatted Results | Tabular Results | Plotted Results | Trade Stuc

Select Results Output Type (Tabulated, Plotted, Formatted): Formatted Output

```
  Thrust ff                                  1.000     1.000     1.000
  Burn-On Time          sec                 0.000     0.000     0.000
Atmosphere
  Temp (Deg C)                             15.000    15.000    15.000
  Baro Pressure         millibars        1013.250  1013.250  1013.250
  Cross Wind            m/sec               0.000     0.000     0.000
  Range Wind            m/sec               0.000     0.000     0.000
{NEWPAGE}


  3000 Monte Carlo error runs with the following error characteristics were completed for each scenario.
                                        Mean Shift   Std Dev
Muzzle Velocity       m/sec             -0.00526     0.82582
Pitch Rate            rad/sec           -0.06905     4.35881
Yaw Rate              rad/sec           -0.11604     4.03204
Temp (Deg C)                            -0.04731     1.98734
Baro Pressure         millibars          0.01172     9.93553
Cross Wind            m/sec             -0.06219     2.73776
Range Wind            m/sec             -0.00204     2.66993
{NEWPAGE}


TRADE STUDY RESULTS FOR THE FIRST     3 OF THE     3 SCENARIOS

Scenario   1
  Nominal Trajectory Terminated at:     Error Runs had a Mean and Std Dev of:
     X       123.784  m                     X       123.579       2.719  m
     Y        -0.612  m                     Y        -0.596       0.221  m
     Z         0.000  m                     Z         0.000       0.000  m
     Time      1.728  sec                   Time      1.729       0.026  sec


Scenario   2
  Nominal Trajectory Terminated at:     Error Runs had a Mean and Std Dev of:
     X       319.511  m                     X       318.126       6.865  m
     Y        -5.213  m                     Y        -5.127       1.519  m
     Z         0.000  m                     Z         0.000       0.000  m
     Time      5.053  sec                   Time      5.045       0.055  sec


Scenario   3
  Nominal Trajectory Terminated at:     Error Runs had a Mean and Std Dev of:
     X       435.782  m                     X       433.245      10.247  m
     Y       -14.632  m                     Y       -14.435       3.544  m
     Z         0.000  m                     Z         0.000       0.000  m
     Time      8.358  sec                   Time      8.338       0.086  sec
```